Reshaping Agriculture and Nutrition Linkages for

Food and Nutrition Security

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डॉ. सीएच. श्रीनिवास राव
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FOREWORD

Sustainable Development Goals (SDGs) developed by United Nations in 2015, introduced nutrition-sensitive agriculture, which referred to improve nutrition and basic causes of malnutrition presented in the UNICEF conceptual framework. Agriculture is the primary livelihood of a majority of the population in India, which houses a large population of undernourished people. Agricultural interventions and farming systems research in India has been largely focused on enhancing production, productivity and profitability of crop without much emphasis on better nutritional outcomes. To improve the nutritional needs of farming community, suitable agricultural interventions has to be addressed for better nutrition outcomes. Accordingly, the present short course sponsored by Indian Council of Agriculture Research (ICAR) on Reshaping Agriculture and Nutrition Linkages for Food and Nutrition Security is being organized at ICAR - Central Research Institute for Dryland Agriculture (lCAR - CRIDA), Hyderabad during 17-26 November 2016, provides understanding on Agriculture and Nutrition Linkages perspective, that leads to formulate effective nutrition interventions to alleviate malnutrition.

There is a meticulous effort by the course organizers in documenting Reshaping Agriculture and Nutrition Linkages, provide insights on the strategies for eradication of malnutrition of women and children to improve understanding among agronomists, plant breeders, soil scientists, policy makers, food technologists and nutritionists. To address the above and enhance the knowledge base of researchers, academicians and other stake holders and further to expose these stakeholders to enhance agriculture and nutrition linkages.

This publication is an outcome of compilation of lecture notes/book chapters of above short course. This will serve as a ready reckoner intended to build knowledge, skills and enable sustainable agriculture nutrition interventions in Indian Agriculture.

19/11/16

CH. SRINIVASA RAO

ICAR - CRIDA, Hyderabad
Date: November 19, 2016

Preface

Over the past century or so, agricultural development has been based on a paradigm of increasing productivity and maximizing the production of cereals. The ramping up of cereal production in the Green Revolution, saved countless lives in India and increased the economic and agricultural growth. At the same time, agricultural intensification has led to a concentration on grain production and neglected nutrient-dense crops like pulses, oil seeds, fruits and vegetables. A look at the current health and nutrition situation suggests agriculture can make an even greater contribution to health and nutrition. Indeed, leveraging agriculture for health and nutrition has the potential to speed progress towards meeting food security of India along with nutrition security. Indian agriculture, already provide billions of people with diverse, healthy diets, yet more needs to be done. Millions of people suffer from serious vitamin and mineral deficiencies. The economic cost of micronutrient deficiencies is estimated to be 2.4–10.0 percent of Gross Domestic Product (GDP) in many developing countries. Most people would say agriculture is about growing food; they are right. Agricultural performance, is measured in terms of production, for example, yield or grain production. The purpose of agriculture, however, does not stop there. At a deeper level, the purpose of agriculture is not just to grow crops and livestock for food and raw materials, but to grow healthy, well-nourished people. Farmers' most important tasks is to produce food of sufficient quantity (that is, enough calories) and quality (with the vitamins and minerals needed by the human body) to feed all of the people sustainably so that they can lead healthy, productive lives. This is effectively one of the goals of agriculture, agricultural production is an important means for most people to get the food and essential nutrients they need.

Indian Council of Agriculture Research (ICAR) Sponsored Short Course on Reshaping Agriculture and Nutrition Linkages for Food and Nutrition Security is being organized at ICAR - Central Research Institute for Dryland Agriculture (ICAR - CRIDA), Hyderabad during 17-26, November 2016. This publication is an outcome of compilation of lecture notes/book chapters of above short course and deals with the importance of current trends in Food Grains Production, Agri food value chain markets, agriculture policies and pathways contributing to nutrition and health, policy imperatives for enhancing agricultural growth for ensuring nutritional security, food based approaches to combating micronutrient deficiencies, impact of diversification in agriculture, nutritional quality of organically grown food crops, opportunities for setting up of food processing industries of CFTRI technologies, macro, micro nutrient and toxic heavy metals interrelationship in soils, plants and human nutrition, scope of insect farming and entomophagy, primary and secondary processing of food grains for value addition, plant breeding cereals and legumes for high nutrition with climate resilience - ICRISAT experiences, enhancing potential of animal agriculture for food and nutritional security in India; tradeoffs and strategies, importance of horticultural crops for nutrition, role of natural anti-oxidants to manage oxidative stress in food crops, changing climatic conditions on uptake, utilization of major nutrients and effect on nutrient quality of food crops, bioinformatics in agriculture, food and nutrition etc.,

We profusely thank Dr. Narendra Singh Rathore, DDG (Education), ICAR and Dr. M.B. Chetti, ADG (HRD), ICAR for their kind encouragement by supporting in organizing this short course, we are highly thankful to Dr. K. Alagusundaram, DDG (Natural Resource Management)/Addl Charge, ICAR for his guidance and support. As editors of this book, we would like to thank all the authors for their efforts and cooperation in bringing out this book in time. We also thank all the participants of this short course for their time and interest. We thank all the staff of ICAR - CRIDA who helped directly or indirectly in organizing this short course successfully. We firmly believe that this publication will be highly useful, in one way or other, for researchers, academicians, extention workers, policy makers, planners, officials in development institutions and students.

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Contents

1 Food and Nutrition Security in India

Ch Srinivasa Rao

Introduction

Food security is characterized as 'a situation . . . when all people, at all times, have physical, social and economic access to suffcient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 2002). This understanding of food security incorporates the idea that access to food includes not just physical availability and affordability, but also requires that individuals do not face social barriers in feeding themselves.

National Food Security

Cereals are staple food in most developing low-income countries of Asia and Africa, where they may contribute as much as 55% of the dietary energy (Fig 1). Rice feeds more than half the world population and meets 21% of energy and protein needs of human population globally. About 90% of rice is grown and consumed in South, Southeast, and East Asia, where about 62.5% of the world's total 925 million hungry people reside; about 25.8% of world's hungry people reside in sub-Saharan Africa (FAO, 2010). Food security implies nutritional security and further acknowledges that in its attainment, it supports the actualization of individual capabilities. It is important to note too that individuals are the focus, although household-level or community level food security is an appropriate concern focuses on some of the key challenges that India faces in ensuring food security. The past few years saw the expression of a long standing demand of civil society groups for a comprehensive legislative framework for ensuring food security in the form of a National Food Security Act (NFSA), overcoming an early reluctance on the part of the government commit to such an Act. While in the years of the food price crisis, this was effective, in recent years, it appears that inflation is in fact virtually a domestic phenomenon, with growing stocks and food subsidies held by the government.

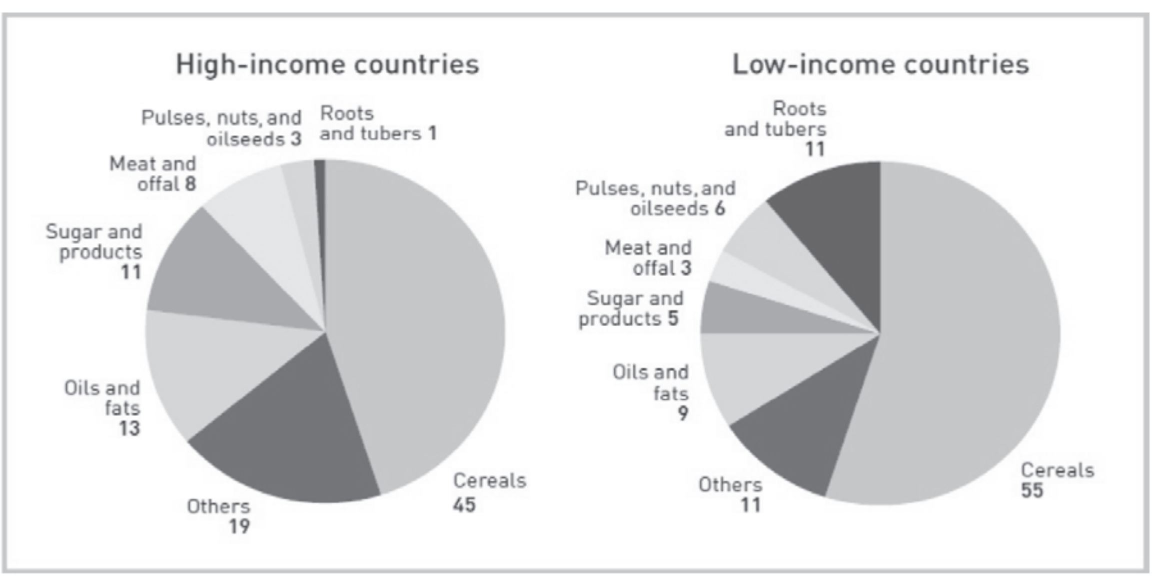

Fig.1. Dietary diversity by source of dietary energy (percentage)

The National Food Security Bill (NFSB)

Last year brought the key issues concerning food management, centered mainly on the proposed NFSB. The NFSA envisions a comprehensive legislative framework for protecting an individual's right to food, furthering the vision expressed in the Constitution of India. It is conceived as a system of interventions following a life-cycle approach, whereby at every stage of an individual's life, a safety net would be provided by the state to ensure food security. This brought into its fold a whole range of interventions that had already been converted to entitlements by the Supreme Court in the Right to Food Case (Peoples' Union of Civil Liberties, Rajasthan vs. Government of India): child nutrition programmes, maternity benefits, social security pensions and other entitlements that would further food security. A related concern was the food grain requirement to support the NFSB. Their estimates suggested that the proposed PDS would require stocks between 54 and 74 million tonnes and at the prevailing economic costs of operations, outlays of the order of about Rs 90,000 crore. Based on base year of 2004-05, the food and nutritional commodities need by 2020-21 is presented in Table 1. Though India has sufficient cereal grain production its distribution is not uniform, leading to hunger and malnutrition. Pulses production has improved in recent years, still imports are higher in oil seed and pulse crops. Still huge yield gaps exists in pulse production leading to lowering per capita availability food legumes, as country is predominantly pulse crop based protein supply (Table 2).

Table 1. Projections of various food products demand in India for 2020-2021 (in million tonnes)

Commodity	Base year 2004-05	Projection 2020-21
Cereals	192.8	262.0
Pulses	14.2	19.1
Foodgrains	207.0	281.1
Milk and milk products	91.0	141.5
Egg (number bilion)	44.1	81.4
Meat	6.0	10.9
Fish	5.9	11.2
Edible oilseeds	35.5	53.7
Vegetables	90.6	127.2
Fresh fruits	52.9	86.2
Sugar (in terms of cane)	262.3	345.3

Source : Chand, 2007

Table 2. Critical yield gaps (q/ha) in major rainfed pulse crops

Crop	Yield potential on research plots	Yield in FLDs at farmers fields	National average
Chickpea	20-22	15-18	8.06
Pigeonpea (Early	15-17	12-15	7.97
Greengram	11-12	9-10	3.81
Blackgram	10-12	8-9	4.40
Fieldpea	20-22	15-18	10.34
Lentil	15-18	12-14	7.32

Food and Nutritional Security Challenges in India

Food production all the required commodities, diversity of crop cultivation, improper distribution of food, in sufficient public distribution system, imbalanced diet habits are important contributers to food and nutritional insecurity of the country. Large and incresead population and variations in rural and urban diversity also contributes to poor nutrition. Additionally, during past 2 decades, climate change impacts such as droughts, floods, cyclones, hailstroms, heat waves etc., impacting food production negatively presented in Fig 1 and 2.

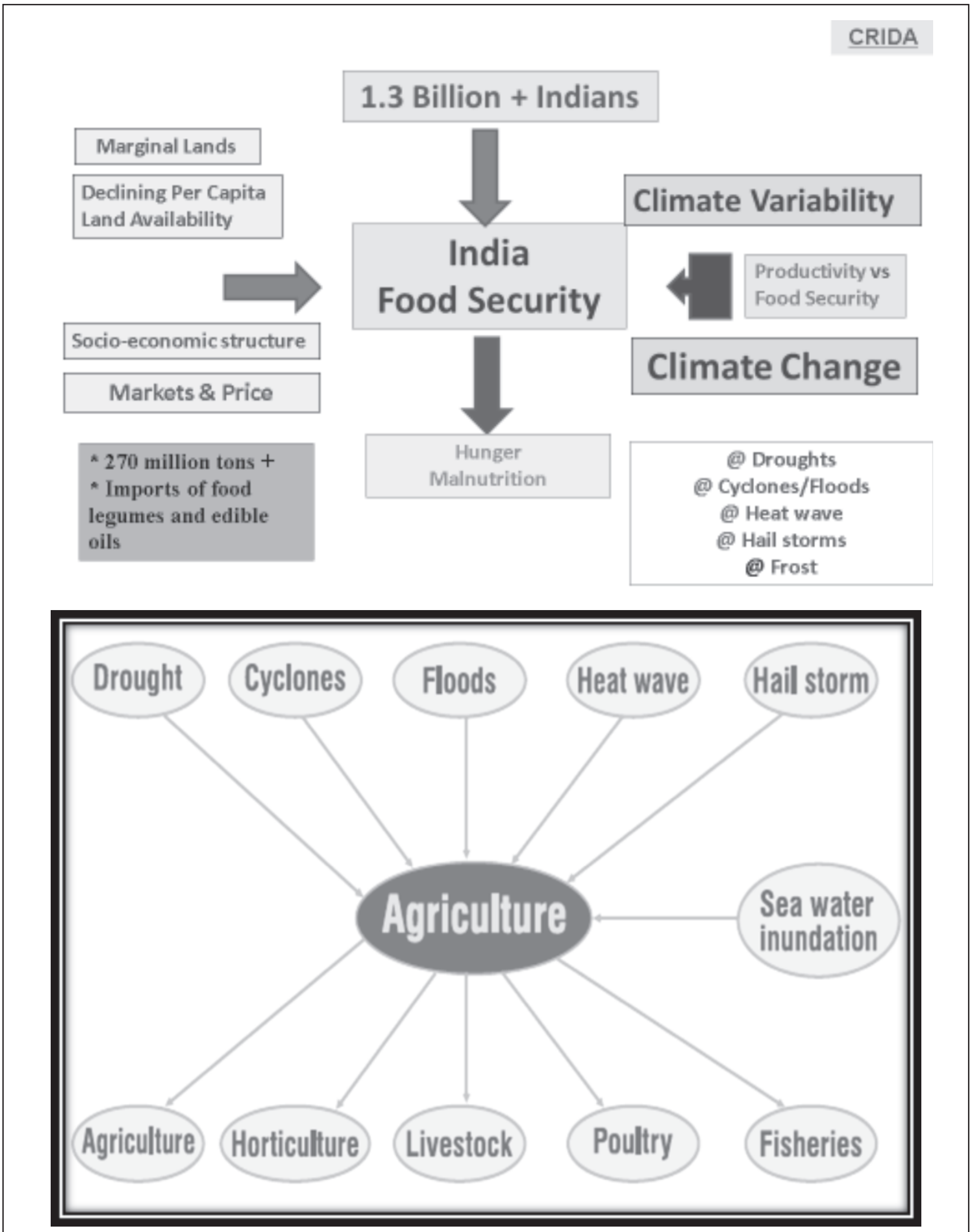

Fig. 2. Impact of climate change on food production

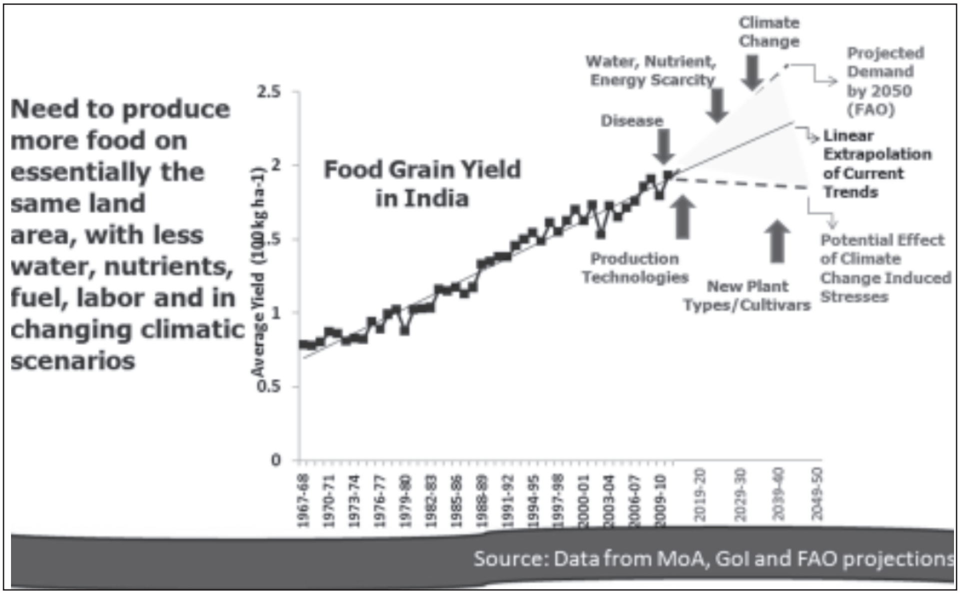

Fig. 3. Food security challenges

Strategies for Enhanced Food and Nutritional Security

Food and nutritional security can be ensured from not only through higher food production of the country by implementing various technological interventions for productivity enhancement but also equally important is through its diversity and social systems such as reduction in food wastage as given below by UN Secretary General (Fig 4). The father of green revolution in India, Prof. MS. Swaminathan proposed 4 point strategy towards achieving this goal.

Source: www.un.org

Fig. 4. Stratagies for enhanced food and nutritional security

Four Areas of Importance to Sustainable Food Security and Elimination of Hunger

- *Conservation :* Family farmers have been at the forefront of bio-resources conservation. Need to recognize the contributions of family farmers and strengthen their gtradition through PPVFRA & Biodiversity Authority of India (BAI).
- *Cultivation :* Impr otant to adopt the evergreen revoltion pathway of agriculture through promotion of green agriculture, organic farming etc.
- *Consumption :* Diversification of farm and crop enterprises with emphasis on millets, horticultural crops, dairy etc. as remedies for the prevailng nutritional maladies.
- *Commerce :* Provide family farmers with adequate financial and scientific support.

  Source : Swaminathan (2014)

Climate-Smart Food Systems for Enhanced Nutrition

Nutrition-sensitive food systems have the potential to be climate-smart. While evidence of effective climate change interventions is still limited, there is already a good understanding of how diets and the environments in which food choices are made can be better managed in response to weather extremes and price volatility. Climate-smart actions which support nutrition entail a focus on diverse, high quality and healthy diets. Solutions lie in the diversification of agricultural and non-farm production systems, the mitigation of climate-related stresses on crop and livestock quality, food value-chain investments to retain nutrients and reduce perishability (including greater efficiency in post-harvest storage, processing and transportation), enhancement of diet quality through more informed consumer choices, and the buffering of purchasing power in the context of supply and price shocks. Climate change is already having measurable effects on food systems around the world. Impacts on agricultural productivity, post-harvest losses and value-chain efficiencies vary according to geography and each country's ability to manage risks. But urgent policy action is required to link food system resilience with higher-quality diets and nutrition.

Climate Change Seen Through a Nutrition Lens

By 2100, it is anticipated that up to 40% of the world's land surface will have to adapt to novel or partially altered climates. Global agricultural production could fall by 2% per decade through to 2050 (based on projections of staple grain yields and livestock output), at a time when global food demand will be increasing by 14% each decade. The largest growth in demand will be occurring in low income countries, which are likely to be most negatively affected by losses in food quality and quantity through the value chain. Indeed, a growing number of projections consistently suggest that climate change will bring improved conditions for agriculture to high-latitude regions, while many parts of the tropics and sub-tropics will experience less favorable conditions and falling yields, particularly of wheat, maize and rice. This already appears to be happening. Maize and wheat yields would have been higher in some of the world's key production zones if climatic parameters had not shifted in the past two decades. Besides affecting food supply, climate change may also affect diversity and nutritional value. Changes in temperature, rainfall and crop and animal disease environments will affect agricultural outputs in different ways. In general, nutrient-rich foods that are currently in short supply in many low-income settings are particularly susceptible to water constraints, pests and diseases, and temperature fluctuations. The principal sources of essential micronutrients are animal-based foods, including milk, meat, eggs and fish, as well as vegetables, fruits and pulses.

Fruits and vegetables are very sensitive to damage and are more perishable than grains or tubers after harvest. Livestock productivity (the source of foods that are critical to young child growth and cognitive development) also tends to be impaired by lack of water and adequately nutritious fodder, as well as by heat and livestock diseases. Recent research has also suggested that higher levels of carbon dioxide in the atmosphere may reduce the nutrient content and/or quality of various staple crops, making them less inherently nutritious

(Wheeler *et al.*, 2013; WHO 2013). If this holds across a wide range of staple foods, the potential degradation of nutrient composition would have a negative impact on nutrient adequacy among the poorest consumers. How crop and livestock production adjusts to changing local patterns of rainfall, temperature and seasonality will strongly influence food systems and the food environment for consumers in the decades ahead. As a result, there is growing recognition of the need to assess impacts of climate change through a nutrition lens, which requires a global focus on healthy diets, "in particular on the quantity, quality and diversity of food (FAO and WHO, 2014)". Healthy diets, which provide adequate, safe, diversified and nutrient rich foods, are an essential building block for physical growth and cognitive development in children.

The International Research Centres of the Consultative Group on International Agricultural Research (CGIAR), therefore made a commitment in 2013 to mainstream improvements in nutrition in all of its crop breeding programs. Biofortification of cereals, by breeding crop varieties rich in micronutrients, or fortification of milled cereals with micronutrients, can also improve micronutrient intake in the diets of the poor (Global Panel, 2015).

Policy Needs for Enhanced Food and Nutritional Security

Policy actions are required across the food system which include the need to increase domestic food production efficiencies, diversify agricultural and value-chain portfolios, enhance engagement in agriculture and food trade (local, regional and global), and establish well-functioning safety nets that protect the purchasing power of the poor in both rural and urban settings. In addition, priority needs to be given to reducing greenhouse gas emissions associated with food processing technologies used in food transportation, storage, and marketing, facilitating private sector investments that will protect food supplies for all consumers, and promoting greater consumer understanding of the environmental implications of food choices (by highlighting otherwise hidden costs of production, processing and distribution). There are many public health interventions that are known to be effective in tackling various forms of malnutrition including chaild stunting, maternal anemia, or iodine deficiencies among school aged children. Attention in food price policies to incentives that can encourage greater availability and accessibility of nutrient-rich foods to all consumers could also have potential value.

National agricultural research policies are integrated goals, pursuing their own research on local crops and animal species and adapting international seed and animal stocks to expected local conditions. Protecting nutrients in the food supply and increasing resilience to climate change beyond productivity requires a focus on reducing post-harvest losses, enhanced storage (to protect food safety and quality of products), improved infrastructure (roads, information systems, refrigeration) that can reduce losses of high nutrient perishable goods, as well as interaction with the private sector.

Engagement with the private sector is necessary to enable a successful promotion of efficient energy use in food processing and packaging, and campaigns to encourage less post-consumer food waste, which can be high in low-income settings, particularly in areas Nila where processed packaged foods represent an important part of the diet. In addition, more efficient market infrastructure and stronger food safety regulations can also contribute to mitigating pest, disease and mould threats. Support for new and adaptive research is urgently needed on ways to enhance and protect the nutrient content of agricultural products in the context of climate change. This includes agronomic research to improve and retain nutrients in foods important to nutritionally-vulnerable populations, but also support for technological innovation in food processing, storage, packaging and transportation.

Climate and economic shocks increases the food prices. When prices are high or uncertain, consumers typically respond by protecting their intake of major staples and then substituting other foods in the diet to make the most of what their purchasing power will allow them. The experience of major food price shocks of the past 15 years or so has shown that in most cases, the purchase and consumption of nutrient-rich foods, such as fruit, vegetable and meat and/or dairy products, declines in the face of a rising share in total consumption of foods that simply provide energy in the form of calories. Recent increase in pigeon pea dal price lead to large scale reduction in in-take of protein in below poverty sections.

Improved marketing and distribution systems are critically important to help reduce supply variability, but so too are price policies and social protection systems that can buffer effective demand and smooth consumption among the poorest consumers. It is critical to protect intakes and enhance diet diversity of the poor rural populations in time of shocks, many low-income countries are also witnessing an increasing urbanization and a growing middle class.

Sustainable Nutritional Security

The procurement, distribution policies of the NFSA, so far the overwhelming attention has been on the major cereals, rice and wheat. An ambitious and holistic programme of food security necessarily requires adequate supply of food at the macro level to meet the effective demand of the country as a whole, but also one that ensures superior dietary quality. The official definition of food security embraces nutrition; in fact the accepted definition is of food security and nutrition and not just food security, as per the Committee on Food Security, a 192 - country UN committee. ‘Likewise, although the NFSA specifies these two separately, ‘to provide for food and nutritional security in human cycle approach....’and repeatedly emphasizes policy tools to address the nutritional security in the arena of public debate, these issues have largely slipped through the cracks.

In the coming years, with rapid structural change in cropping patterns influenced by changing demand patterns, food availability through domestic production would ideally have to come from productivity improvements in agriculture. Yield gaps between India and the world average continue to be significant, and there is scope to augment food production. With the spectra of climate change and the concomitant impact on agricultural production, there is a growing view that there must be a refocusing of priorities to leverage local agro-food systems to address nutritional concerns.

Government of India started several national programs to meet the food and nutritional security besides state government programs. National Food Security Mission, MGNREGA, NMSA etc. are some of the examples in this direction. Crop diversification, integrated farming systems, value addition and promotion of millets, vegetable and fruit based productions at the village level are some of the crucial needs to cover nutritional security of the country particularly in tribal and rural population (Figs 5 to 8).

Public procurement of a broad cross section of grains, and ensuring a remunerative price to the farmers should be the starting point of the food security system and then you build in the pipeline, i.e., it goes to the people through the PDS system and so on, and local procurements so that we do not get into these distortions. If enough thought and effort went in, *jowar*, *bajra* and *ragi* and all these grains could have been included in the PDS and their production also could have been increased to actually meet the demands of the PDS system.

Fig. 5. Livelihood diversification to meet climate risks

Fig. 6. Intigrated Farming System Model in Chianki, Jharkhand

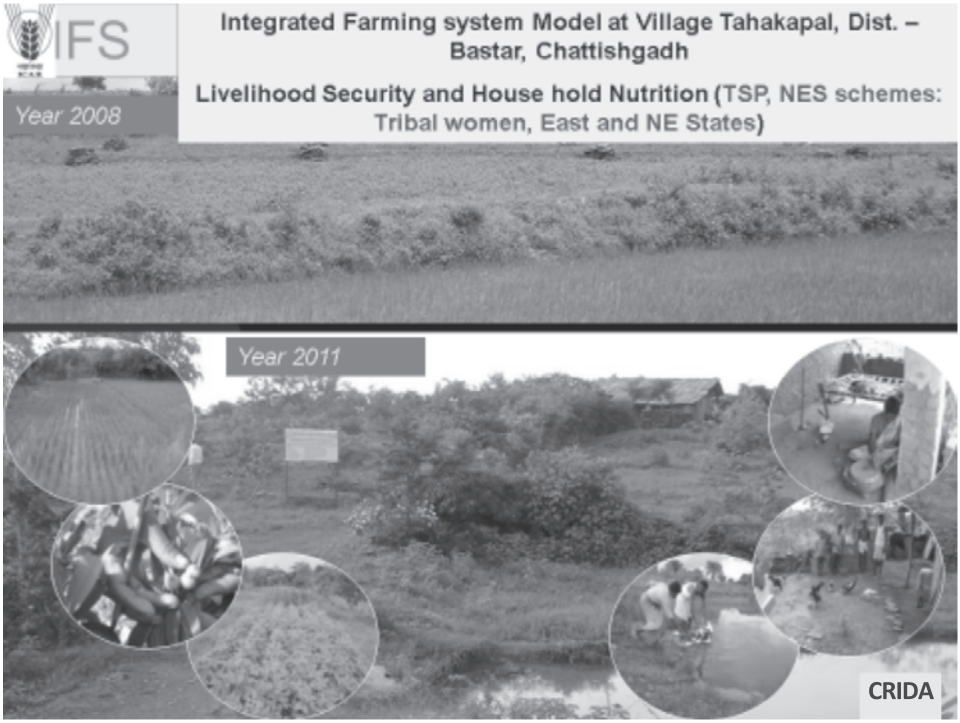

Fig. 7. Integrated Farming System Model at Village Tahakapal, Dist. Bastar, Chattishgadh

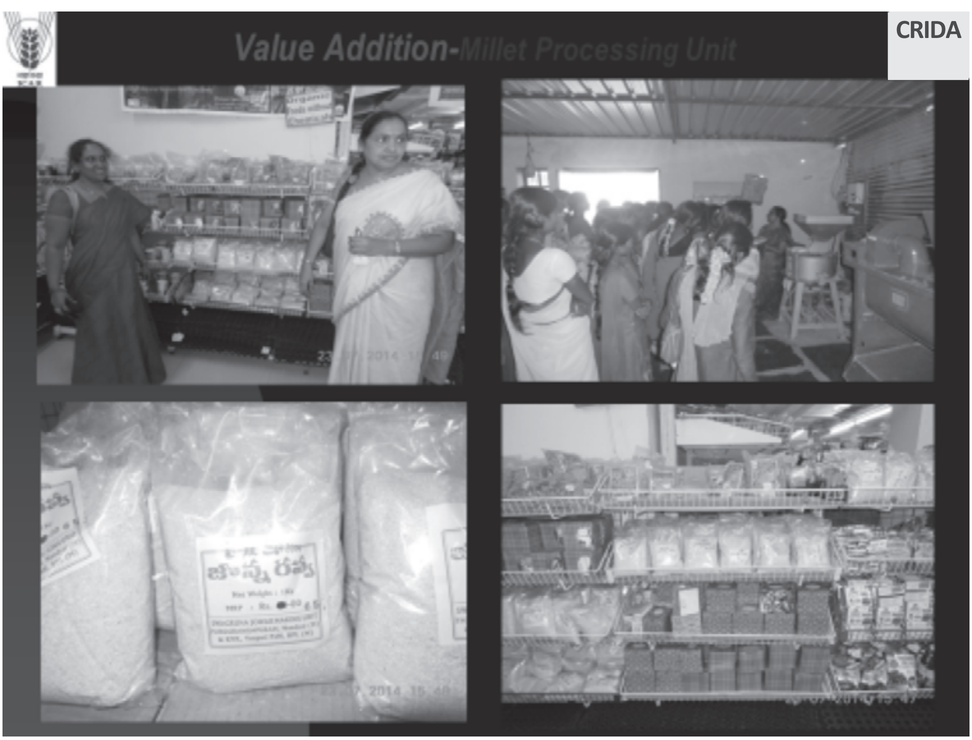

Fig. 8. Value addition - Millet processing unit

Conclusion

The imperative of food security in India is now widely acknowledged, but deep disagreements persist on the best way forward. The year 2014 saw the passing of the NFSA designed to be a comprehensive set of interventions support food security over the life cycle of an individual. PDS, supporters suggest that this is the best way to ensure food access in many contexts in rural India. The immediate challenges for India lie in revisiting operational aspects of food procurement and distribution for a more cost effective and nimble system. There are specific opportunities for policy change across multiple domains in the food system that can simultaneously enhance food and nutrition security in the face of climate change.

The multiple burdens on health created today for low and middle income countries by food-related nutrition problems include not only persistent undernutrition and stunting, but also widespread vitamin and mineral deficiencies and growing prevalence of overweight, obesity and non-communicable diseases. These different forms of malnutrition limit people's opportunity to live healthy and productive lives and impede the growth of economies and whole societies. With continuing efforts at augmenting food production and diversification in sustainable ways.

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2 Dryland Cereals: Future Crops with Climate Resilience and High Nutrition

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Introduction

Sorghum and millets are the important food and fodder crops predominantly in semi-arid regions are gaining importance in a world that is increasingly becoming populous, malnourished and facinglarge climatic uncertainties. These crops are adapted to range of temperatures, moisture-regimes and input conditionssupplying food and feed to millions of dryland farmers, particularly in the developing world. Besides they also form important raw material for potable alcohol and starch production in industrialized countries. Among these crops, sorghum is the world's fifth most important cereal, in terms of both production and area planted. Millet, a general category for several species of small-grained cereal crops, is the world's seventh most important cereal grain (FAO, 1995), and more than 75% area under millets is pearl millet followed by finger millet, proso millet and foxtail millet (Rao and Basvaraj, 2015). Roughly 90 percent of the world's sorghum area and 95 percent of the world's millet area lie in the developing countries, mainly in Africa and Asia (Table 1). These crops are primarily grown in agro-ecologies subjected to low rainfall and drought. Most such areas are unsuitable for the production of other grains unless irrigation is available. Sorghum is widely grown both for food and as a feed grain, while millet is produced almost entirely for food. These crops are also moving to new niches like rice-fallow sorghums in India.

Table 1. Production (in milliontons) and value of production (VOP in USD billions) for milletsand sorghum worldwide and in low-income food deficit countries (LIFDC)[1]

Crop	Production (MT)		VOP (USD billion)	
	LIFDC	World	LIFDC	World
Millets (finger and pearl)	26.5	29.9	4.9	5.4
Sorghum	31.6	61.5	4.6	8.8
Total	58.1	91.4	9.5	14.2

1 FAOSTAT 2014. FAO's classification and criteria for low-income food-deficit countries (LIFDC) can be found at http://www.fao.org/countryprofiles/lifdc.asp?lang=en

The economic importance of the millets is increasing in terms of feed value, particularly that of sorghum (Blummel and Rao, 2006) though it is grown in contrasting situations in different parts of the world. The world sorghum economy can be broadly categorized under two production and utilization systems. Intensive, commercialized production, mainly for livestock feed, characterize the developed world and parts of Latin America and the Caribbean. Hybrid seed, fertilizer and improved water management technologies are used fairly widely, and yields average 3-5 t/ha. Such commercialized production systems cover less than 15 percent of the world's sorghum area, but produce over 40 percent of global output. Roughly 40 percent of this grain is traded on international stock feed markets. In sharp contrast are the low-input, extensive production systems in most of the developing world, where sorghum is grown mainly for food. While improved varieties are being adopted in such systems, particularly in Asia, management practices generally remain less intensive than in the commercialized systems. Fertilizer rates are low and the adoption of improved moisture conservation technologies is limited (FAO, 1995). As a result, average yields remained low between 0.5 and 1.0 t/ha in many areas but gradually increasingin spite of area decline in some regions (Table 2).

Table 2. Annual compound growth rates in sorghum and millet area and yield

Crop/ Region	Area				Yield			
	1981-90	1991-00	2001-10	1981-10	1981-90	1991-00	2001-10	1981-10
Sorghum								
WCA	5%	1%	0%	9%	--3%	1%	0%	--1%
SA	--1%	--2%	--2%	--7%	1%	2%	2%	2%
ESA	--1%	2%	2%	3%	0%	0%	2%	1%
Millet								
WCA	5%	1%	1%	7%	--1%	1%	0%	0%
SA	--2%	--1%	--1%	--4%	2%	3%	1%	5%
ESA	1%	1%	2%	5%	--1%	--1%	1%	0%

CGIAR Research Program on Dryland Cereals -2012

Millets are grown in the harshest environments where there is limited scope for growing other crops. Millet production systems in Africa and Asia are generally characterized by extensive production practices and limited adoption of improved varieties. Yields still average only 0.3 to 1.0 t/ha. While hybrids are being adopted in parts of Asia, most of the world's millet area remains under traditional varieties. Few farmers apply fertilizer or use improved moisture conservation practices. Therefore the yield levels remained low for long but increasing wherever improved hybrids and management practices are increasingly adopted like in India.

The sorghum and millets are crucial to the world food economy because they contribute to household food security in many of the world's poorest, most food-insecure regions. In the main production regions in Africa and Asia, more than 70 percent of the sorghum crop and over 95 percent of the millet crop are consumed as food. A large proportion of farm households aim simply to produce enough grain to meet household requirements and many often fail to meet even this limited goal. Only a small proportion of the harvest is traded, mostly on local food markets. In some countries like India, sorghum contributes to 1% of the total agricultural GDP while it goes up to 7% in Maharashtra and 5% in Karnataka the two major sorghum growing provinces in India.

Most sorghum and millet growing areas are characterized by high population, poverty and malnutrition with limited access and affordability to buy better food (Table 3) and low agricultural productivity is one the major reasons contributing to these problems. Growing environments and technology adoption play key role in enhancing millet productivity. In Africa, the agro-climatic factors most responsible for food insecurity also constrain the adoption of improved technology. Farmers at the margins of subsistence find it risky to invest in new technology. A growing proportion of farmers are beginning to adopt new varieties because only a small investment is required to change seed. However, they are less willing to allocate scarce cash resources to purchase chemical fertilizer or manure. Allocations of capital and family labor required to improve water and nutrient availability to the crop are limited because of the perception of higher returns from alternative farm and non-farm enterprises. In recent years, sorghum and millet production in Africa has expanded mainly due to increases in cropped area. Yields have failed to increase or have even declined because production is being pushed into more marginal areas and poorer soils, even in areas that are already drought-prone. Nonetheless, farmers are expected to begin intensifying production practices as land constraints become binding and the costs of food production shortfalls mount. There are some investmentsbeing made under the Harnessing Opportunities for Productivity Enhancement (HOPE) project and CGIAR Research Program on Dryland Cereals jointly by the NARS, CGIAR centers, Govt. departments, Famers Associations and Community Based Organizations (CBOs) to enhance the productivity of sorghum and millets across Africa and Asia.

Table 3. Population, poverty and malnutrition indicators, by region

Indicator[1]	SA[2]	WCA	ESA
Rural Population (millions)	1,166	248	285
Urban Population (millions)	563	194	115
Stunted Children (millions)	81	14	21
Prevalence of Stunting	55%	36%	44%
Number of poor (millions earning less than USD 1.25/day)	591	150	161
Number of poor (millions earning less than USD 2.00/day)	1,082	210	230

[1] Rural and urban population estimates for 2011 were obtained from the United Nations, Department of Economic and Social Affairs, Population Division (http://www.un.org/esa/population/). Statistics for the number of stunted children, prevalence of stunting, and number of poor were extracted from datasets from the Generation Challenge Program's framework for priority setting (https://sites.google.com/site/gcpprioritysetting/Home).

[2] SA – South Asia, WCA – Western and Central Africa, ESA – Eastern and Southern Africa

While continuing the thrust on productivity enhancement it is important to increase the profitability of sorghum and millets to farmers. End-product specific cultivar use, value-addition and market linkages are critical to make these crops more profitable to farmers. Market infrastructure in Asia is relatively well developed, especially in areas with high population density. As a result, adoption of improved technology has been earlier and more widespread than in Africa, resulting in significant yield growth over the past three decades. Production systems in the drier and less populated regions are more similar to those in Africa, with unimproved production and management practices, low adoption of improved technology and food insecurity.

Overall, the area planted to sorghum and millet has bee

n declining in Asia. Slow productivity growth and low producer prices have reduced the competitiveness of these cereals, resulting in crop substitution in many areas. In some cases, sorghum and millet have shifted into more marginal lands, where their adaptation to drier, less fertile conditions gives them a comparative advantage over other cereals. To change this situation it is increasingly important to make more investments in R & D of sorghum and millets towards sustainable intensification of production and in value-addition to make them more remunerative for the farmers. Further the nutritional benefits of these crops should be highlighted in a big way to generate large consumer demand. Some of the recent progress made in this direction is briefly discussed hereunder.

Recent Advances in Increasing Sorghum and Millets Yield Potential, Addressing Production Constraints and Value Addition

Exploiting the photoperiod sensitivity and temperature insensitivity

Photoperiod plays a major role in sorghum and millets production. Photoperiod sensitivity basically allows for the length of the vegetative phase to vary with planting date, such that flowering occurs around the same time each season (Vaksmann *et al.,* 1996). In West Africa and also in postrainy season in India this mechanism works particularly well as the end of the season is far more predictable (and less variable) than the start (Craufurd *et al.,* 2011). In studies at ICRISAT Patancheru involving diverse sorghum genotypes in postrainy season it was established that M35-1, the postrainy season ruling variety has a distinct feature of photoperiod sensitivity and thermo-insensitivity that offers the ability to flower in more or less same time even in delayed sowings (Reddy *et al.,* 1987). Further breeding work involving M 35-1 as parent, several improved progenies were developed for postrainy season adaptation (Reddy *et al.,* 2009). Further studies at ICRISAT-Patancheru on the flowering response of various postrainy sorghum genotypes under different dates of sowings showed that in December, the critical photoperiod decreases to 10.5 hrs from 12 hrs and temperature to 15^0C from 24^0C. The rainy season adapted genotypes like ICSB 52 and ICSR 149 being photoperiod insensitive takes more time to mature in later dates of sowing and are not suitable for postrainy cultivation. Postrainy sorghum cultivars like

Phule Vasudha and SPV 1359 did not respond for photoperiod but ParbhaniJyoti and Dagadi Solapur showed photoperiod sensitivity and temperature insensitivity by taking less time for flowering in third date of sowing compared to the first date of sowing (Fig 1). This clearly indicated the need for season specific selection while breeding for postrainy season. However, the material can be advanced in rainy season without selection, to speed up the breeding program. Photoperiod sensitivity is exploited well in pearl millet and sorghum improvement particularly in WCA region. High yielding photoperiod-sensitive cultivars have been developed and commercialized. In future, identification of molecular markers linked to photoperiod sensitivity QTLs and cloning and transformation of other maturity genes may help in transferring photoperiod sensitivity to elite cultivars for better adaptation to tropical and sub-tropical environments.

In addition to photoperiod-sensitivity, tolerance to early and mid-season cold temperature is needed for increasing the production in temperate and tropical sorghum production areas around the world where the plants experience cold stress during emergence and/or at anthesis. Tolerant genotypes show increase in seedling vigor, resulting in greater biomass and grain yield in cold and dry environments.

At ICRISAT - Patancheru, the simple and cost effective screening methodologies were developed to screen genotypes for cold tolerance in the same field trials that are intended for grain yield selections. It involves adjusting the planting date of test material in such a way that the flowering coincides with the period of lowest minimum temperatures in the year. Among various traits, the seed set percentage and panicle harvest index in the material flowered under low temperature conditions give an indication of cold tolerance of the material(Krishnamurthy *et al.*, 2014). Further a field and growth chamber based testing has been standardized for cold tolerance screening.

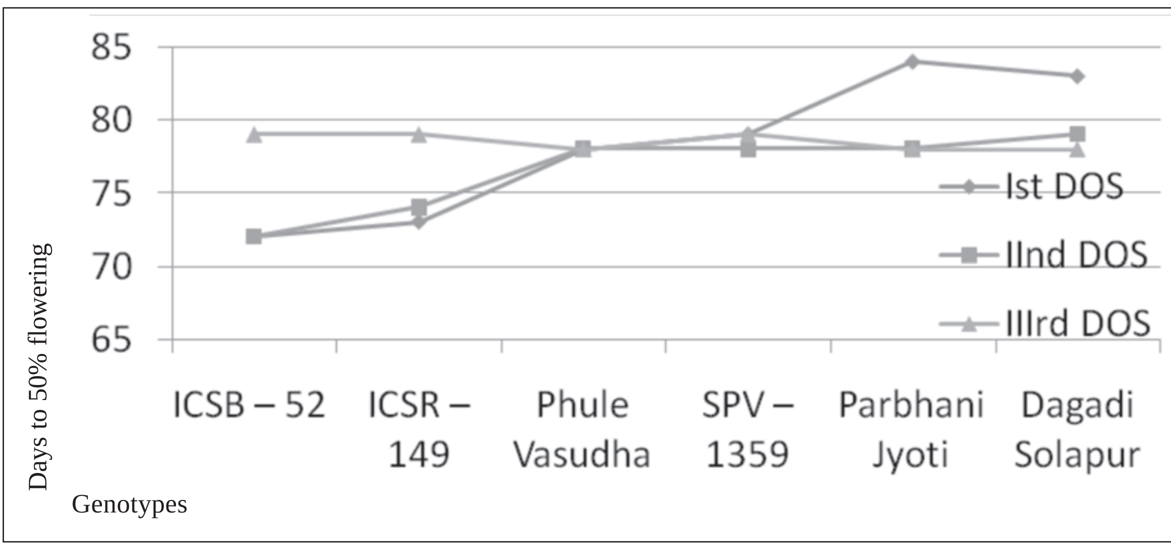

Fig. 1. Flowering behavior of selected sorghum genotypes in different dates of sowing at ICRISAT, Patancheru, postrainy season 2010

(a) Yield potential

Among various millets, sorghum has a high yield potential, comparable to those of rice, wheat, and maize. On a field basis, yields have exceeded 11 000 kg/ha, with above average yields ranging from 7000 to 9000 kg/ha where moisture is not a limiting factor. In those areas where sorghum is commonly grown, yields of 3000 to 4000 kg/ha are obtained under better conditions, dropping to 300 to 1000 kg/ha as moisture becomes limiting (House, 1985). Grain yield is the most important trait in millets breeding as in other crops; however stover yield is equally important in sorghum and pearl millet particularly in countries like India with large deficits on dry and green fodder supply. Breeding for grain yield improvement is carried out by selecting genotypes directly for grain yield and for component traits. Heterosis for grain and stover yield is high in sorghum and pearl millet and therefore hybrids development should be targeted in dual purpose back ground. A heterosis of 30-40% for grain yield is reported in hybrids compared to the best varieties (Ashok Kumar *et al.*, 2011b). Hybrids are the cultivar options and hybrid parents' development is critical for exploiting heterosis in these crops. A total of 270 cultivars have been released so far using the ICRISAT - bred sorghum germplasm in 44 countries and most recent among them are two hybrids released in India (SPH 1641 and RVICSH 28) in 2015 and two varieties (ICSV 112 and ICSV 93046) in Kazakhstan in 2016. The hybrid adoption rates are high in sorghum (>90% in India) resulting in significant yield increase (average yield 1.2 t ha^{-1})

In addition to dual-purpose types, hybrid parents improvement to develop dwarf hybrids for mechanized harvesting and fodder purpose hybrids with high recovery ability (for multi-cut forage purpose) in a range of maturity (70 to 85 days to 50% flowering) should be the major focus. Additionally, forage varieties amenable for both single- and multi-cuts to meet the needs of farmers and dairy industry should be given high thrust. For e.g. apartnership (ICRISAT and Indian NARS) multi-cut forage sorghum variety CSH 24MF (ICSA 467 × Pant Chari 6) is highly popular with farmers in India where the demand is green forage is fast increasing. Further ICRISAT is working on three-way cross forage hybrids development that has >80 t ha^{-1} fresh stalk yield and more than 20 hybrids crossed this yield potential. The newly developed pearl millet varieties recorded 50-60 tons/ha of green fodder and 12-15 tons /ha of dry fodder at 80-day cut (AICPMIP, 2013). Some of the recently developed pearl millet experimental hybrids have shown 5-6 tons of dry biomass in single-cut and 12-15 tons /ha of cumulative dry biomass in two cuts (Rai *et al.*, 2012; Gupta *et al.*, 2015). Also, a highly efficient A5 CMS system discovered at ICRISAT can enhance the pace of breeding forage type male sterile lines for use in breeding high-yielding forage hybrids. In case of finger millet and small millets being highly self-pollinated, OPVs are the cultivar choice with main focus on the grain and dual-purpose nature.

Genetic and cytoplasmic diversification of hybrid parents needs to be given high thrust in developing improved male and female parents in sorghum and pearl millet. In sorghum the *caudatums*and *durras*are mostly exploited in breeding programs but bringing *guinea* race in to breeding programs brings next level diversification and yield advantage(Reddy *et al.*, 2011). Use of *iniadi* germplasm lines contributed to significant yield improvement in pearl millet and there is large scope for increasing the yields by exploitation of new CMS sources in parental line development. Population improvement is a good option in long-term for improving the grain and stover yields in both maintainer and restorer back grounds in sorghum and millets.

Availability of cytoplasmic-nuclear male sterility (CMS) system, higher heterosis % in the improved hybrids, and strong private sector presence facilitated the development of improved sorghum hybrids in large part of the globe. In addition to the widely used Milo-cytoplasm (A_1), cytoplasmic male-sterile lines are also available in A_2, A_3, A_4, A_{4M}, A_{4VZM}, A_{4G1}, A_5, A_6, 9E and KS cytoplasms in sorghum (Ashok Kumar *et al.,* 2011b). Considering the restoration frequency, hybrid performance and comparable A_1 and A_2 CMS effects for grain yield and resistance to shoot fly and grain mold, it is advantageous to use A_2 CMS system for developing hybrid parents, among the alternate cytoplasms available. This not only increases the cytoplasmic diversity but reduces the possibility of epidemics occurrence when a single source of cytoplasm is used.Pearl millet hybrid development programs globally have been based on A1 CMS system, hence at ICRISAT more emphasis is given on diversification of the CMS systems. Among the various alternative CMS systems evaluated (A2 and A3 from India, A4 from USA, Av from France, and Aegp and A5 identified at ICRISAT), it was found that A4 and A5 CMS systems to be distinctly different from others. (Rai *et al.,* 2005). Additional advantage is that the genetic background of male-sterile lines in A_4 and A_5 cytoplasm does not affect the fertility restoration of hybrids, whereas the genetic background of A_1 cytoplasm has significant effect on the fertility restoration (Gupta *et al.*, 2010).

(b) Insect pests management

Sorghum and millets are affected by a large number of insect pests. On sorghum itself nearly 150 insect species have been reported as pests, of which sorghum shoot fly (*Atherigonasoccata*), stem borers (*Chilopartellus*and

Busseolafusca), sugarcane aphid (*Melanaphissacchari*), sorghum midge (*Stenodiplosissorghicola*), and head bugs (*Calocorisangustatus* and *Eurystuylusoldi*) are the major pests worldwide (Sharma, 1993).

Infester row, artificial infestation, and no-choice-cage screening techniques have been standardized to evaluate sorghum germplasm, breeding material, and mapping populations for resistance to insect pests (Sharma *et al.*, 1992). Large-scale screening of the sorghum germplasm at ICRISAT has resulted in identification of several lines with reasonable levels of resistance to shoot fly, stem borer, midge, and head bugs (Sharma *et al.*, 2003). Sources of resistance to insects in sorghum have been used in the breeding program, and many varieties with resistance to insect pests have been developed (Sharma *et al.*, 2005). Recent studies showed that sorghum genotypes CSV 22, ICSB 422, ICSB 425, ICSB 428, ICSB 432, ICSB 458, ICSB 463, IS 2312, IS 5480, IS 18662, Phule Chitra, RSV 1093, IS 18551, and RSV 1235 exhibited resistance to sorghum shoot fly, *Atherigonasoccata* damage across seasons. Principal coordinate analysis placed the maintainer lines ICSB 422, ICSB 432, ICSB 435, ICSB 456 and ICSB 458 in one cluster and ICSB 425, ICSB 428 and ICSB 463 in another cluster. The open pollinated varieties were placed in a different group (CSV 22, IS 5480, IS 2312 and RSV 1093), suggesting the possibilities for developing hybrids with adaptation to the postrainy season (Sharma *et al.*, 2015; Riyazaddin *et al.*, 2015 and 2016).

Cultivars with resistance to midge have been released in India and Myanmar, but are cultivated on a limited area due to non-availability of seed. However, these lines have been used by the seed industry to develop midge-resistant hybrids in Australia and USA. Resistance to midge and shoot fly has been transferred into maintainer lines, which have been supplied to, and used by the NARS partners and the industry in developing improved varieties in different regions (Ashok Kumar *et al.*, 2011b).

Wild relatives of sorghum belonging to *Parasorghum*, and *Stiposorghum*have shown high levels of resistance to shoot fly, stem borer, and sorghum midge (Sharma and Franzmann 2001; Kamala *et al.*, 2008 and 2012), and have diverse mechanisms of resistance to insects. These can be used to transfer resistance genes into the cultigen. The presence of trichomes has been found to contribute to oviposition nonpreference and the trichomes controlled by a single recessive gene (House, 1985). Polymorphic simple sequence repeat (SSR) loci associated with resistance to shoot fly and the traits associated with resistance to this insect have been identified (Folkertsma *et al.*, 2003), and are now being transferred into the locally adapted hybrid parental lines via SSR based MAS. The QTLs associated with antibiosis and antixenosis mechanisms of resistance to sorghum midge (Tao *et al.*, 2003), and tolerance to green bug (Nagaraj *et al.*, 2005) have also been identified. MAS will allow for rapid introgression of the resistance genes, and ultimately gene pyramiding, into the high yielding varieties and hybrids. At ICRISAT-Patancheru, three shoot fly resistant QTLs are being introgressed in to four elite backgrounds that include two B-lines and two varieties (Ashok Kumar *et al.*, 2014). Shoot fly resistance QTLs (3) introgressed in to two elite sorghum lines, Parbhani Moti and ICSB 29004. The QTL introgression lines showed significant yield increase over the recurrent parent besides significantly lower shoot fly dead hearts (Sunita Gorthy and Ashok Kumar, manuscript under development). The Sorghum plants having *cry1Ac* gene have been developed (Girijashankar *et al.*, 2005). Combining transgenic resistance to insects with the conventional plant resistance will make plant resistance an effective component for insect pest management in sorghum. In pearl millet and other millets, insect problem is manageable under field conditions.

(c) Diseases management

In most semi-arid tropical environments, economically important diseases are grain moldin sorghum and downy mildew in pearl millet. While anthracnose, leaf blight, downy mildew, charcoal rot, rust, ergot and smuts are other important diseases in sorghum blast is emerging a major production constraint in millet. These diseases, either alone or in combinations, cause substantial damage to crops resulting in heavy economic losses every year (Thakur *et al.*, 2007). Grain mold is a major disease of improved white-grained, short to medium duration sorghum cultivars that mature during rainy season. The disease affects both grain production and quality and can cause 30-100% losses depending on cultivar, time of flowering and weather conditions during flowering to harvest (Singh and Bandyopadhyay 2000). Several toxigenic *Fusarium* spp. associated with grain mold complex that produce mycotoxins, such as fumonisins and trichothecenes have been characterized (Sharma *et al.*, 2011).

Anthracnose, leaf blight and rust are the important foliar diseases and under favorable conditions up to 50% losses have been reported (Thakur *et al.*, 2007). Downy mildew is another destructive due to its systemic nature of infection resulting in the death of plants or lack of panicle initiation. Charcoal rot is the most important disease of post-rainy (*rabi*) season sorghum that is generally grown on residual soil moisture in India. The disease is more severe and destructive on high yielding sorghum cultivars when grain filling coincides with low soil moisture in hot dry weather. Management strategy for these diseases has been mainly through host plant resistance (HPR), which is economical, environment friendly and technically feasible at farmers' level. Disease management through HPR involves development of a simple and effective screening technique to identify genetic resistance that could be appropriately utilized in breeding programs to develop disease resistant cultivars. Over the years, screening techniques have been developed and refined for major sorghum diseases, such as grain mold, anthracnose, leaf blight, downy mildew, ergot, rust and charcoal rot. Although high level of mold resistance is not available in white-grained sorghum, several tolerant lines have been identified and utilized in breeding program. Efforts are also being made to map QTLs for grain mold resistance for their introgression into elite backgrounds. In addition, efforts are also required to identify resistance against toxigenic Fusaria associated with grain mold complex. Several sorghum germplasm and/or breeding lines with moderate to high levels of resistance to anthracnose, downy mildew, rust and leaf blight have been identified and used in trait-specific breeding program at ICRISAT (Thakur *et al.*, 2007). Recently grain mold resistance hybrids in white grain backgrounds were developed at ICRISAT (Ashok kumar *et al.*, 2008 and 2011a). High level of charcoal rot resistance is not available; moreover, abiotic factors such as soil moisture stress and high temperature predispose plants to charcoal rot infection and disease development. Therefore, there is need to explore other methods of disease control in addition to host plant resistance for the management of charcoal rot.

Downy mildew (DM) caused by *Sclerosporagraminicola* is a widespread and economically most important diseaseof pearl millet causing substantial annual yield losses,particularly in single-cross F1 hybrids. With increasing area under hybrid cultivationsince the 1970s the disease has become more severe dueto evolution of new virulent pathotypes in response tonew hybrid genotypes. At ICRISAT, breeding for DMresistance using conventional breeding andmore recently marker-assisted backcross breeding hasbeen successful, and a large number of disease resistanthybrids have been developed and deployed. This has, to alarge extent, helped in arresting the occurrence ofwidespread DM epidemics since the 1990s. In view of theincreasing severity of the disease and evolution of newmore virulent pathotypes, along-term DM resistance breeding strategy was proposed that involves conducting on-farm surveys, development of DM nurseries in different adaptation zones, development greenhouse screening facilities, designate hybrid parental lines for resistance to specific DM pathotypes (Thakur *et al.*, 2008). Recently sequence data of isolate Sg 445 of *S. graminicola* with over 100 X coverage has been generated at UC Davis. At ICRISAT 14 isolates of *S. graminicola* have been re-sequenced through MiSeq platform to generate normal paired end data with 20X coverage for each isolate (R Sharma personal communication).

(d) Managing weeds

Striga is the most important weed affecting sorghum and millets production, predominantly in sub-saharan Africa where in limited fertilizers are used on these crops. *Striga* is a genus of obligate, root parasitic flowering plant, with most of the species is occurring in Africa. These include *Strigahermonthica, S. asiatica, S. aspera and S. forbesii.* Of these, *S. asiatica*used to be a major constraint limiting yield in sorghum in Asia.

During 1972 to 1985, ICRISAT - Patancheru concentrated its major efforts in developing a three stage screening technique for identifying resistant sources and improving them for high yield under adaption to rainy season conditions in India. The SAR 1 to SAR 36 refers to improved restorer lines and varieties developed at ICRISAT- Patancheru. Work was also directed at identification of resistant mechanisms (mechanical, strigol negative and antibiosis). Also several improved *Striga* resistant improved male sterile lines were developed at ICRISAT- Patancheru during 1985 to 2003 (Reddy *et al.*, 2004). These include ICSB 567, ICSB 568, ICSB 569, ICSB 571, ICSB 572, ICSB 584, ICSB 594, ICSB 598, and ICSB 599 (Reddy *et al.*, 2007). The improved management practices (better tillage, fertilizer application and intercultivation) are by and large keeping the striga under control in most parts of Asia.

In Africa, much of the research work on *Striga* control was carried out initially in the national programs of Nigeria, Sudan, Uganda and Kenya before 1970 and of late in Bamako-Mali. Efforts were carried out to develop resistant varieties (Obilana and Reddy 1996), and also various other control measures such as cultural management (Hess and Dembele 1996), chemical control (Hess and Grard 1996) and biological control (Abbasher *et al.*, 1996). Obilana (2004) indicated that the future research includes adopting new breeding strategies adopting marker technology, identifying the physiological basis of *Striga* pathogen variability, adopting non-conventional approach to *Striga* control including transposon- based mutation and integrated *Striga* control technology exchange and up scaling.

The networking efforts of ICRISAT in use and adoption of biotechnology tools- developing RIL populations of 296 B × Framida (SRN 4841) (stimulant negative), and N 13 (mechanical resistant) × E 36-1, at ICRISAT- Patancheru, phenotyping in pot and field conditions in Western Central Africa (WCA) and Eastern and Southern Africa (ESA) thru networking with national programs, genotyping and identification of markers and QTLs in Germany and at ICRISAT- Patancheru (Haussmann *et al.*, 2000) and adoption of marker assisted back cross breeding paid rich dividends in developing and release of four *Striga* resistant varieties in Sudan in the genetic backgrounds of popular, but *Striga* susceptible improved sorghum varieties, Tabat, Wad Ahmed and AG 8. These four released varieties are Asareca.T1, Asareca.W2, Asareca.AG3 and Asareca.AG4 (Reddy *et al.*, 2012).

(e) High temperature tolerance

Sorghum and millets are known for their adaptation to a range of temperatures. Sorghum grows well in a temperature range of 15-40^{0}C but temperatures below and above this may have a bearing on crop germination, establishment, flowering and seed setting. Sorghum flowers and set seed under high temperatures (up to 43^{0}C) provided soil moisture is available (House, 1985). In many regions of the world, sorghum production encounters heat and drought stress concurrently but heat and drought tolerances are unique and independent traits (Jordan and Sullivan, 1982). Despite the level of adaptation of sorghum in the semi-arid tropics, seedling establishment is still a major problem. Failure of seedling establishment due to heat stress is one of the key factors that limits yields and affect stability of production (Peacock, 1982). Thomas and Miller (1979) reported that sorghum seedlings respond differently when exposed to varying temperatures, and genetic variation for thermal tolerance in sorghum has been shown to exist in certain lines that are capable of emerging at soil temperature of about 55^{o}C. Peacock *et al.,* (1993) and Howarth (1989) have discussed the need for greater diversity in sorghum seedling tolerance to heat in superior genotypes, as this will improve the crop establishment in the semi-arid tropics. Genetic variability for heat tolerance among the genotypes at seedling stage was demonstrated by Wilson et al (1982). Using screening techniques such as leaf disc method (Jordan and Sullivan (1982) and leaf firing ratings by ICRISAT breeders, genetic variability past the seedling stage was demonstrated and positive correlation found between grain yield and heat tolerance thus making breeding for heat tolerance a viable option. Genetic variability for heat tolerance in sorghum was also reported by other researchers (Sullivan and Blum 1970; Seetharama *et al.,* 1982; Jordan and Sullivan, 1982).

Khizzah *et al.,* (1993) reported that two loci were responsible for expression of heat tolerance, and complete dominance at both gene pairs, but one gene when dominant is epistatic to the other. The importance of additive gene effects over dominance effects for heat tolerance index was reported by Setimela *et al.*, (2007). However, selection for heat tolerance has limited success as (i) laboratory techniques to screen for heat tolerance have not been effective in improving heat tolerance in field studies; (ii) field screening for heat tolerance is difficult to manage and is often confounded with drought tolerance (Rooney, 2004). Due to the confounding effects, though the heat and drought tolerance are independent traits, the selection for drought tolerance traditionally has been assumed to improve heat tolerance.

ICRISAT's experimentation during 2013 and 2014 identified some promising sorghum lines (B-lines, R-lines and varieties) which flowered normally and showed 100% seed set under temperatures above 40^{0}C. However not all sorghums show heat tolerance. The 1000 test genotypes (600 B- lines, 300 R-lines and 100 varieties) at ICRISAT showed lot of differences for growth and flowering. Some of the genotypes flowered early, some flowered normally, some flowered late while some of them did not flower at all. Genotypes like ICSR 14001, ICSR 8, ICSR 21, ICSB 55, ICSB 84, ICSB 603, ICSV 162, ICSV 376 flowered normally, similar to their flowering time in the rainy season with a seed set percentage of 100% indicating the heat tolerance of these lines. These studies also showed that planting the material in first week of March gives best results for field screening for heat tolerance and the traits flowering time, seed set % and panicle harvest index serves as good proxies for selecting for heat tolerance. In pearl millet, based on multi-location and multi-year screening in target ecology, large genetic variation for tolerance to heat at reproductive stage among pearl millet breeding lines and populations has been observed, and heat-tolerant lines have been identified. These include several maintainer lines (ICMB 92777, ICMB 05666, ICMB 00333, ICMB 01888, ICMB 02333 and ICMB 03555), improved populations (ICMV 82132, MC 94, ICTP 8202 and MC-Bulk) and germplasm accessions (IP 19799, IP 19877 and IP 19743) (Gupta *et al.,* 2015). They can be exploited in developing improved cultivars for expanding summer pearl millet.

(f) Drought management

Millets and sorghum show high degree of drought tolerance though there are large genotypic differences. Sorghum has the capacity to survive some dry periods and resume growth upon receipt of rain. Sorghum also withstands wet extremes better than do many other cereal crops especially maize. Sorghum continues to grow, though not well, in flooded conditions; maize by contrast will die.

In sorghum four specific droughts were recognized. These are: 1. Seedling emergence under deep planting and high temperature, 2. Early seedling drought, 3. Mid-season drought or pre-flowering drought and 4. Post flowering/terminal drought. Among these, the two distinct drought-stress responses, a pre-flowering drought tolerance that occurs prior to anthesis and a post-flowering drought-stress that is observed when water-limitation occurs during grain-filling stage as in post rainy season adaptation have been considered as the most important in sorghum (Rosenow and Clarke 1981; Rosenow *et al.*, 1983).

At ICRISAT, growth-stage-specific breeding for drought tolerance, which involves alternate seasons of screening in specific drought and well-watered environments, has been used to breed sorghum that can yield well in both high-yield-potential environments as well as in drought-prone environments (Reddy *et al.,* 2009 and 2011). Since hybrids have exhibited relatively better performance than open pollinated (OP) cultivars for grain yield under water-limited environments, hybrid cultivar development (including their parents) should be given strategic importance for enhancing sorghum production in water-scarce environments (Reddy *et al.,* 2009).

Some of the drought tolerant sources identified in sorghum in early work at ICRISAT include Ajabsido, B35, BTx623, BTx642, BTx3197, El Mota, E36Xr16 8/1, Gadambalia, IS12568, IS22380, IS12543C, IS2403C, IS3462C, CSM-63, IS11549C, IS12553C, IS12555C, IS12558C, IS17459C, IS3071C, IS6705C, IS8263C, ICSV 272, Koro Kollo, KS19, P898012, P954035, QL10, QL27, QL36, QL41, SC414-12E, Segaolane, TAM422, Tx430, Tx432, Tx2536, Tx2737, Tx2908, Tx7000 and Tx7078 (www.icrisat.org). ICRISAT has identified lines that are tolerant to drought at various growth stages (Table 4). Drought tolerance of M 35-1, a highly popular post rainy season adapted landrace in India, has been amply demonstrated (Seetharama *et al.,* 1982).

Table 4: Sorghum germplasm and breeding lines tolerant to drought at specific growth stages, ICRISAT-Patancheru, India

Growth stage	Tolerant sources/ improved lines
Seedling emergence	IS 4405, IS 4663, IS 17595 and IS 1037, VZM1-B and 2077 B, IS 2877, IS 1045, D 38061, D 38093, D 38060, ICSV 88050, ICSV 88065 and SPV 354
Early seedling	ICSB 3, ICSB 6, ICSB 11 and ICSB 37, ICSB 54 and ICSB 88001
Mid-season	DKV 1, DKV 3, DKV 7, DJ 1195, ICSV 272, ICSV 273, ICSV 295, ICSV 378, ICSV 572, ICSB 58 and ICSB 196
Terminal drought	E 36-1, DJ 1195, DKV 3, DKV 4, DKV 17, DKV 18, ICSB 17

Source: ICRISAT 1982; Reddy et al 2004

In another study, the results for the measured variables [carbon exchange rate, (CER), transpiration, transpiration ratio (CER/transpiration), leaf diffusive resistance, leaf water potential and osmotic adjustment] showed a general trend for greater drought resistance in sorghum than in millet, indicating that the commonly observed adaptation of the millets to dry environments may be due to other factors, such as drought escape or heat tolerance (Blum and Sullivan 1985).

Among several drought tolerant traits, stay green trait in sorghum (the capacity of certain genotypes to maintain their leaves green during the grain-filling period) is the well characterized and exploited as a post-flowering drought tolerant trait (Reddy *et al.,* 2009; Haryarimana et al 2010). It's well documented to be polygenic and heritable, and is used extensively in breeding programs for developing drought tolerant cultivars (Harris *et al.,* 2007; Jordan *et al.,* 2012). This phenotype is also reported to be associated with reduced stalk lodging, reduced susceptibility to charcoal rot and maintenance of seed size (Borrell *et al.,* 1999 and 2000). Several studies had identified genomic regions/Quantitative Trait Loci (QTLs) underlying stay green expression (Tuinstra *et al.,* 1997a, Crasta *et al.,* 1999; Subudhi *et al.,* 2000a and 2000b; Tao *et al.,* 2000; Xu *et al.,* 2000; Kebede *et al.,* 2001 and Sabadin *et al.,* 2012). Physiological mechanisms such as improved capacity and WUE for water extraction, response to Vapor Pressure Deficit (VPD), transpiration efficiency (TE), leaf conductance and kinetics, specific leaf area and canopy development have been associated with stay green QTLs (Vadez *et al.,* 2011). These QTLs are been used for developing drought tolerant cultivars through marker-assisted backcrossing (Kassahun *et al.,* 2010; Jordan *et al.,* 2012) and effects of each QTL on stay green expression, grain and fodder yield had been reported. This needs to be further validated across several genetic backgrounds and different target regions. Similarly modeling efforts to characterize soil and agro-climatic parameters for production areas where post rainy sorghum is grown had been reported (Hammer *et al.,* 2010).

Drought scenarios in postrainy sorghum have been classified and quantified using crop simulation at ICRISAT. Variation in traits that hypothetically contribute to drought adaptation (plant growth dynamics, canopy and root water conducting capacity, drought stress responses) were virtually introgressed into the most common post-rainy sorghum genotype, and the influence of these traits on plant growth, development, and grain and stover yield were simulated across different scenarios. Limited transpiration rates under high vapour pressure deficit had the highest positive effect on production, especially combined with enhanced water extraction capacity at the root level. Variability in leaf development (smaller canopy size, later plant vigor or increased leaf appearance rate) also increased grain yield under severe drought, although it caused a stover yield trade-off under milder stress. Although the leaf development response to soil drying varied, this trait had only a modest benefit on crop production across all stress scenarios. Closer dissection of the model outputs showed that under water limitation, grain yield was largely determined by the amount of water availability after anthesis, and this relationship became closer with stress severity. All traits investigated increased water availability after anthesis and caused a delay in leaf senescence and led to a 'stay-green' phenotype. These studies concluded that breeding success remained highly probabilistic; maximum resilience and economic benefits depended on drought frequency and maximum potential could be explored by specific combinations of traits (Kholova *et al.,* 2013 and 2014).

Nutritional value

Sorghum and millets have predominant role in meeting the dietary energy and micronutrient requirements particularly in the low income group populations in Africa and south Asia. Efforts were made to understand the genetic control of nutritional quality in sorghum and millets. Protein content is relatively more studied in sorghum where in high genetic variability reported. Gains in protein content were also reported by various authors. The best method for phenotyping for protein content is through using Microkjeldahl method or Technicon autoanalyser (TAA) method. A study on limited number of germplasm lines, hybrid parents in sorghum did not show appreciable variability for â-carotene content in sorghum (Reddy *et al.,* 2005). Similar is the case with yellow endosperm lines where in the â-carotene did not exceed 1.1 ppm. For phenotyping for this trait, spectrophotometry can be followed but estimation using High-Performance Liquid Chromatography (HPLC) gives more accurate information.

Grain Fe and Zn enhancement is one of the major breeding objectives at ICRISAT and elsewhere. Large scale screening of sorghum core germplasm accessions, hybrid parents and commercial hybrids showed high genetic variability for grain Fe and Zn contents and most of this variation is heritable (Reddy *et al.*, 2005 and Ashok Kumar *et al.*, 2012). Significant positive association exists between grain Fe and Zn contents (r^2=0.6-0.8) and it is possible to simultaneously improve both the traits (Ashok Kumar, 2009 and Reddy *et al.*, 2011). Additive gene action plays significant role in conditioning the grain Zn content while non-additive gene action is predominant for grain Fe content (Ashok Kumar *et al.*, 2013a). Identification of QTL controlling grain Fe and Zn in sorghum is underway. Improved high Fe and Zn sorghum varieties and hybrids are being field tested in multilocation trials (Ashok Kumar *et al.*, 2013b). The X-ray Fluorescence Spectrometry (XRF) can be used for rapid phenotyping of large number of breeding products to select the high Fe and Zn lines and the final validation can be done using the Inductively Coupled Plasma – Emission Spectrometry (ICP-ES) (Ashok Kumar *et al.*, 2013b). At ICRISAT improved sorghum variety ICSR 14001 and hybrid ICSH 14002 have been developed that have 50% higher Fe and Zn concentration than the base levels (30 ppm Fe and 20 ppm Zn) in sorghum that are currently tested in All India Coordinated Sorghum Improvement Program and state multilocation trials for their commercialization (Ashok Kumar *et al.*, 2015). Further two more varieties ICSV 15012 and ICSV 15013 were identified that have higher yield and very high Zn concentration (48-50 ppm) over and above the targeted 40 ppm in sorghum.

Pearl millet has higher protein content than other major crops with more balanced amino acid profile and high protein efficiency ratio. Its gluten-free protein has therapeutic effect for those prone to gluten allergy and celiac disease. It also has high dietary fibre. Thus, foods prepared from pearl millet have low glycemic index, and are suitable to those suffering from or prone to diabetes. Phytochemicals found in pearl millet, though act as anti-nutritional factors, have anti-oxidant properties. Pearl millet *also* has high levels of several minerals. Of the greatest interest of these are the iron (Fe) and zinc (Zn) contents, for which widespread deficiencies with numerous adverse health effects have been found worldwide, especially in populations of the developing countries heavily dependent of cereal-based diets (Rai *et al.*, 2015).

Excellent progress has been made in biofortifying the pearl millet. Large genetic variability for Fe and Zn, quantitative inheritance, predominance of additive gene action, strong positive correlation between Fe and Zn were reported (Gupta *et al.*, 2009; Rai *et al.*, 2012 and Velu *et al.*, 2011). An improved high Fe pearl millet cultivar 'Dhanashakti' was released for commercial cultivation in India. It has 10% high Fe and 5% high yield than the 'ICTP 8203' from which it was developed. In a study to assess the bioavailability of Fe from the high Fe cultivar, iron-deficient Indian children under the age of three who ate traditionally-prepared porridges (sheera, uppama) and flat bread (roti) made from iron-rich pearl millet flour absorbed substantially more iron than from ordinary pearl millet flour, enough to meet their physiological requirements. As an added bonus, this iron-rich pearl millet also contained more zinc, which was similarly absorbed in sufficient amounts meet the children's full daily zinc needs. This vindicates biofortified products can potentially increase Fe absorption (www.harvestplus.org).

Bio-Energy

Energy security is a critical concern in India and other developing countries and there is large Sorghum has distinct advantage as energy sorghum because of its high biomass production and adaptation across semi-arid tropical environments. Hence, this crop is widely believed as a model biofuel feedstock owing to its adaptation and ease of handling segregating generations. Sorghum biomass yields vary between 15 and 25 t ha^{-1}, but have been reported to be as high as 40 t ha^{-1} (Rooney *et al.*, 2007). It is a very robust plant that not only produces high biomass but also accumulates large quantities of sugars in the stalks that can be used for biofuels production without scarifying the grains. Sweet sorghum or high energy sorghum can also thrive under moderate water stress conditions on marginal lands, and with little external inputs (Reddy *et al.*, 2004, Reddy *et al.*, 2008, Srinivasarao *et al.*, 2009). It also can be grown successfully in degraded and marginal lands contaminated with heavy metals (Zhuang *et al.*, 2007). Thus, energy sorghum (both biomass and sweet sorghum) is well suited for land of low productivity or at higher risk for drought or water logging stress and is unlikely to replace food crops from higher-quality land (Srinivasarao *et al.,* 2010). Specific traits of interest are stalk sugars accumulation, biomass yield, post-flowering drought adaptation, water-use efficiency, non-lodging, and cell wall composition. Elucidating the genetic basis of stem sugar and stem juice accumulation, modifying cell wall composition through *bmr* alleles introgression so that sorghum biomass can be processed more efficiently, maximizing biomass yield for a given geographic area and production system, and understanding the different mechanisms underlying drought tolerance are the main focus areas among sorghum researchers that target bioenergy traits. As mapping populations and collections of mutants increase, it will become easier to identify genes of interest, and it will ultimately become possible to identify all the genes involved in a particular process or pathway, and know how they interact. Efforts are underway in combining this information to generate germplasm that will enable sustainable bioenergy production using sorghum and pearl millet.

Fodder quality

The stover of sorghum and millets is an important animal feed particularly in dry areas. Extensive market survey of fodder trading in India has shown that the ratio of stover to grain price is narrowing with stover: grain price ratio approaching now 0.5 (Sharma *et al.,* 2010). Additionally price premiums are paid for higher quality stover and a difference of about 1 percentage unit in stover digestibility was associated with a price premium of about 5% (Blümmel and Rao 2006).

Phenotyping for stover fodder quality of pipelined and release tested hybrids and OPVs has shown that about 5 units difference in stover digestibility exists that can be exploited without detriment to grain and stover yield (Blümmel *et al.,* 2010). Price premiums for such stover are 25 to 30%. Near Infrared Spectroscopy (NIRS) platforms were developed and validated to phenotype for stover quality in multidimensional crop improvement programs (Sharma *et al.,* 2010). The dry stalks are controlled by a simple dominant gene, D; juiciness is recessive (House, 1985).High yielding dual-purpose and forage sorghum and millet cultivars were developed with high *invitro* drymatter digestibility.Stay green QTL introgression can improve stover digestibility by 3 to 5 percentage units without detriment to grain and stover yields, in addition to improving drought resistance of sorghum cultivars and their water use efficiency. Brown mid rib introgressions improved stover quality similarly, but had a depressing effect on grain and stover yields.

Fortification and densification works has shown that sorghum stover based feed blocks, feed mash and feed pellets have the potential to increase average milk yields (currently < 4 kg/day) by three to 4 folds (12 to 16 kg/day, Anandan *et al.,* 2010).The effect of such intensification on natural resource usage and greenhouse gas emission is dramatic. For example an increase in average daily milk yield from 4 to 6 kg would reduce methane emission from Indian dairy by more than 1 million tons per year (Blümmel *et al.,* 2010). Recent studies indicated that when sweet sorghum bagasse (SSB) was processed into complete diets, in terms of nutrient utilization and microbial N supply, the expander extruded pellet diet was better utilized than chopped or mash form by the growing ram lambs (NaliniKumari *et al.,* 2014).

Alternative uses

Sorghum and millets are predominantly used as food by making various products out of them which are country/region specific. For e.g., sorghum is consumed in the form of *roti, bhakri or chapathi*in India *and ugali, kisra, injera, To, etc.,* in Africa. Similarly millets in the form of *bhakri or porridge or gruel*.The possible promising alternative food products from sorghum and millets are bakery products, maltodextrins as fat replacers in cookies, liquids or powder glucose, high fructose syrup and sorbitol. Malted sorghum and millets can be a good alternative for baby weaning foods. Popped sorghum and sorghum noodles, also as breakfast or snack foods form good alternative uses.

The industrial products made from sorghum grain include alcohol (potable grade) and lager beer. Other technologies such as production of glucose, maltodextrins, high fructose syrup and cakes from sorghum are yet to be scaled up. The juice from sweet sorghum stalks is fermented to produce ethanol (Biofuel) and other sweet sorghum products like syrup and *jaggery* have received good attention in production of food products like sweets and ready to serve foods.

Recently the NutriPlus Knowledge (NPK) program of the Agribusiness Business and Innovation Platform (AIP) at ICRISAT has demonstrated that sweet sorghum juice and syrup can be used as sugar alternative for meeting certain requirements of the beverage industry (DattaMazumdar *et al.*, 2012). Value addition, through conversion of the juice to syrup and beverages, offers farmers an excellent opportunity to improve farm income and productivity in semi-arid regions. In this study a new method to produce clarified sweet sorghum juice was demonstrated. Further, flavoured nutritious beverage formulations, with acceptable sensory properties were successfully developed using the clarified juice and syrup. Further the efforts are underway to increase the shelf-life of pearl millet using genetic and mechanical approaches.

Conclusion

Sorghum and millets continue to be important food and feed crops in developing world. Their versatility in multi-purpose use, stress adaptation and nutritive value makes them even more important crops in the era of extreme climate variability and high incidence of dietary induced malnutrition. Recent advances in sorghum and millets research and development in enhancing their yields, adaptation, stress resistance, nutritional value and processed products development discussed above contributes to increased economic value of these crops to the producers, particularly in dry lands. Forage is another area where both sorghum and pearl millet play critical role in enhancing dryland farmers' incomes. The biofortified pearl millet and sorghum, sweet sorghum for bioenergy are some of the examples showcasing the potential of these crops in providing nutritional and energy security in developing world. Sorghum genome sequence is available and put to use for improving various traits. An ICRISAT-led consortium has recentlysequenced the pearl millet genome and being published. Efforts are underway to sequence the finger millet genome also. The challenge will be to make use of the genome information and developing customized research products and technologies to suit various climatic, food, nutritional and product quality requirements. Besides productivity enhancement the whole value chain should be looked in to make these crops more remunerative to farmers and processors. This calls for increased interest and investment from national governments and private sector for developing thriving integrated value chains for sorghum and millets.

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3 Impact of Diversification in Agriculture on Food Consumption and Nutrition

Vijaya Khader

Introduction

India has the second largest population after China. Agriculture occupies nearly 45% of the total geographical area and is the primary occupation of 64% of the total population. The Green Revolution in the1960s has made India a food surplus country. National Nutrition Policy (1993), National Nutrition Plan of Action (1995) and National Nutrition Mission (2001) have not at achieved nutrition goals**.** The reason is nutrition is a poor cousin even in health and agriculture planning and execution. Nutrition improvement is not a stated goal with measurable parameters in National Food Security Mission, National Horticulture Mission and National Rural Health Mission**.** This paper deals with the diversification of Agriculture, intervention of Horticulture, Dairy, Fisheries, Mushroom, Value addition, Women empowerment and Nutrition education for food and nutrition security.

Experimental methodology used starting from Surveys, Chemical analysis, Biochemicalestimations, bio-availability studies on rats as well as human subjects; clinical observations and histological studies were used as per the study design. Product development, value addition, Technology transfer, Entrepreneur skills development, income generation activities and creating awareness through Nutrition Education were also used. Research carried out on impact of agriculture diversification on nutrition security is discussed under Diversification of Agricultural; Horticulture; Mushrooms; Dairy; Fisheries; Value addition; Nutrition Education; Welfare Programs; Economic Empowerment of Women and unexploited biodiversity.

Agricultural Diversification

Integrated Crop Management (ICM) Modified form of System of Rice Intensification (SRI) designed and promoted by the Food and Agricultural Organization is an effective strategy to realize the maximum of the potential yield of a crop variety.According to the World Health Organization, an estimated 334 million children in developing countries are malnourished. In 2020, one out of every four children in these countries will still be malnourished. It is recognized that modern agriculture must diversify production and achieve sustainable higher output to supplement food security.

Crop diversification/cropping systems

- Intercropping of ragi and redgram in 8:2 ratio is found to give additional income of Rs.5,500/- ha compared to sole crop of ragi.
- Ground nut intercropped with either red gram (4151 kg/ha) or castor (4238 kg/ha) in 7:1 ration recorded maximum
- Redgram based cropping systems, redgram+ clusterbean (3263 kg/ha) in 1:7 ration gave highest redgram
- Among different alternate crops tried to groundnut during late rabi, blackgram recorded maximum net returns (Rs. 26801/ha) and followed by sesasum (Rs. 20697/ha)
- Cluster bean and field bean are excellent alternative crops for rain fed groundnut in bad years.

Home based low cost energy protein rich preparations using Horse gram for vulnerable groups (Vijayakhader et al., 1998): The horse gram which is commonly used for cattle feed can be diversified for human consumption with less investment**.** Processed horse gram flour was prepared using Puffing and Roasting, Processed Soya bean flour was prepared by Dehulling and Roasting. The low cost energy protein rich products namely RAGINA and EPRF were prepared using the simple home scale processing methods like germination, roasting and puffing, to improve the nutritional status. Horse gram has been identified as potential food resource for the tropics and also occupies an important place among pulses because of its ability to resist severe drought conditions. Soya bean (*Glycine max*) is one of the best vegetable proteins and has tremendous potential to meet the protein deficiency in the cereal based Indian Diets at a low cost. Product development can be taken as income generating activity in the rural areas by the illiterate women. Products can be included in supplementary feeding programs in order to improve the nutritional status of the vulnerable groups of the population.

Nutrient intake, morbidity and nutritional status of preschool children are influenced by agricultural and dietary diversity in western Kenya(Mary Walingo Khakoni, 2013): A cross sectional survey was set up to assess the influence of agrobiodiversity and dietary diversity on morbidity, nutrient intake and the nutritional status of preschool children in Western Kenya. About 34.8% preschool children were severely stunted, 21.5% severely underweight and 8.3% were severely wasted. There was a positive and strong relationship between agricultural biodiversity, dietary diversity and caregivers' level of education. Morbidity level and dietary diversity had significant influence on underweight levels and stunting. Consideration of agro biodiversity in terms of dietary diversity can improve the nutrition and health status of a preschool child.

Horticulture Intervention

This will focus on increasing the supply nutrient-rich crops, in part through the promotion of home gardening. Horticulture intervention will involve the Ministry of Agriculture for the supply of seeds, extension, and storage support. Vitamin A and Iron Nutritional status of nutritionally vulnerable segments of population subsisting on Horticulture crops and dairy farming in East Godavari district of A.P. (Aruna, 1997) showed very significant improvement in their nutritional status. Significant impact of Nutrition Garden / Home garden reflected on Iron & Vitamin status of the families under study.

Transfer of home level preservative techniques of selective fruits and vegetables to rural women in Guntur district (Vijaya Khader et al., 1994): There was a significant, negative correlation between age of the respondents and gain in knowledge. There was a significant positive correlation of socio economic variables such as educational status, family income, and land holding on gain in knowledge.

Operational feasibility of RPO supplementation to pre-school children in Anganwadi centers of ICDs Project (Vijayakhader et al., 2008): Vitamin A deficiency causes many health problems especially among children. A study was undertaken to screen the effect of supplementation of Red Palm Oil (RPO) obtained from the fruits of tree *Leis guineensis Jac.*The oil is rich in B-carotene, a precursor of Vitamin A.Supplementation of crude RPO to Anganwadi Children increased the attendance of children, increase in heights and weights of children. Decrease in Grade 11 and Grade 111 malnutrition was observed in respect of sex.

Effects of dried Gymnema Sylvestre leaf powder showed a significant reduction on blood glucose, lipid profile and blood pressure in newly diagnosed type 11 diabetic subjects- a pilot study (Aparna Kuna *et al.*, 2010)

Mushrooms

Rural Women as Entrepreneurs in Mushroom Cultivation (Vijaya Khader, 1994) **:**Every woman is an entrepreneur as she manages, organizes and assures responsibility for running her house. It has been increasingly realized that women possess entrepreneurial talent which can be har nessed to create employment opportunities. In the rural areas a woman can easily manage 4-10 beds depending on the space available, helping them to earn Rs.180 to Rs.450 per month. The results of the studies revealed that spawn multiplication can be done by women as a co-operative venture and mushroom cultivation can be undertaken at household level as an income-generating activity.

Intervention of dairy

Impact of dairy programme on the nutritional status of women and preschool children in Vihiga District, Kenya Africa (Mary Khakoni Walingo et al., 2000): The dairy programme in Kenya has a significant impact on the overall improvement of the family in specific to improving production, consumption and marketed surplus of milk. Food and nutrient intake and nutritional status of women and preschool children from participant households improved.The prevalence of under nutrition in preschool children in participant households was lower (1.7%) than that of children in non participant households(2.9%).Stunting was 8.7 % and 21.4% in preschool children from participant and non- participant households respectively. Less percent (6.7%) of women in participant households had body mass index less than 18.5, whereas 7.3% of women from non- participant households fell below this cut off point.

Fishery intervention

Role of Women in Fisheries in Coastal Eco-System of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. (Vijaya Khader et al., 2005). Fish eaters in the study area comprise 47 per cent of the total population ranging from 237 per cent in Tamil Nadu to 85 per cent in Kerala. Though the position of Tamil Nadu in terms of number of coastal districts and possession of coast line including the number of landing centers is envious, the number of fish eaters in the state is minimal. Andhra Pradesh employs 32 per cent of its fisherwomen in fish curing/drying/net making and 27 per cent in processing plant works.

Studies on Fisher Women in the Coastal Eco System of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (Vijaya Khader,et.al. 2004): Two Equipments I) Low Cost Ice Cream Freezer, II) Fresh Fish Vending and Display Table have been fabricated and received Patents and the technology was licensed to Smt.G.Varalakshmi, W/o. Sri G.Satya Kiran, M/s. Yogi Industries, and Secunderabad for manufacturing these two equipments for a period of two years. She is the sole authority to manufacture in the country. After expiry of two years the technology on low cost ice cream freezer was licensed second time to another women entrepreneur namely Mrs. Lakshmi Bhuvaneswari W/o Devi Hariprasad, D.No.23/321, Bachupeta, Hindu College Road, Machilipatnam – 527 001 on 16th September, 2006 for a period of 6 years. These equipments were fabricated mainly to improve the Health & Nutrition Security.

Health &Nutritional status of preschool children in coastal fishing villages of South India Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (Vijayakhader, et.al., 2005): The consumption of vegetables, fruits was found to be low, milk consumption was fairly low among the preschool children & fish consumption was found to be 34 gm/ CU. The intake of nutrients in case of preschool children was found to be less than the RDA. It was observed that macro nutrient intake was fairly better when compared to the micro nutrient intake. 31 % of preschool children were anemic. The other clinical symptoms like angular stomatitis, chelosis & dryness of skin were 35 % on an average .The reason for high anemic might be due to low consumption of iron rich foods, poor health ,hygiene & sanitation and also might be due to lack of nutritional awareness.

Value Addition

*To study the effect of feeding malted food on the nutritional status of vulnerable groups (Vijayakhader et al., 2012) :*Amylase Rich Malted Mixes (ARMM) two types were formulated using Ragi/Wheat and suitable products namely *Laddu, Roti, Kheer, and Porridge* were prepared using formulated malted mix. The ARMM's found to be nutritional dense. For the supplementation of malted mixes 8 villages of Lepakshi Mandal, Ananthapur District was selected. Preschool children (400), pregnant women (100) and Lactating women (100) were selected and fed with two types of malted mixes (Ragi / Wheat) for a period of 3 months. Anthropometric data, Food intake showed a significant increase in the preschoolers, pregnant women and Lactating mothers. Clinical assessment showed considerable reduction i.e. (50%) in nutritional deficiency symptoms and morbidity rate of all the subjects. Training programmes were conducted to 40 members by lecture and method demonstrations using developed education material such as Posters, Flip book, Manual and CD-Rom. After the training 60-70% improvement was observed in Knowledge, Attitude and Practices scores of the trainees, project profile for bulk production was also developed. Supplementation of ARMM's helped to improve the nutritional status of the vulnerable groups of population in rural areas especially with regard to *protein, energy, iron, and calcium and B-complex vitamins.* Promotion of malt based small scale food industry not only provides opportunity for rural women to develop entrepreneurship and employment but also provided Food and Nutritional Security through income generation.

Therapeutic food supplementation in ICDS projects of Andhra Pradesh (Yasoda Devi & Vijayakhader, 2004): Total 2267 children of age range of 1-3 years were selected (892 children from rural ICDS project, Saravakota; 507 children from new ICDS project, Kottem; and 778 children from tribal ICDS project, Seethapeta) for a period of 1 year. The three types of supplements were prepared and distributed by A.P. Foods, Hyderabad. The supplements were distributed either in the form of Laddu or as in the form of powder. Nutritive value of 100g of supplements provides 400 to 480 Kcal 12.5 to 13.8 g proteins.

It was very encouraging to note that 92% of grade III children showed improvement in their weight and height; 80% of moderately malnourished; 42% of mildly malnourished and 44% with normal grade showed improvement. It was also observed that there was positive correlation between the calorie and protein intake and also improvement in weight and height. All 100% of mothers as well as Anganwadi workers preferred these supplementary foods better as compared to earlier supplied food i.e. ready to eat food.

Nutrition Education

*Tribal mother's attitude towards lactation performance (Vijayakhader,et.al,1996):*Tribal women are mostly involved in food preparation (25%) where as men are involved in occupational activities. Majority (85%) of tribal women do not think lactation as a necessity to take special care about either food because they were lactating. Majority of mothers (66%) were aware of the reason for decrease in lactation performance. Only a small number of mothers (5%) knew that sickness and insufficient food (2%) played a role in decreasing the lactation performance. As nursing mothers, they do not receive any special attention from the family members regarding the additional intake of food. A positive change was observed in lactating mothers through Nutrition Education as a tool.

Health Status of Tribal'sof Chinthapalli Block (Vijayakhader, et.al.,1996): Health problems of the tribal's are related to number of factors which include illiteracy, ignorance of the disease and its prevention,poverty,poor nutritional status Poor environmental sanitation and poor personal hygiene, non-availability of safe drinking water, which make people more vulnerable to infections. Superstitions and beliefs add to the health problems and complicate the situation. Malnutrition leading to tuberculosis and goitre are major disease in tribals.Vomiting; diarrhoea and consequent dehydration are causes for death among infants and children. Skin diseases especially scabies and heat boils are common.

Welfare Programs

Effect of Jawahar Rojgar Yojana Programme during lean season on the Nutritional Status of Women in Landless Labour Families of Drought prone areas (Uma Maheswari et al., 2001): The study was conducted in eight villages of four interior Mandals having low rainfall (500-750mm) in Ananthapur a drought prone district of Andhra Pradesh. A household survey was conducted to screen the families having at least one women of child bearing age from the eight selected villages of the four Mandals. A total of 120 families were selected for the study of which 60 families were JRY beneficiary families' where at least one member of the family was being employed under JRY scheme and 60 families were non-JRY beneficiary families. The study showed that the additional income gained by the landless labourer families during the lean season from Jawahar Rojgar Yojana (JRY) programme had beneficial effect on the nutritional status as assessed by the anthropometric measurements as well as clinical observations. The results indicated the past malnutrition status of the population in Ananthapur district because of the repeated and prolonged droughts.

Effect of Jawahar Rojgar Yojana scheme during lean season on the Expenditure (Uma Maheswari and Vijaya Khader, 2001a): A significant positive trend towards improvement in the *quality of food taken* by the landless labour families with the additional income generated through welfare programme i.e., Jawahar Rojgar Yojana in lean season as evinced by *better food* and non-food expenditure pattern of the JRY beneficiary families over the counterpart non JRY families in dryland and drought prone areas of Ananthapur district, Andhra Pradesh.

*Coping mechanisms adapted for food security at household level in drought prone areas of Ananthapur, Andhra Pradesh (Uma Maheswari et al., 2003):*Astudy was carried out in eight villages of four interior Mandals having low rainfall (500-750 mm), in Ananthapur a drought prone district of Andhra Pradesh. Families having at least one women of child-bearing age were enumerated. Two rounds of survey were conducted to understand the difference in coping mechanisms operating between peak and lean seasons. The study centered around the empirical examination of eight major groups of coping mechanisms comprising of land, livestock, economic, food procurement and production, food consumption and distribution, food storage, social and health based mechanisms adapted by the families. The various economic activities under taken by the women in the study area included Agriculture, Agriculture labour, basket making, Beedee making, brick making, broom making, cattle rearing, firewood collection, flour mill, fodder collection, forest produce collection, goat / sheep rearing, laundering, mat weaving, non-agricultural labour, petty trade, pottery, poultry rearing, ring making, sericulture, tailoring, tamarind peeling, vegetable vending and weaving clothes etc. Most often children especially girls were involved in home based trades like groundnut shelling, beedi making, tamarind peeling etc. A few of the mechanisms were found to be beneficial and can be encouraged.

Economic Empowerment of Women

*Family income and nutritional status of pre-scholars' in rural areas of Tenali division (Vijayakhader et al., 1993):*The increase in the annual per capita income of the family increased slightly the nutritional status of pre-scholars .The results also reveal that no significant difference was observed between the body weight of children and income of the parents in all the age group. In spite of having high purchasing power, lower educational status of the mothers and also low nutritional awareness, majority of the children are in Grade 1 degree malnutrition.

*Impact of women's supplementary income on families' nutritional status (Vijaya Khader, 1999):*The study was carried in 4 villages of Rajendarnagar Mandal & Ranga Reddy District on vegetable vendera, Shop Keepers, Washers, Fruit venders, Tea & Snack Venders. The results reveal that the supplementary income of women has a positive impact on food & nutrient intake of the family.

Un Exploited Biodiversity

2,50,000 - 3,00,000 species of plants exist, 10,000 - 50,000 are edible 150 - 200 are used as animal food. Three species rice, maize and wheat supply almost 60% of the calories and protein humans derive from plants.

Conclusion

Intervention of various technologies to improve the food & nutritional status of the population proved the following facts: Promotion of malt based small scale food industry not only provides opportunity for rural women to develop entrepreneurship and employment, but also provides food and nutritional security through income generation. To address this several technologies were developed under NATP like value addition to fish & prawn products, artificial pearl culture, processing of salted fish, which helped the self help group women of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu to improve their economic status. Received two patents & licensed the technology which helped the women to reduce their drudgery and also preserve the fresh fish for a longer time without getting spoiled. Product development can be taken as income generating activity in the rural areas by the illiterate women. Products can be included in supplementary feeding programs in order to improve the nutritional status of the vulnerable groups of the population. The horse gram which is commonly used for cattle feed can be diversified for human consumption with less investment. Mothers as well as Anganwadi workers preferred amylase rich supplementary foods which reduced Grade 111 and grade 1V malnutrition in Pre- school children significantly. The studies revealed that spawn multiplication can be done by women as a co-operative venture and mushroom cultivation can be undertaken at household level as an income-generating activity. Introducing red palm oil is beneficial to overcome vitamin A deficiency. Formers are encouraged to grow back yard nutrition garden. Impact of women's supplementary income on family's nutritional status showed that the supplementary income of women has a positive impact on the socioeconomic status of the family. This impact is particularly felt on the food and nutrient intake of the family contributing towards food and nutrition security.

Strategies for food and dietary diversification: Promotion of mixed cropping and integrated farming systems; Introduction of new crops (such as soybean); Promotion of underexploited traditional foods and home gardens; Small livestock raising; Promotion of fishery and forestry products for household consumption; Promotion of improved preservation and storage of fruits and vegetables to reduce waste, post-harvest losses and effects of seasonality; Strengthening of small-scale agro-processing and food industries; Income generation;Nutrition education to encourage the consumption of a healthy and nutritious diet year round.

Strategies toAaddress Micronutrient Malnutrition

Three of the main strategies for addressing micronutrient malnutrition are food systems diversification, fortification (including bio fortification) and supplementation

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4 Agriculture Policies and Pathways Contributing to Nutrition and Health

K Manorama

Introduction

Agriculture involves the cultivation of crops, mainly for food use and also for other commercial purposes. Humans and animals depend on Agriculture for their food and feed needs. Food and feed provide the necessary nourishment to the animal and human body. Nourishment of the body is through the nutrients present in the food that is eaten. The purpose of this lecture is to understand the basic concepts of Food Groups and the nutrients that they supply, to inculcate an understanding of the functions of various nutrients in the human body, in maintenance of health and well being, to discuss about the role of Agriculture in providing Food and Nutritional security to the population, as contributor of Food and Nutrition through foods cultivated and as a provider of livelihood to farming communities, with the main objective understanding how Agricultural policy can affect Food and Nutrition Security. The different pathways that link Agriculture and Nutrition are also discussed.

Population present all over the world differ in their consumption levels of food through their varied diets. Food is a source of nutrients that are essential for the healthy function of the body. Consumption of excess of food, and in turn excess of nutrients can be called as over nutrition and consumption of insufficient food and nutrients results in under nutrition. Both conditions are together called as malnutrition.

The agriculture sector is widely regarded as playing an important role in accelerating the reduction in undernutrition. A number of factors play a role in determining what foods are produced by a nation and it's different regions. Among them Food Security is of foremost importance, as provision of sufficient food for the nation's population is the priority of the nation. Secondly, Nutritional security also needs to be addressed as it is not sufficient just to provide enough food but also nutritious food to the population for improved diets, maternal care and adequate infant growth.

The multiple causes of undernutrition, at the individual, household, and societal levels, are now well recognized. Scientific consensus exists on the effectiveness of a core package of nutrition-specific interventions in addressing the immediate causes of child undernutrition. But wider recognition of the need for nutrition-sensitive development to tackle the underlying and basic determinants of undernutrition—development draws on diverse sectors, such as agriculture, education, health, water, and sanitation.

India alone contains around one-third of the world's undernourished children, and its exceptionally high rates of undernutrition have declined only marginally in the face of rapid economic growth. Eradicating undernutrition at the global level will therefore require tackling the immense burden of undernutrition in India, and leveraging the potential of a wide range of nutrition-sensitive sectors.

Concept

High on the list of nutrition-relevant sectors in India is agriculture. The combination of agricultural production and socio-cultural norms can lead to linkages with nutrition, particularly via maternal health and nutrition and childcare practices In theory, the potential for agricultural systems to influence nutrition is sizeable. Agriculture can impact nutrition in two principal ways:

- Through production of crops that serve as nutritious food.
- Through provision of livelihoods and income.

This paper covers following topics :

- Agricultural crops as sources of nutrients
- Basic nutrients required by the body
- Agriculture as a source of livelihood of farming communities
- Agriculture as a source of food
- Agriculture as a source of income for food and non-food expenditures
- Agricultural policy and food prices
- Women in agriculture and intrahousehold decision making and resource allocation
- Maternal employment in agriculture and child care and feeding
- Women in agriculture and maternal nutrition and health status

Firstly, we shall look at various Agricultural crops, with their segregation based on the type of nutrients they provide, as well as the functions of these utrients supplied by Agricultural crops. Here we can also include livestock and poultry as sources of food and nutrients, as well as horticultural and plantation crops, which also contribute to the nutrient repertoire.

Discussion

Agricultural crops and their nutrients

Food is important for life. To be healthy and active, we should certainly have enough food. But the foods we eat should also be safe and rich in all the nutrients our body needs. We should choose from a wide variety of foods and we should eat them regularly, throughout the day, every day of the year (Fig 1).

Food provides our bodies with what they need to

- stay alive, be active, move and work;
- build new cells and tissues for growth;
- stay healthy and heal themselves;
- prevent and fight infections.

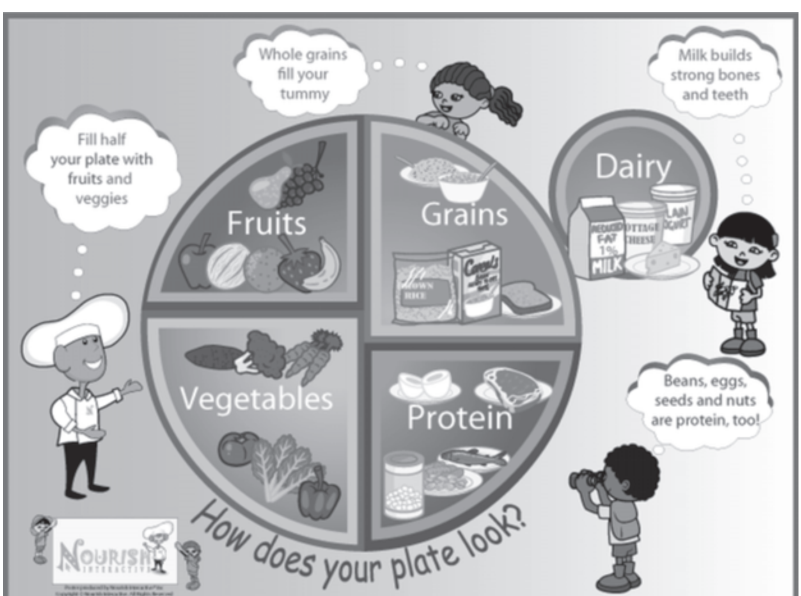


Fig. 1. Agricultural crops and there nutrients

Cereals and millets, and their nutritional properties

The biggest group, Grains, consisting of cereals and millets, contain the nutrients which provide energy and warm our bodies and should be eaten in larger quantities. Cereal grains are grown in greater quantities and provide more food energy worldwide than any other type of crop; they are therefore staple crops. Energy to the body is supplied by two principal nutrients, mainly, carbohydrates and fats. Carbohydrates supply 4 kcals energy per g whereas fats provide 9 kcals per g. Cereal and millet grains are rich sources of the main available form of energy from carbohydrates, that is starch (65 to 70g) and millets. Energy is required for the body for all the main functions listed above, for maintaining adequate health and functioning efficiently. The amount of cereals consumed by Indians in their daily diets ranges between 300 to 500 g per day supplying about 60 to 70% of the daily energy needs.

Apart from energy, this group of food grains are also a good source of proteins because of the quantity consumed by Indian population. Since the protein content of cereals millets ranges from 6.5 to 12%, roughly, about 45 to 50 g of proteins are supplied by cereals and/or millets in our diets. However, the protein available through cereals and millets is not of adequate quality as it lacks in one or two essential amino acids required for normal and healthy functioning of the body. A complete protein is that which supplies all the essential amino acids in the right proportions. The two limiting amino acids in cereals and pulses are lysine and threonine. However, in mixed diets containing balanced amounts of all foods, the limiting amino acids are supplemented and compensated for through other food groups like pulses, milk etc.

Whole grain cereals are also good sources of complex carbohydrates like dietary fibre and cellulose, which provides roufghage for the efficient functioning of the intestines. In addition certain minerals like iron, zinc, calcium, phosphorous and magnesium are provided by cereals and millets.

Certain B-complex vitamins like Thiamine, riboflavin and niacin are also provided by whole grain cereals, but are lost on dehusking and polishing. Cereal brans are extremely healthy and oils as well as vitamins are abundant in them.

Pulses and legumes and their nutritional properties

A legume is a plant in the family Fabaceae (or Leguminosae), or the fruit or seed of such a plant. Legumes are grown agriculturally, primarily for their grain seed called pulse, for livestock forage and silage, and as soil enhancing green manure. Well-known legumes include alfalfa, clover, peas, beans, lentils, lupins, mesquite, carob, soybeans, peanuts and tamarind. Commonly consumed legumes in India are pigeon pea (redgram), Chick pea (Bengalgram), greengram and blackgram. Legumes in India are consumed as dhals or decorticated pulses,

Legumes are notable in that most of them have symbiotic nitrogen-fixing bacteria in structures called root nodules. For that reason, they play a key role in crop rotation. Nutritionally, pulses are a good source of vegetable proteins for a predominantly vegetarian population of India. However, like cereals, they are also having certain limiting amino acids, but they are different from those limiting in cereals and millets. The limiting amino acids of pulses are methionine and tryptophan, which can be supplemented by combining cereals with pulses in the diet. Legumes are a significant source of protein (18 to 24g/100g), dietary fiber, carbohydrates and dietary minerals; for example, a 100 gram serving of cooked chickpeas contains 18% of the Daily Value (DV) for protein, 30% DV for dietary fiber, 43% DV for folate (a B complex vitamin) and 52% DV for manganese. Like other plant-based foods, pulses contain no cholesterol and little fat or sodium.

Legumes are also an excellent source of resistant starch which is broken down by bacteria in the large intestine to produce short-chain fatty acids used by intestinal cells for food energy.

The International Year of Pulses 2016 (IYP 2016) was declared by the sixty-eighth session of the United Nations General Assembly. The Food and Agriculture Organization of the United Nations has been nominated to facilitate the implementation of IYP 2016 in collaboration with governments, relevant organizations, non-governmental organizations and other relevant stakeholders. It’s aim is to heighten public awareness of the nutritional benefits of pulses as part of sustainable food production aimed towards food security and nutrition. IYP 2016 will create an opportunity to encourage connections throughout the food chain that would better utilize pulse-based proteins, further global production of pulses, better utilize crop rotations and address challenges in the global trade of pulses.

The root nodules are sources of nitrogen for legumes, making them relatively rich in plant proteins. All proteins contain nitrogenous amino acids. Nitrogen is therefore a necessary ingredient in the production of proteins. Hence, legumes are among the best sources of plant protein.

Vegetables and fruits, and their nutritional properties

Fresh vegetables endow almost all of the nutritional principles does human body requires. The health benefits of vegetable nutrition are enormous. They are good source of vitamins, minerals, anti-oxidants and dietary fiber.

Vegetables, like fruits, are low in calories and fats but contain good amounts of vitamins and minerals. All the Green-Yellow-Orange vegetables and fruits are rich sources of calcium, magnesium, potassium, iron, beta-carotene, vitamin B-complex, vitamin-C, vitamin-A, and vitamin K.

As in fruits, vegetables too are sources for many antioxidants. These health benefiting phyto-chemical compounds *firstly*; help protect the human body from oxidant stress, diseases, and cancers, and *secondly*; help the body develop the capacity to fight against these by boosting immunity.

Additionally, vegetables are packed with soluble as well as insoluble dietary fiber known as non-starch polysaccharides (NSP) such as cellulose, mucilage, hemi-cellulose, gums, pectin etc., These substances absorb excess water in the colon, retain a good amount of moisture in the fecal matter, and help its smooth passage out of the body. Thus, sufficient fiber offers protection from conditions like chronic constipation, hemorrhoids, colon cancer, irritable bowel syndrome, and rectal fissures.

Animal foods and their nutritional properties

Animal source foods (ASF) include many food item that comes from an animal source such as meat, milk, eggs, poultry, cheese and yogurt. Many individuals do not consume ASF or consume little ASF by either personal choice or necessity and non-affordability, as ASF may not be accessible or available to these people.

Even though they strictly do not belong to the category of Agricultural products, they may be products of livestock, poultry and dairy industry. The production of meat and other produce, such as eggs, may be considered environmentally friendly (if this is done in an industrial, high-efficiency manner). In addition, raising goats (for goat milk and meat) can also be environmentally quite friendly.

Animal foods are good sources of high quality protein, with all amino acids available in the right proportions. Egg ranks first followed milk and milk products, fish and meat with respect to the quality of proteins. Animal foods also contain good amounts of fats which are rich sources of energy. However, these foods contain saturated fatty acids as components of their fats, which are considered more harmful to cardiovascular health than unsaturated fatty acids.

Fish are good sources of the healthier omega-3-fatty acids, namely, eicosapentaenoic and docosahexaenoic acids, which lowere the risks involved in developing cardiovascular diseases by keeping the bolood thinner and preventing blood from clotting, which is a major cause of atherosclerosis.

Aside from performed vitamin A, vitamin B_{12} and vitamin D, all vitamins found in animal source foods may also be found in plant-derived foods. Examples are tofu (paneer made from soya milk) to replace meat (both contain protein in sufficient amounts), and certain seaweeds and vegetables as respectively kombu and kale to replace dairy foods as milk (both contain calcium in sufficient amounts). There are some nutrients which are rare to find in sufficient density in plant based foods. One example would be zinc.

Most humans eat an omnivorous diet (comprising animal source foods and plant source foods) though some civilisations have eaten only animal foods. Although a healthy diet containing all essential macro and micronutrients may be possible by only consuming a plant based diet (with vitamin B_{12} obtained from supplements if no animal sourced foods are consumed), some populations are unable to consume an adequate quantity or variety of these plant based items to obtain appropriate amounts of nutrients, particularly those that are found in high concentrations in ASF. Frequently, the most vulnerable populations to these micronutrient deficiencies are pregnant women, infants, and children in developing countries. In the 1980s the Nutrition Collaborative Research Support Program (NCRSP) found that six micronutrients were low in the mostly vegetarian diets of children in malnourished areas of Egypt, Mexico, and Kenya. These six micronutrients are vitamin A, vitamin B_{12}, riboflavin, calcium, iron and zinc. ASF are the only food source of Vitamin B_{12}. ASF also provide high biological value protein, energy, fat compared with plant food sources.

Nuts and oilseeds and their nutritional properties

Dried fruits, nuts like cashew nuts, almonds, walnuts and oilseeds like groundnuts, sunflower seeds, safflower seeds, maize, mustard etc are energy dense due to large amounts of fats and oils. These oils can be extracted and used as dietary fats and oils. They are also rich in vegetable proteins, minerals and vitamins, as well as fibre. In this manner, Agricultural commodities provide all the nutrients required for human health and well being.

Basic Nutrients Required for Good Health

Carbohydrates

Carbohydrates can be grouped into two categories: simple and complex. Simple carbohydrates are sugars whereas complex carbohydrates consist of starch and dietary fibre. Carbohydrate provides about 4 kcal (kcal = kilocalories = Calories) per gram (except for fibre) and is the energy that is used first to fuel muscles and the brain. Soluble fibre (fruits, legumes, nuts, seeds, brown rice, and oat, barley and rice brans) lowers blood cholesterol and helps to control blood sugar levels while providing very little energy. Insoluble fibre (wheat and corn bran, whole-grain breads and cereals, vegetables, fruit skins, nuts) doesn’t provide any calories. It helps to alleviate digestive disorders like constipation or diverticulitis and may help prevent colon cancer. Most calories (55-60%) should come from carbohydrates. Sources of carbohydrates include grain products such as breads, cereals, pasta, and rice as well as fruits and vegetables.

Protein

Protein from food is broken down into amino acids by the digestive system. These amino acids are then used for building and repairing muscles, red blood cells, hair and other tissues, and for making hormones. Adequate protein intake is also important for a healthy immune system. Because protein is a source of calories (4 kcal per gram), it will be used for energy if not enough carbohydrate is available due to skipped meals, heavy exercise, etc. Main sources of protein are animal products like meat, fish, poultry, milk, cheese and eggs and vegetable sources like legumes (beans, lentils, dried peas, nuts) and seeds.

Fat

The fat in food includes a mixture of saturated and unsaturated fat. Animal-based foods such as meats and milk products are higher in saturated fat whereas most vegetable oils are higher in unsaturated fat. Compared to carbohydrate and protein, each gram of fat provides more than twice the amount of calories (9 kcal per gram). Nevertheless, dietary fat does play an important role in a healthy diet. Fat maintains skin and hair, cushions vital organs, provides insulation, and is necessary for the production and absorption of certain vitamins and hormones. Nutrition guidelines state that individuals should include no more than 30% of energy (calories) as fat and no more than 10% of energy as saturated fat.

Vitamins

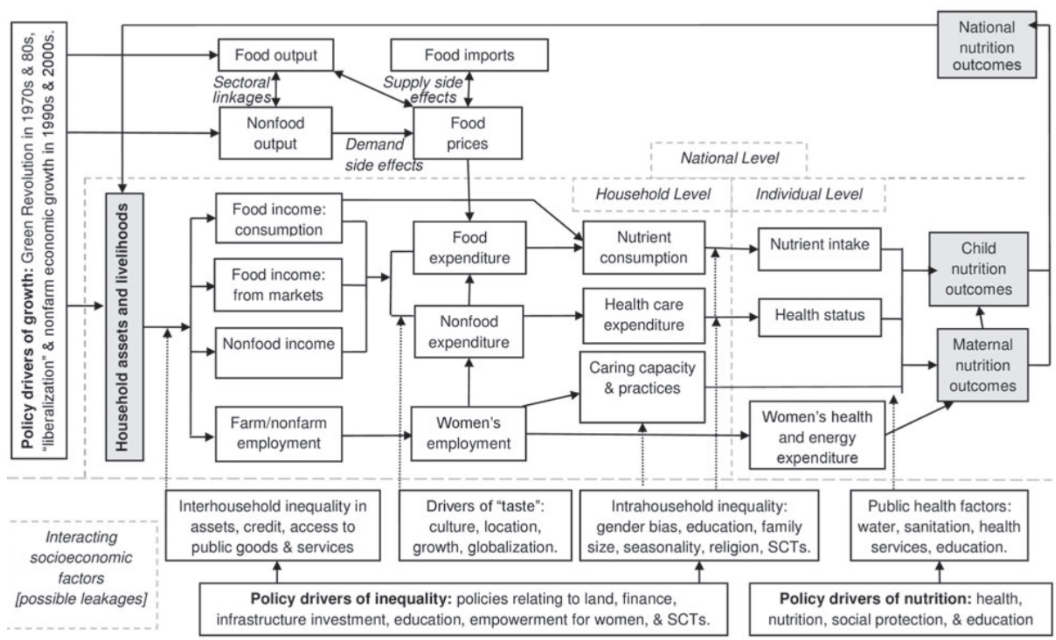
Vitamins help to regulate chemical reactions in the body. There are 13 vitamins, including vitamins A, B complex, C, D, E, and K. Because most vitamins cannot be made in the body, we must obtain them through the diet. Many people say that they feel more energetic after consuming vitamins, but vitamins are not a source of energy (calories). Vitamins are best consumed through a varied diet rather than as a supplement because there is little chance of taking too high a dose. Vitamin A is required for healthy eyes, skin, mucous membranes and prevention of nutritional blindness. Vitamin D is required for bone density and absorption of calcium and phosphorous. Vitamin E is a powerful anti-oxidant and vitamin K is necessary for blood clotting. Vitamin C is water soluble and prevents scurvy, helps in absorption of iron and is also an anti-oxidant. B complex vitamins are important co-enzymes for enzymes involved in metabolism and utilization of carbohydrates, proteins and fats.

Minerals

Minerals are components of foods that are involved in many body functions. For example, calcium, phosphorous and magnesium are important for bone structure, and iron is needed for our red blood cells to transport oxygen. Zinc is an important cofactor for enzyme functioning and is therefore involved in many body processes. Sodium, potassium and Chloride maintain acid base balance and help maintain osmosis of intra and extracellular fluid. Like vitamins, minerals are not a source of energy and are best obtained through a varied diet rather than supplements. Unless the body receives all of the above nutrients on a daily basis, it is difficult to maintain adequate health. Hence, Agriculture plays a major role in the production of food rich in all these nutrients.

The Second Important Role of Agriculture in Providing for Food and Nutritional Security is as a Source of Livelihood of Farming Communities:

It was found to be a paradox that the failure of economic and agricultural growth to make significant inroads into reducing malnutrition in India. The following figure outlines the mapping of Agriculture-Nutrition pathways in India (Fig 2):



Source: Kadiyala et al, Ann. N.Y. Acad. Sci. 1331 (2014) 43–56ISSN 0077-8923

Fig. 2. Mapping of Agriculture-Nutrition pathways in India

Agriculture as a source of food

Farmers produce for own consumption. In this context, crop diversification seemed to show a positive association with dietary diversification (Kadiyalas *et al*., 2014). In Andhra Pradesh, 23 children from households with a more diverse food basket and those growing non food as well as food crops were more likely to recover from growth faltering. For all rural India, Bhagowalia *et al., 2012* find that irrigation and farm size are important determinants of crop diversification (controlling for household income), with irrigation compensating for smaller farm sizes. Second, livestock assets appear to be a very important determinant of animal-sourced foods. In the nationally representative study by Bhagowalia *et al.*, cow and buffalo ownership was strongly associated with household milk consumption. An older study on Operation Flood found a positive association between joining dairy cooperatives and increased milk production, sales, and consumption (Alderman, 1987). Finally, several studies look at the inability of farm households to meet their nutrient requirements and allude to the importance of diversification of livelihood and food sources, especially with increasing land fragmentation and landlessness.

Agriculture as a source of income for food and non-food expenditures

As a major direct and indirect source of rural income, agriculture influences diets and other nutrition-relevant expenditures. Income and expenditure are important determinants of dietary quality, yet nutritional outcomes have improved very slowly in a period of rapid economy-wide growth in India. Available evidence suggests that slow income growth among more undernourished populations, slow improvement with regard to micronutrient rich food consumption or non-income factors (nutrition education, infrastructure, water, sanitation, and health services), and intergenerational inertia but with little conclusive evidence on the matter.

Agricultural policy and food prices

Agricultural conditions can change the relative prices and affordability of specific foods and foods in general, thus affecting the nutritional security of the population. Agricultural developments on either the supply or demand side clearly have substantial scope to influence the price of food relative to non-food prices (including wages), as well as the relative price of specific foods of particular nutritional importance. Indian districts with higher food prices in the period 2004–2009 also saw larger rural wage growth, to the extent that all rural households benefited from higher prices to some extent[5]. In India, relatively few studies rigorously inform the question whether real income effect dominated the relative price effect. The analysis by Gaiha *et al.*, 2010 is one exception since the study analyzes the demand for different nutrients in a dynamic context over the period 1993–2004. They find that an increase in rice or wheat prices would increase protein consumption, though higher prices for animal-sourced foods have varying (positive and negative) effects on protein consumption. In general, their results suggest that income effects largely dominate relative price effects, at least for protein consumption. Consistent with this result, an analysis of national survey data did not show an adverse effect on child anthropometry (weight-for-age) of a sudden rise in the price of rice supplied by the Public Distribution System (PDS), which largely subsidizes rice and wheat consumption (Tarozzi, 2005). A quantitative but more descriptive analysis by Headey *et al.*, 2012 concludes that the steep rise in coarse grain prices relative to other foods (particularly rice and wheat) explains the widely noted decline in coarse grain consumption.

Women in agriculture and intra-household decision making and resource allocation

may be influenced by agricultural activities and assets, which in turn influences intra-household allocations of food, health, and care. Not very conclusive evidence exists to indicate that additional female wages were sufficient to alter the overall spending pattern on nutritious food. More studies are required to come to any definite conclusion as evidence is contradictory (Kadiyala, 2014).

Maternal employment in agriculture and child care and feeding

A mother's ability to manage child care may be influenced by her engagement in agriculture. Economic recessions and income volatility were found to increase female labour force participation, particularly in agriculture, with detrimental effects on healthcare seeking, and child survival (Ghosh, 2007), which appears to be related to the opportunity cost of maternal time. The risk of rural infant mortality was reported to be 50% higher if the mother works in agriculture and her participation in rural agricultural activity also had consistently adverse effects on indicators of health seeking, such as place of delivery and antenatal care seeking. Children of mothers in agricultural work (compared to children of mothers in non-agricultural work and children of fathers in agricultural or non-agricultural work) were reported to be more likely to contract both diarrhoea and respiratory disease, and were less likely to be treated and immunized.

Women in agriculture and maternal nutrition and health status

Maternal nutritional status may be compromised by the often arduous and hazardous conditions of agricultural labour, which may in turn influence child nutrition outcomes.

Conclusion

With more than one-third of the world's undernourished children, India's relatively poor progress in reducing malnutrition is an issue of both national and global concern. Accelerating progress on this front will require a range of nutrition-specific and nutrition-sensitive interventions, including agricultural interventions. Clearly, there is scope for agricultural policies to influence nutrition through any of these pathways.

A number of gaps in research and action remain to be filled (IFPRI, 2011). Research-ers face the task of collecting much more evi-dence on the links among agriculture, nutrition, and health and on how they can be effectively exploited to improve human well-being. But it is also important not to be paralyzed in the face of a lack of evidence. For instance, more could be done to change the incentives embedded in agricultural policies to encourage farmers to pro-duce more highly nutritious foods. Looking at the whole bioeconomy including agriculture's role in producing food, feed, fiber, energy, and new industrial raw materials may offer perspectives on how to make the whole system function more effectively for better health and nutrition. Food cannot be viewed just like any other commodity it is a basic human need, like air, and policies must reflect this reality.

So far, the agriculture and nutrition sectors have tended to operate in separate spheres, and little effort has been made to use agricultural policies and programs specifically to improve human nutrition. A few programs and approaches, how-ever, point to the significant potential for lever-aging agriculture to improve nutrition.

Food products often undergo many stages between farm and fork, and this value chain that is, the supply chain along which value is added to a product offers opportunities for improving nutrition. Value-chain analysis can be used to assess why foods are or are not avail-able in specific communities, why foods cost what they do, and how the nutrient quality of foods changes through the chain. Once problems are identified, value-chain approaches can be used to design and implement solutions to increase the availability, affordability, and quality of nutritious foods. For example, this approach can lead to increased production, better distribution, and greater consumption of fruits and vegetables or biofortified foods (that is, crops with extra nutrients bred into them), resulting in new initiatives to create more nutritious process foods or to buy nutri-tious products from local farmers.

Any solutions designed to leverage agriculture for better nutrition and health will have to work in the context of a rising global population, growing incomes that lead to changing diets, and climate change that will likely put pressure on already scarce resources.

The Knowledge Gaps can be filled by

- Learning more about how different patterns of agricultural growth affect nutrition and health.
- Investing in research, evaluation, and education systems capable of integrating information from all three sectors.
- Filling the gap in governance knowledge at the global, national, and community levels.

More action is required by

- Mitigating the health risks posed by agriculture along the value chain.
- Designing health and nutrition interventions that contribute to the productivity of agricul-tural labor.
- Look carefully at the downstream effects of subsidies for production or consumption on consumers' nutrition and health.
- Designing agriculture, nutrition, and health pro-grams with cross-sectoral benefits.
- Incorporating nutrition into value chains for food products.
- Increasing consumers' nutrition literacy and highlight the consequences of dietary choices.

Although the effort to exploit the synergies among agri-culture, nutrition, and health is still in its infancy, this effort offers real potential for improving the lives of millions of people worldwide.

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5 Soil and Human Health

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Introduction

Many people probably think about things such as an active exercise program, wise food choices, good medical care, and proper sanitation when they consider their health, but few probably think about soils. Soils are important for human health: approximately 78% of the average per capita calorie consumption worldwide comes from crops grown directly in soil, and another nearly 20% comes from terrestrial food sources that rely indirectly on soil (Brevik and Burgess, 2013). Soils are also a major source of nutrients, and they act as natural filters to remove contaminants from water. However, soils may contain heavy metals, chemicals, or pathogens that have the potential to negatively impact human health. Relationships between soil and health are often difficult to extricate because of the many confounding factors present. Nevertheless, recent scientific understanding of soil processes and factors that affect human health are enabling greater insight into the effects of soil on our health. The direct relationships between soils and human health will be discussed in detailed as follows.

History of Soils and Human Health in Brief

The Vedic hymn to the earth, the Prithvi Sukta in Atharva Veda, *"Mata Bhumih Putroham Prithivyah":* earth is my mother, I am her son. Mother earth is celebrated for all her natural bounties and particularly for her gifts of herbs and vegetation. Her blessings are sought for prosperity in all endeavors and fulfillment of all righteous aspirations.

The present: A number of articles have been published over the last decade reviewing the status of our knowledge of soils and human health. Brevik and Burgess (2013a) edited a volume that is the first modern book to focus exclusively on the links between soils and human health. Modern research has led us to recognize that soils influence human health through (1) food availability and quality (food security), (2) human contact with various chemicals, and (3) human contact with various pathogens (Brevik and Burgess, 2013).

Concept of Soil Health/Quality

Soil health and quality are essentially the same idea. Soil Health: more frequently used by farmers; Soil quality: more frequently used by academic researchers (Magdoff and Van Es, 2009)."Healthy soils have the capacity to function, with in ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health" (Doran *et al.*, 1994).

"Healthy soil does need adequate organic matter, good structure and diverse mixture of micro-organisms and macro-organisms" (Brevik, 2009). Healthy soils are very important to human health. Healthy soils also lead to reduced erosion and better air and water quality. Keeping in view of the definitions of the soil health or quality by different academic researchers, will be discussed briefly about the formation of soil and its health / quality.

Soil is a dynamic natural body composed of mineral and organic solids, gases, liquids and living organisms which can serve as medium for plant growth. The collection of natural bodies occupying part of the earth's surface that is capable of supporting plant growth and that has properties resulting from the integrated effect of climate and living organisms acting upon parent materials conditioned by topography, over the period of time" (Brady and Weil, 2008) . The formation and with different quality properties of soil will depend on five factors viz., parent material (materials from which the soil is formed eg. Residuum, sediments and also important for physic-chemical characteristics), topography (refers to slope, aspect and landscape position. Sleeper slope: greater erosion; Gentle slope: more water infiltration and less loss of runoff and especially towards depth of soil and south facing slopes get more solar energy than north facing slopes in northern hemisphere and visa vis in southern hemisphere), climate (primarily refers to precipitation and temperature and their distribution come together to create climate variable in soil formation), organisms (refers to plants and animals in the soil at both a micro and macro scale) and time (refers to how long a soil has had to form eg., Horizons and also determines the soil nutrients layer wise). These factors are not completely dependent of one other.

The soil physical properties viz., composition, structure, pore space, Bulk density, water holding capacity and colour influences water storage, ease with which roots can penetrate the soil, in turn influence chemical and biological process. Soils are composed of minerals (45%), Organic matter (5%) water and air (50%) i.e. pore space by volume. 25% each of air and water called as ideal soil (Fig 1).

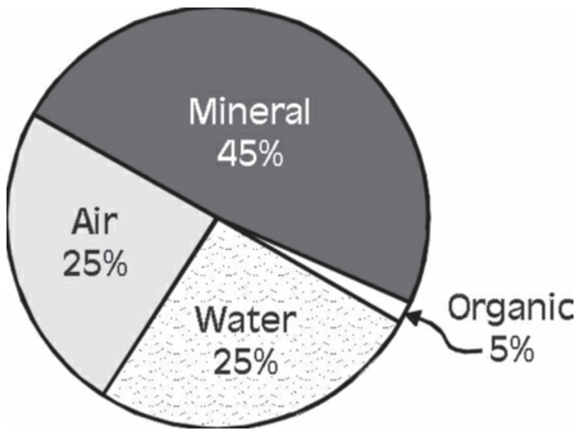


Fig . 1. Basic composition of an ideal soil

The chemical properties like clay and Ph etc., clay is referred as size range regardless of chemical composition and chemically clay minerals are site for chemical reactions with larger surface area per gram of soil. Seat for CEC (CEC: the ability negatively charged surfaces in the soil to attract and exchange positively charged cat ions). Humus and clay called as Colloids. pH controls the availability of soil nutrients (pH: 5.5: micronutrients and 7.5: macro nutrients) (Fig 2).

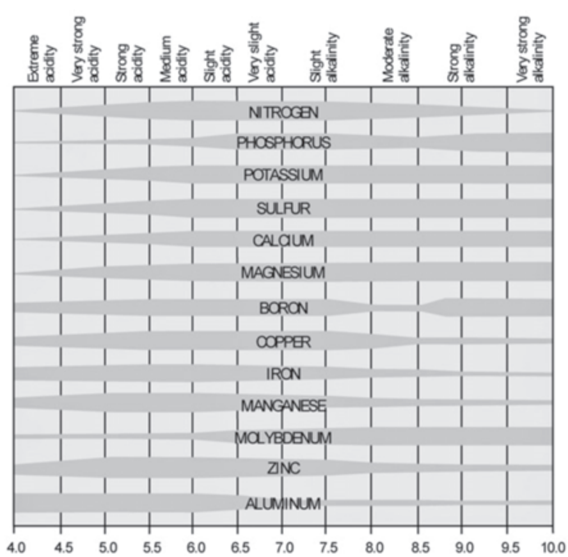


Fig. 2. How soil pH affects availability of plant nutrients

Nutrient Cycling is important process in soil. Nutrients are taken up and utilized by organisms during their life cycle. With any nutrient cycle there are number of pools that the nutrients can move between. In a soil system C, N, P, K, S, Ca, Mg, Fe, Cu, Mn, Zn, B, Cl, Mo and Ni cycles will be present. These are essential nutrients supplied by the soil. While a cycle has no beginning or end. Soils are not closed system in regard to nutrient cycling.

Organic matter (source: plant tissues, animal tissues, debris and waste or manure) plays many significant roles in the soil system, promotes and maintains soil aggregation, water holding capacity and low bulk density, important contributor to CEC, fundamental source of energy and nutrients for soil organisms and important part of the global carbon cycle. All these will contribute to the soil quality.

Concept of Human Health

Health was defined by the World Health Assembly. 1948, as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity”. This definition includes three primary aspects of health: (i) physical, (ii) mental and (iii) social.

Physical fitness is achieved through proper nutrition in the daily diet and regular exercise. Mental fitness is achieved through emotional and psychological well-being and is also partially dependent on proper nutrition and social fitness is achieved through the ability to operate comfortably within the expectations of the society the individual lives in. Soils are integral part to food security and also to human health (Pimentel, 2006; Abrahams, 2002).

Human health depends on 6 essential nutrients. An essential nutrient is a nutrient that the body cannot synthesize on its own or not to an adequate amount and must be provided by the diet. These nutrients are necessary for the body to function properly, these include carbohydrates, proteins, fat, vitamins, minerals (Macro minerals: Na, Cl, K, Ca, P, Mg & S; Micro / trace minerals: Fe, Zn, I, Se, Cu, Mn, F, Cr & Mo) and water.

Promotion of Human Health Through Soils

There are 14 elements that are essential for plant growth that comes from the soil (Havlin *et al.*, 2005) also essential for human health (Combs, 2005; Klasing *et al.*, 2005) end up in the human diet are primarily supplied through food (that took the elements up from the soil during growth) or animal products (after the animal obtained those essential elements from plant through soils) (Klasing *et al.*, 20; Abraham, 2002).

The plants depend on the soil for their nutritional needs and all higher animals, including human, depend directly or indirectly on plants for their nutrition, plants from the base of the food chain and consequently, a major portion of the nutrients needed for human health originate with the soil.

Soil Elements Necessary for Human Health

The 14 elements in the soil that are essential for plant growth are: N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B, Cl, Mo and Ni. There are additional elements that are needed by some but not all plants such as: Co, Br, Va, Si and Na (Havlin *et al.*, 2005). In addition to these soil elements, C, H, O are also essential for plant growth but are obtained from air and water called non metal nutrients. Most of these elements are also essential for human health.

Eleven elements comprise 99.9% of the atoms found in the human body, subdivided in to major and minor elements. Major elements (4): C, H, O and N make up about 90% of the atoms in the body. Minor elements (7): P, K, Ca, Mg, S, Na and Cl make up about 0.9% of the atoms in the body. There are approximately 18 additional elements considered as essential in small amounts to maintain human life also known as trace elements, include Li, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W (tungsten), Mo, Si, Se, F, I, Ar, Br, and Sn (tin) in the body (Combs, 2005).

Soil and Human Health

There are approximately 29 elements considered essential for human life, 13 are essential plant nutrients obtained from the soil and another 5 are elements obtained from the soil that are needed by some, but not all, plants, Although the elements Cr, W, Se, F, I, As and Sn are not considered essential for plant health, these elements are also found in trace amounts in plants that grow in soils containing them. Therefore, soils that provide a healthy nutrient- rich growth medium for plants will result in plant tissues that contain many of the elements required for human life. In fact, most of the elements necessary for human life are obtained from either plant or animals tissues (Combs, 2005; Brevik and Burgess, 2012). Plant tissues are among the most important sources of Ca, P Mg, K, Cu, Zn, Se, Mn and Mo in the human diet (Table 1a and 1b) and these elements are obtained by plants from the soil.

Table 1a. Some Important Sources of Elements or Minerals Essential to Human health and their role and deficiency symptom in human life.

Elements	Important Sources	Function
Na	Table salt, Soy sauce and processed foods	For proper fluid balance, nerve transmission and muscle contraction
Cl	Table salt, Soy sauce and processed foods	For proper fluid balance & stomach acids
K	Fruits, cereals, vegetables, beans, peas, lentils; Meat, milk	For proper fluid balance, nerve transmission and muscle contraction
Ca	Kale, collards, mustard, greens, broccoli; Milk and milk products and canned fish	For healthy bones and teeth, muscle relax and contract, nerve functioning, blood clotting, blood pressure regulation & immune system
P	Nuts, beans, peas, lentils, grains; Meat, fish, milk, eggs	For healthy bones and teeth & maintain acid-base balance.
Mg	Seed, nuts, beans, peas, lentils, whole grains, dark green vegetables & sea foods	Needed for protein making, muscle contraction, nerve transmission & immune system
S	Legumes, nuts, milk, fish, eggs (as part of protein)	Involved in protein molecules.

Table 1b. Micro minerals

Elements	Important Sources	Function	Deficiency/ disorder
Fe	Dried fruits, leafy vegetables, fortified cereals; Organ meat, red meat, Fish, poultry, egg yolk,	Part of hemoglobin, red blood cells O_2 transformer & needed for energy metabolism	Anemia, problem of pregnancies, stunted growth, impaired mental functions and neural motors.
Zn	Nuts, whole grains, beans, peas, lentils; Meat, fish & poultry	Taste perception, normal fetal development, production of sperm, normal growth and sexual maturation & immune system	Growth retardations, delayed sexual maturity, defects in immune functions.
I	Vegetables, cereals, fruits; Seafood, Iodized salt	Found in hormone thyroid, regulates growth, development and metabolism.	Goiter, mental retardations & reproductive failures.
Se	Grain products, nuts, garlic, broccoli (if grown in high-se soils); meat, seafood.	Antioxidant	
Cu	Beans, peas, lentils, whole grains, nuts, peanuts, mushrooms; organ meat.	Part of many enzymes, needed for iron metabolism	

Mn	Whole grains, beans, peas, lentils, nuts, tea. (purely from plant food only)	Part of many enzymes	
F	Drinking water, tea and fish	Formation of bone and teeth & prevent tooth decay	
Cr	Whole grain, nuts; liver, cheese & brown yeast	Works with Insulin to regulate blood sugar.	
Mo	Beans, peas, lentils, dark green leafy vegetables; milk & liver	Part of some enzymes	

(http://www.webmd.com/vitamins-and-suppliments)

Animal Products and Soil Nutrient Status

The nutrient status of the soil also impacts the nutritional quality of meat, milk, and other animal products produce for human consumption (Jones, 2005; Klasing *et al.*, 2005). This derives from the fact that the feed for animals, whether it is grass, cereals, or other plant materials is grown in the soil. Just as with plants, the nutritional content of these animal products in turn influences the general health of the people who consume them. Some minerals, such as Cd, Pb, Sc and Hg, can accumulate in animal products at levels that are not detrimental to animal health but are detrimental to human health if those animal products are consumed (Klasing *et al.*, 2005). Table 1 also shows some of the most important animal nutrient sources in the human diet.

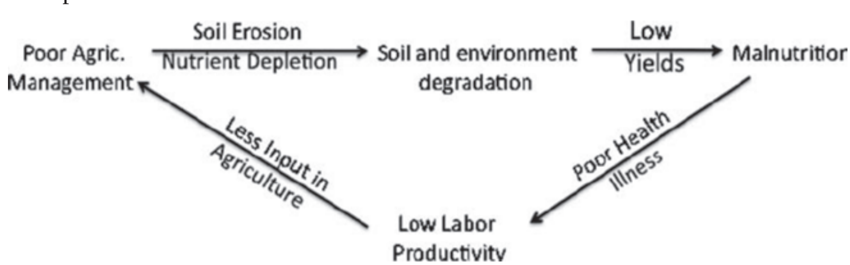
Health and Nutrient Imbalances in Soil

There are many ways to occur nutrient imbalances in soil. The occurrence of imbalanced nutrients in soil primarily due to conventional agricultural practices, degradation and problematic and P-occluded soils, the imbalance of nutrients in the soils also depends on soil pH, soil conditions and antagonistic effects.

Conventional, industrial approach to agriculture leads to soil degradation, and requires increasing use of inorganic, chemical inputs to maintain crop yields. There are seven basic farming practices that form the back bone of modern industrial agriculture:

Intensive tillage

- Monoculture
- Irrigation
- Application of inorganic fertilizers
- Chemical pest control
- Genetic manipulation of domesticated plants
- Many of the techniques that have been used to increase productivity have a great many negative consequences that, in the long term, work to undermine the productivity of agricultural land. Conventional means of increasing productivity will need to be supplemented to help meet the increasing food needs of an expanding global population. Degraded soils reduce crop yields and produce crops with poor nutritional value, leading to malnutrition in the people who depend on those soils to produce their food.



P-occluded soils: due to immediate fixation by Fe, Al and Ca to the soil, these soils exhibits antagonistic effects with some of the micronutrients like Zn, Cu, Fe and B and yields will be reduced. There is the possibility to show synergistic effect with N, K and S. With the application of Zn and B and reduction in P, the yields may be increased to optimum levels by reducing cost on P-fertilizers (Anonymous, AICRP on STCR, 2010-12). Occurrence of nutrient imbalances in problematic soils like in acid soils: Ca and P and in alkali soils: Fe and Mn and calcareous soils not only B other micronutrient imbalances could be observed.

Soil pH also influences nutrients and toxic element availability. Acidic soil pH levels tend to make Fe, Al, Mn, and heavy metals such as lead (Pb), cadmium (Cd, and Ni more available and nutrients such as iodine and Se less available (Oliver, 1997).

Soil conditions: Mineral deficiencies or imbalances also occur in relation to soil conditions as described in Table 2.

Table 2. Occurrence of mineral deficiencies in relation to soil condition

Nutrient	Soil Conditions
Macro minerals	
N	Light soils, low O.M soils, Peat soils & under improper drainage
P	Light soils, soils derived from Fe- stone soils, Heavy leaching soils & High rain fall
K	Light and sandy soils
Ca	Acid soils, low Ca content soils & high leaching soils
Mg	Light soils, high dressings of SOP, Acid sands & accentuated in wet season
S	Light soils & low O.M soils
Na	Sandy soils away from sea areas
Cl	--

Nutrient	Soil Conditions
Micro / trace minerals	
Fe	High pH soils, high P-soils & reduced conditions
Mn	Calcareous soils, pH >6.5 soils, organic soils 7 high water table soils
B	Calcareous soils, sandy soils & dry seasons
Zn	Light soils & high P-soils
Cu	Light sandy soils & Peat soils
Mo	Acidic soils & pulses grown areas

(Thomas Wallace.1973)

Another way that nutrients deficiencies may occur is through antagonism, a process by which ions with the same valence will reduce the uptake of another ion. Examples of antagonism include arsenic (As) antagonizing P and strontium (Sr) Antagonizing Ca.There is also concern the Sr released during the Chernobly nuclear disaster in 1986 could antagonize Ca uptake (Brevik and Burgees, 2012). Zinc antagonisms are possible with Ca, Fe, Cu and Ni (Oliver, 1997). These interactions depend on soil type, physical properties, pH, ambient temperatures and proportion of participating nutrients. There is a highly controlled selectivity process involved in uptake of nutrients by plants and that is the reason why the plant does not contain the same ratio of nutrients inside the plant as found in the soil (Fig 3).

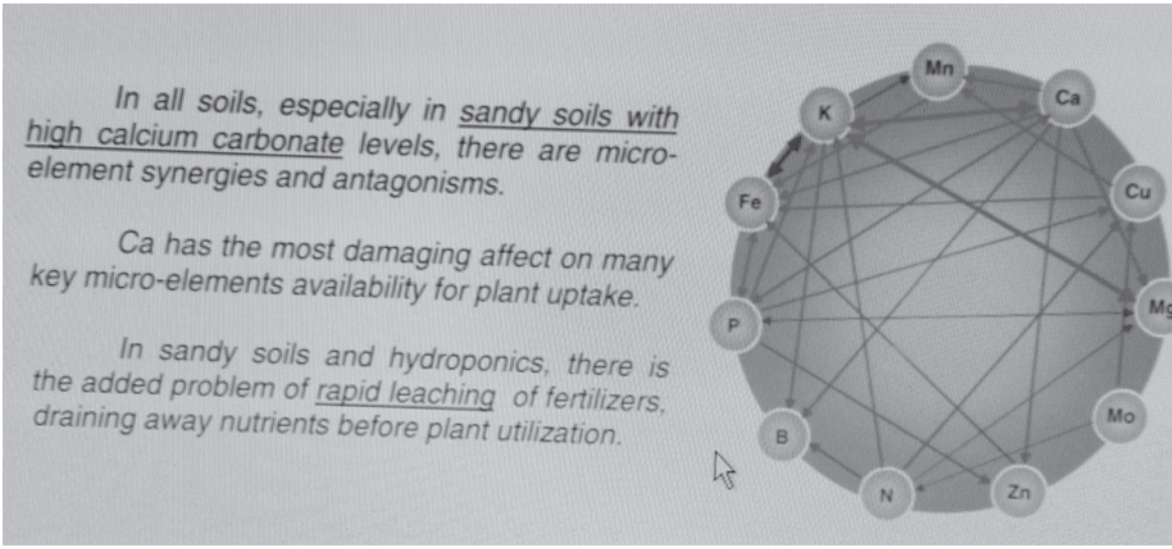


Fig. 3. Synergy and antagonism between nutrients in soils

Nutrient Immbalances on Human Health

There are several adverse health effects that can arise from nutrient deficiencies:

Iron (Fe): deficiency is probably the most common example (http://www.who.net/en). Iron-deficient soils can lead to low Fe content in upland crops especially: rice, sugar cane and chick pea in soils with low organic matter (Chatterjee, 2010), in upland rice occurs in alkaline and calcareous soils (Rattan *et al.*, 2009) and its deficiency in the humans who eat them, but low Fe in soils is rarely a problem except in arid regions Blood loss to parasites such a hook worms, a disease causing organism associated with the soil, is another major cause of Fe deficiency.

Iodine (I): is another soil-related form of malnutrition is iodine deficiency in the high-altitude interior of continents (Combs, 2005: http://www.who.net/en/-World), which leads to goiter (abnormal enlargement of the thyroid gland), severe cognitive and *neuromotor deficiencies,* and other *neuropsychological disorders*. Iodine deficiency is the single most important preventable cause of brain damage and the World Health Organization has made the elimination of iodine deficiency disorders a priority. Regions known to have soils deficient in iodine are mainly located although iodine deficiency has been eliminated in many developed countries by introducing iodine supplements to foods such as salt and bread (http://www.who.net/en/-World). Most iodine deficiency problems today are found in developing easily bound by Ca, Al or Fe depending on the soil pH (Brady and Weil, 2008), In both cases, it is possible to have ample amounts, of Zn, or P in the soil for nutritional needs, but inadequate amounts of Zn or P to be taken up by plants due to chemical reaction occurring within the soil that bind these elements.

Vitamin-A: Its deficiency can lead to poor night vision, eye lesions and permanent blindness. Golden rice was the first genetically engineered bio-fortified crop to produce beta- carotene or pro-vitamin-A in the edible portion of the grain (Jeeyan and Mary Lou, 2008).

Toxicity Issues Related to Soils

In addition to providing elements at levels that are essential for human health, soils can also provide elements such as Pb, Cd and As, as well as radioactive elements such as uranium (U), radium (Ra0, and radon(Rn), at levels that are detrimental to human health. The soils is also a sources of several organic compounds, introduced primarily by industrial and agricultural functions, that are toxic to humans when exposure occurs at high enough levels. In some cases these organic compounds were purposefully applied to crops or directly to the soil as pesticides.

Health Effects from Exposure to Heavy Metals in Soil

Heavy metals are metallic elements that have densities great than 4500 kg/m-1. Heavy metals cannot be degraded into nontoxic forms, but it is possible to create insoluble forms that are non biologically available (Baird and Cann, 2005). Heavy metals originate naturally from the weathering of rocks, but have also been introduced to soils through human activity. Heavy metals may occur as a by product of mining ores and are therefore present in mine spoils and in the immediate surroundings of metal processing plants (Brevik and Burgess, 2012).

E-wastes, or those associated with electronic appliances such as computer and mobile phones are also becoming an increasing source of heavy metals such a Pb,Sb, Hg, Cd and Ni in the soil (Brevik and Burgess, 2012).

Urban soils are particularly susceptible to significant accumulations of heavy metals due to different types of industries, disposal of industrial effluents and also through sewage and slude. Due to the industrialization and urbanization the soil, water and plants getting polluted with toxic heavy meatal accumulatin in soil, water, feed abnd fodder, milch animals, fish, poultry and in human beings in continuum mode (Bhupal Raj *et al.*, 2009).

Heavy metals have also been used in chicken feed (As) and swine feed (Cu, Zn) to promote growth and control disease (Brevik and Burgess, 2012) and Cd in chicke feed (Bhupal Raj *et al.*, 2009). These metals can end up in the soil if the manures produced are spread on fields. Heavy metal contents in agricultural soils have increased significantly in industrialized countries over the past century.

Transport of heavy metals form one place to another most commonly occurs through the atmosphere as metal containing gases or when the metals are suspended on particles such as dust. Many heavy metals in the atmosphere are linked to the burning of fossil fuels or industrial waste products. Surface runoff and river sediments are another facet of heavy metal transport. The ultimate sink for heavy metals, however, is in sols and sediments.

Soil pH and drainage are important considerations when dealing with heavy metal contaminated soils. Maintaining the soil pH at about 7.0 will reduce the mobility of heavy metals, making them less available for plant uptake. With the exception of Cr, draining wet soils will also decrease heavy metal mobility. Applications of phosphate fertilizers will reduce the availability of most metal cations duet to the formation of P-metal complexes, but P-Fertilization make As more available in the soil (Brady and Well, 2008).

Heath Effects from Exposure to Organic Pollutants in Soil

The main concern with organic chemicals comes from materials known as persistent organic pollutants (POPs). These are organic chemicals that resist decomposition in the environment or that bioaccumulation through the food web and therefore pose a risk of causing adverse effect to human health and the environment (Lee *et al.*, 2003). Some common organic chemicals of concern include organochlorines, organophosphates, carbamates, chloroacetamides, glyphosate, and phenoxy herbicides.

As pesticides in agricultural situation and through their accumulation in landfills or other disposal sites due to inadequate disposal practices (Brady and Weil, 2008; Vega *et al.*, 2007).E-wastes are also new sources of POPs such as polychlorinated biphenyls (PCBs). And burning of e-wastes can generate other POPs such as dioxins and furans. Common routes of exposure to organic chemicals include dermal contact with soil and soil ingestion.

Role of Agricultural Research in Soil and Human Health

The research on crop responses on micronutrients management or increasing the deficient micronutrient content in agricultural crops or now a day's calling as bio-fortification but strictly it can be called as ferti-fortification, This type of research activities may directly or indirectly increases its content in edible parts that can be meet the upcoming malnutrition in the society. Such type of work was taken up in larger way in cereals, millets and pulses and also through screening of genotypes for genetically bio-fortified.

Crop Response and Micronutrient Management: Usually crop responses are measured in terms of incremental yield and/or quality improvement. Crops like maize (41%), sorghum (31%) and green gram (52%)

(Table 3), showed greater response to applied iron in the soils of southern and northern Telangana regions (Aravind K. Sukla *et al.*, 2015)

Studies conducted on vegetables (tomato, brinjol and chillies) exhibited variable response to Zn and Fe rates and methods of application. Results of experiments conducted at farmers fields revealed that basal application of zinc was superior over foliar feedings.The percent increase over control was ranged from 6 to 39% in tomato, 10.8 to 30.7% in brinjal and it was 7.1 to 20% in chillies respectively in zinc content but there was no response with iron, but chillies responsonded to iron and its increased from 4.0 to 31% only (Aravind K. Sukla *et al.*, 2015).

As per the research studies conducted at IARI – New Delhi, indicated that, the highest mean yield of rice was obtained under seed soaking with the solution of 0.05 M-Fe-EDTA (3.65 g pot-1) followed by 0.5 M (3.38 g pot-1) and 0.25M FeSO4 .7H2O (3.35 g pot-1) (Table 4).

Table 3. Response of crops to applied nutrients in soils

Nutrient	Crop	Response in kg/ha (%)
Fe	Mize	19-279 (41)
	sorghum	10-880 (31)
	Green gram	- (51)

Aravind K. Sukla *et al.*, 2015

Table 4. Effect of Iron sources used for seed soaking on dry matter yield (g pot-1) on rice cultivars

Cultivars ©	Source and concentration of Fe				
	Control	0.5M FeSO4	0.25M FeSO4	0.05M-Fe-EDTA	Mean
IR-64	2.84	3.15	3.13	3.64	3.19
Pusa sugandha	3.57	3.60	3.57	3.66	3.60
Mean	3.21	3.38	3.35	3.65	
CD (P=0.05)	Fe=0.21	C=0.15	C XD= 0.21		

Meena *et al.*, 2013

The results in table 5 indicated that, Zinc content in fruit yield (mg/kg) was increased with the increases dose of Zn as soil application. The highest mean zinc content was in brinjal (36 mg/kg) followed by tomato (30 mg/kg) then bendi (28 mg/kg). Whereas the highest percent increase in zinc content was more in tomato (38.7%), followed by bendi (34.4%) and the least (21%) in brinjal over the control.

Table 5. Effect of different doses of Zn in fruit Zn content and response of Zn

Treatments	Zinc content in Fruit yield (mg/kg)				% increase in zinc content over farmers			
	practice	Tomato	Bhendi	Brinjal Mean	Tomato	Bhendi	Brinjal	Mean
FP	22	20	28	23.3	0	0		0
10 kg/ha	26	24	32	27.3	18.2	20.0	14.3	14.3
20 kg/ha	30	30	36	32.0	36.4	25.0	12.5	12.5
30 kg/ha	42	38	49	43.0	61.5	58.3	36.1	36.1
Mean	30	28	36.25	31.4	38.7	34.4	21.0	21.0

(Shankar. 2013, personnel communication)

Conclusion

To overcome the malnutrition problems through diet supplements or pharmaceuticals are quite expensive and impractical. On the globe majority countries are under and developing. Agricultural approaches to finding the sustainable solutions to these problems are urgently needed and should be point based to prevent the micronutrient malnutrition. Focus should be given on enhanced bioavailability to human kind rather than their increased levels and getting sustainable or optimum yields though important to serve the increasing population. Developing agronomic approaches such as, ferti-fortification of crops and preparations of mixed cereal products and by-products for supplemental purposes. Scientific investigations to find out the reason to less bio-availability of bio-fortified crops. There should be multi disciplinary research towards soil and human health issues.

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6 Nitrogen, Phosphorus and Potassium Interrelationship in Soils, Plants and Human Nutrition

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Introduction

Soil is the critical component of the earth system, functioning for the production of food, fodder and fiber and also maintenance of local, regional and global environmental quality. Growers have practiced a cultural system that ensured stable yields while maintaining a desired level of fertility in soil. This equilibrium was disturbed by the need to increase production through introduction of high yielding varieties, intensive use of chemical fertilizers and pesticides and extensive tillage.

Deficiencies of Macro Nutrient (N, P, K) in Indian Soils

Poor fertility of the Indian soils has been reported in the Report of Royal Commission on Agriculture in India submitted as early as in 1928 to Parliament. The report clearly recognized the existence of deficiencies of nitrogen (N), phosphorus (P_2O_5) and potash (K_2O). Today situation is same as was in the first half of the 20th century, whether judged by the extent of deficiencies or even the ideal nutrient consumption ratio of 4:2:1. Nitrogen is universally deficient in Indian soils with 99% of soils responding to N application. Being a constituent of proteins, N holds a key to the life on Earth. It follows a Liebig's law of minimum and unless its deficiencies are corrected first, addition of other nutrients becomes a wasteful exercise.

Nitrogen

Bulk of nitrogen in soils is present in the organic form as a part of the soil organic matter, in the western and central plateaus, high temperature and low rainfall limit organic matter accumulation, while in the Eastern region and Western Ghats, high temperatures and heavy rainfall cause a rapid decomposition of soil organic matter. Thus, under both these situations, total soil nitrogen is low. High total N in soil is found only in the hilly regions in the north.

Reported values of total N in Indian soils (0-15 cm layer) other than hill region vary from 0.02 to 0.1 % as reported by researchers from different states- Krishnamoorthy and Govindarajan (1977) from Andhra Pradesh; Tiwari *et al*. (1968) from Bihar; Reddy and Mehta from Gujarat (1970); Agrwal *et al*. (1974) and Ahuja *et al*. (1078) from Haryana; Venkata Rao and Badigar (1977) from Karnataka, Padmanabhan *et al*. (1966) and Varghese *et al*. (1970) from Kerala; Gawade, and Biswas (1967) from Madhya Pradesh; Bhattacharjee *et al*. (1977) from Maharashtra; Mahajan and Kanwar (1974) from Punjab; Gupta (1958) from Rajasthan; Menon and Mariakulandi *et al*. (1957a,b) and Ramaswami (1966) from Tamil Nadu; and Yadav *et al*. (1977) from Uttar Pradesh. Total N in the soils of Andaman and Nicobar Islands varied from 0.018 to 0.176% (Tamhane *et al*., 1956).

Nitrogen content is higher in the north-eastern regions of the country. Bora and Mazumdar (1969) reported total N of 0.115% in alluvial, and about 0.203% in forest soils of Assam. Similarly, in the tea growing soils of Himachal Pradesh, 85 % of soils contained 0.1 to 0.15% of the total N (Kanwar and Takkar, 1963) and in apple- growing region it varied from 0.04 to 0.112% (Sharma and Rao, 1957). In the soils of Nilgiri hills of Tamil Nadu, Manickam (1965) reported the total N value from 0.01 to 0.319%.

The value of total N in Indian soils reported above is in accord with the generalizations made by Jenny and Raychaudhari (1960). They also observed that rice-growing soils in the traditional rice belt, in general, contained more total N than non-rice soils of the region. This would be expected because rice is traditionally grown on low-lying heavier soils, and also because the rate of mineralization of organic matter is slow under submerged soils. These generalizations, however, do not hold true for non-traditional rice soils of the Rice-Wheat cropping system belt of north-western India.

Phosphorus

The phosphorus (P) availability to plants may be limited by its low abundance in the soil, but also, and very commonly, by its adsorption onto various soil minerals. In acidic soils, phosphorus may be adsorbed by iron or aluminium oxides, and various clay minerals. Many of the most fertile and productive soils in tropical zones are derived from volcanic material containing allophane minerals, which have a large phosphorus fixing capacity. Phosphorus deficiency is often the major limitation to crop growth on these soils, particularly where previous cropping has caused a depletion of soil organic matter and increased acidification. Phosphorus deficiency is also common on highly weathered tropical soils and siliceous sands; in fact, few soils are naturally well endowed with this nutrient.

Based on about 9.6 million soil tests, 49.3 percent of districts and Union Territories are low in available P, 48.8 percent are medium, and 1.9 percent are high (Hasan, 1996). In comparison to an earlier compilation by Ghosh and Hasan (1979), this present survey indicates the low P fertility class has increased by 3.0 percent while medium and high categories have decreased by 2.7 and 0.3 percent, respectively. Both surveys highlight the need for P fertilizer application for proper crop growth in nearly 98 percent of India's districts.

Potassium

There are a number of reviews dealing with status of potassium in Indian soils. According to Hassan (2002), among 371 districts, the respective number of districts characterized as low, medium, and high are 76, 190, and 105, respectively. Thus, 21% of the districts are low, 51% are medium, and 28% are high. Available soil K was extracted with 1N ammonium acetate (NH_4OAc, pH 7.0) and soils containing less than 130 kg K_2O/ha were categorized as low, between 130 and 335 kg K_2O/ha as medium, and above 335 kg K_2O/ha as high. Out of the 109 soils series, 17.5% were low, 40% were medium and 42.5% were high in available K. Low fertility soils series were reported to occur mainly in states of Punjab, West Bengal, Karnataka, Rajasthan, Maharashtra and Madhya Pradesh.

Critical Limits for N, P and K in Soils

Critical limit of nutrient in soil is defined as amount of that nutrient present in the soil below which there is a response to the addition of that nutrient.

Nitrogen

Nitrogen occurs in soils as organic and inorganic forms. Nitrate nitrogen (NO_3-N) is most commonly measured in standard soil tests because it is the primary form of nitrogen available to trees and, therefore, an indicator of nitrogen soil fertility. However, soil concentrations of NO_3-N depend upon the biological activity and may fluctuate with changes in soil temperature, soil moisture, and other conditions (Table 1).

Table 1. Critical levels of nitrate nitrogen (NO_3-N) levels in soil test results.

Fertility Level	mg kg^{-1} soil (ppm)
Low	<10
Medium	10-20
High	20-30
Excessive	>30

Ammonical nitrogen (NH_4-N) is also a plant available form of nitrogen in soils and it can be determined with soil testing. Ammonical nitrogen concentrations of 2-10 ppm are common. Levels of NH_4-N above 10 ppm may occur in cold, wet soils or in soils irrigated with a water supply that is high in ammonium nitrogen. Total nitrogen which is a measure of all organic and inorganic forms of nitrogen in soil can be determined with soil testing.

Phosphorus

The Bray P1 Test is used for neutral and acid soils (pH 7.0 and lower) and the Olsen sodium bicarbonate test is used primarily for alkaline soils (pH>7.0) but can be used on soils with pH >6.5. These phosphorus soil tests measure ortho-phosphate (PO_4-P) and provide an index of the phosphorus availability. The critical limits of phosphorus as estimated by different methods for evaluating phosphorus soil fertility are presented in Table 2.

Table 2. Critical levels of phosphorus (PO_4) levels in soil.

Fertility Level	**Bray P1 method PO_4 Concentration (ppm)**	**Olsen method PO_4 Concentration (ppm)**
Low	<20	<10
Medium	20-40	10-20
High	40-100	20-40
Excessive	>100	>40

Potassium

Potassium undergoes exchange reactions with other cations in the soil such as calcium, magnesium, sodium, and hydrogen and this affects the plant available potassium. Therefore, an ammonium acetate extraction method is the most common method to model these soil reactions and analyze for potassium fertility (Table 3).

Table 3. Critical levels of potassium (K) in soil.

Fertility Level	**Extractable K (ppm)**
Very Low	< 75
Low	75 -150
Medium	150 - 250
High	250 -800
Very High	> 800

Functions of N, P, K in plants

Nitrogen

- Necessary for formation of amino acids, the building blocks of protein
- Essential for plant cell division, vital for plant growth
- Directly involved in photosynthesis
- Necessary component of vitamins
- Aids in production and use of carbohydrates
- Affects energy reactions in the plant

Phosphorus

- Involved in photosynthesis, respiration, energy storage and transfer, cell division, and enlargement
- Promotes early root formation and growth
- Improves quality of fruits, vegetables, and grains

- Vital to seed formation
- Helps plants survive harsh winter conditions Increases water-use efficiency Hastens maturity

Potassium

- Carbohydrate metabolism and the break down and translocation of starches
- Increases photosynthesis
- Increases water-use efficiency
- Essential to protein synthesis
- Important in fruit formation
- Activates enzymes and controls their reaction rates
- Improves quality of seeds and fruit
- Improves winter hardiness
- Increases disease resistance

N, P and K Nutrition Related to Soils and Plants

Nitrogen

Nitrogen is the key input in augmenting India's food grain production, particularly the cereals, which form the staple food and supply 63.3% of the total energy needs, 61.2% of protein needs, and 16.5 % of the fat needs of the Indian people. Kumar (1998) emphasized that by the year 2020, India will need about 300 million metric tons of food grain/yr, which can be achieved only if the consumption (11 million metric tons N/yr during 1998) is more than doubled to 22-25 million metric tons N/yr. As a contrast to these high demands of nitrogen, Indian soils are very poor in total N, which, for most soils of the country, except those in the hills, varies from 0.02 to 0.1 % in surface 0-15 cm layer; in the hill soils the values may be 0.3% or even more. About 18-30 % of the total N in soils is present as protein, 3-7% as amino sugars, and 18-43% as non-hydrolyzable N (Table 4).

Table 4. Comparative share (%) of various food items in meeting total dietary energy supply (DES), protein and fat supply in India

Food item	Energy		Protein		Fat	
	India	USA	India	USA	India	USA
Cereals	63.3	22.1	61.2	21.7	16.5	2.2
Pulses and nuts	7.2	2.9	15.0	4.5	11.5	4.4
Meat, Fish etc	2.6	19.9	3.9	64.4	12.5	37.1
Milk	4.5	10.1	10.2	19.7	14.1	14.1

Source: FAO (1996), Prasad (2003)

Phosphorus

Phosphorus is the second most important macronutrient for the plant growth and comprises approximately 0.2% of a plant's dry weight (Schachtman *et al.*, 1998). It plays a critical role in plant metabolism, cellular energy transfer, respiration and photosynthesis (Bathellier *et al.*, 2007). Phosphorus accumulates rapidly in grains during ripening along with other substances such as lipids and starch. In seeds, phytate is the main stored form of P (Nadeem *et al.*, 2011). Phytate is considered as having anti-nutrient characteristics when consumed by non ruminant animals (Raboy *et al.*, 1989). Phytate content of cereals is highly correlated with total P (Lockhart and Hurt, 1986).

Potassium

Potassium (K) is regarded as one of the major nutrient element which effects the yield and quality of grain and fruits. This nutrient plays an essential role in plant growth and metabolism (Ruiz and Romero, 2002). It activates enzymes, serves as an osmoticum to maintain tissue turgor pressure, regulates the opening and closing of stomata, and balances the charge of anions. As soon as the potassium reserves of the seed are exhausted, the plant die (Mengel, 2007). Sahu and Mitra (1992) reported that the dry matter yield of rice increased with increasing doses of K. However, they indicated that the excess amounts of K depressed the plant growth and yield.

N, P and K Contents in Food Grains and Pulses

India is the world's largest producer of millet. In the 1970s, all of the millet crops harvested in India were used as a food staple. By the 2000s, the annual millet production had increased in India, yet per capita consumption of millet had dropped by between 50% to 75% in different regions of the country. As of 2005, most millets produced in India are being used for alternative applications such as livestock fodder and alcohol production (Basavaraj, 2010). Indian organizations are discussing ways to increase millet use as food to encourage more production; however, they have found that some consumers now prefer the taste of other grains (Gayatri, 2012).

In 2010, the average yield of millet crops worldwide was 0.83 tonnes per hectare. The most productive millet farms in the world were in France, with a nationwide average yield of 3.3 tonnes per hectare in 2010 (FAOSTAT, 2010) (Table 5).

Table 5. Components (per 100 g portion, raw grain) of various crops

Component (per 100 g portion, raw grain)	Wheat	Rice	Sweet corn	Sorghum Millet	Proso Millet
Water (g)	13.1	12	76	9.2	8.7
Energy (kJ)	1368	1527	360	1418	1582
Protein (g)	12.6	7	3	11.3	11
Fat (g)	1.5	1	1	3.3	4.2
Carbohydrates (g)	71.2	79	19	75	73
Fiber (g)	1.2	1	3	6.3	8.5
Sugars (g)	0.4	>0.1	3	1.9	
Iron (mg)	3.2	0.8	0.5	4.4	3
Manganese (mg)	3.9	1.1	0.2	<0.1	1.6
Calcium (mg)	29	28	2	28	8
Magnesium (mg)	126	25	37	<120	114
Phosphorus (mg)	288	115	89	287	285
Potassium (mg)	363	115	270	350	195
Zinc (mg)	2.6	1.1	0.5	<1	1.7

(Source: Millet Network of India, http://www.milletindia.org)

N, P and K Interrelations in Soils, Plants and Human Nutrition

Several factors directly or indirectly influence the levels of minerals in plants and hence the amounts available for humans depend on plants for foods. The amount of a particular nutrient in the diet may be insufficient to meet the requirements. There are many metabolic and absorptive interrelationships among the mineral elements which contribute to variations in the degree of physiological response to deficient or toxic levels. These relationships make it difficult to determine the optimum dietary level for the individual elements required for humans and domestic animals.

Excessive N fertilizers can adversely affect the accumulation of vitamin C in various vegetable crops such as lettuce (Lactuca sativaL.), beets (Beta vul-gariscicla L.), kale (Brassica oleracea acephala DC.), endive (Cychorium endivia L.), and brussels-sprouts (Brassica oleracea gemmifera DC.) by as much as 26% (Salunkhe and Desai, 1988). Adding K to the combined N and P fertilizer treatments increased the â-carotene by 27% over-fertilized plants not receiving K. Use of excessive N fertilizers has also been reported to reduce vitamin C concentration in the fruits of several species including oranges, lemons, mandarins, cantaloupe, and apple. Also, higher rates of K fertilization are associated with greater concentration of vitamin C in fruits (Nagy *et al*., 1988).

Nitrogen balance is a measure of nitrogen input minus nitrogen output. Sources of nitrogen intake include meat, dairy, eggs, nuts and legumes, and grains and cereals. Examples of nitrogen losses include urine, feces, sweat, hair, and skin.

Nitrogen Balance and Protein Metabolism

Nitrogen is a fundamental component of amino acids, which are the molecular building blocks of protein. Positive nitrogen balance is associated with periods of growth, hypothyroidism, tissue repair, and pregnancy. This means that the intake of nitrogen into the body is greater than the loss of nitrogen from the body, so there is an increase in the total body pool of protein. Negative nitrogen balance is associated with burns, serious tissue injuries, fevers, hyperthyroidism, wasting diseases, and during periods of fasting. A negative nitrogen balance can be used as part of a clinical evaluation of malnutrition (WHO, 2007).

Nitrogen balance is the traditional method of determining dietary protein requirements. Determining dietary protein requirements using nitrogen balance requires that all nitrogen inputs and losses are carefully collected, to ensure that all nitrogen exchange is accounted for. In order to control nitrogen inputs and losses, nitrogen balance studies usually require participants to eat very specific diets (so total nitrogen intake is known) and stay in the study location for the duration of the study (to collect all nitrogen losses). Because of these conditions, it can be difficult to study the dietary protein requirements of certain populations using the nitrogen balance technique (e.g. children).

Phosphorus Imbalance

Phosphorus imbalance refers to conditions in which the element phosphorus is present in the body at too high a level (hyperphosphatemia) or too low a level (hypophosphatemia).

Almost all of the phosphorus in the body occurs as phosphate (phosphorus combined with four oxygen atoms), and most of the body's phosphate (85%) is located in the skeletal system, where it combines with calcium to give bones their hardness. The remaining amount (15%) exists in the cells of the body, where it plays an important role in the formation of key nucleic acids, such as DNA, and in the process by which the body turns food into energy (metabolism). The body regulates phosphate levels in the blood through the controlled release of parathyroid hormone (PTH) from the parathyroid gland and calcitonin from the thyroid gland. PTH keeps phosphate levels from becoming too high by stimulating the excretion of phosphate in urine and causing the release of calcium from bones (phosphate blood levels are inversely proportional to calcium blood levels). Calcitonin keeps phosphate blood levels in check by moving phosphates out of the blood and into the bone matrix to form a mineral salt with calcium. Most phosphorus imbalances develop gradually and are the result of other conditions or disorders, such as malnutrition, poor kidney function, or a malfunctioning gland.

Hypophosphatemia (low blood phosphate) has various causes. Hyperparathyroidism, a condition in which the parathyroid gland produces too much PTH, is one primary cause. Poor kidney function, in which the renal tubules do not adequately reabsorb phosphorus, can result in hypophosphatemia, as can overuse of diuretics (water pills) and antacids containing aluminum hydroxide. Problems involving the intestinal absorption of phosphate, such as chronic diarrhea or a deficiency of Vitamin D (needed by the intestines to properly absorb phosphates) can cause the condition. Symptoms generally occur only when phosphate levels have decreased profoundly. They include muscle weakness, tingling sensations, tremors, and bone weakness. Hypophosphatemia may also result in confusion and memory loss, seizures, and coma.

Hyperphosphatemia (high blood phosphate) also has various causes. It is most often caused by a decline in the normal excretion of phosphate in urine as a result of kidney failure or impaired function. Hypoparathyroidism, a condition in which the parathyroid gland does not produce enough PTH, or pseudoparathyroidism, a condition in which the kidneys lose their ability to respond to PTH, can also contribute to decreased phosphate excretion. Hyperphosphatemia can also result from the overuse of laxatives or enemas that contain phosphate. Hypocalcemia (abnormally low blood calcium) can cause phosphate blood levels to increase abnormally. A side-effect of hyperphosphatemia is the formation of calcium-phosphate crystals in the blood and soft tissue.

Hyperphosphatemia is generally asymptomatic; however, it can occur in conjunction with hypocalcemia, the symptoms of which are numbness and tingling in the extremities, muscle cramps and spasms, depression, memory loss, and convulsions. When calcium-phosphate crystals build up in the blood vessels, they can cause arteriosclerosis, which can lead to heart attacks or strokes. When the crystals build up in the skin, they can cause severe itching (Barcia *et al.*, 1997).

Potassium in Human Health

The health benefits of potassium includes blood pressure, anxiety, stress, muscular strength, metabolism, heart strokes, kidney disorders, water balance, electrolytic functions, nervous system and many other health benefits are well documented (Poirier, 1984; Sacks *et al.*, 1998). It contains qualities for maintaining a high level of human well-being and a cheerful lifestyle (Heyka, 2009). Apart from acting as an electrolyte, this mineral is required for keeping heart, brain, kidney, muscle tissues and other important organs of human body in good condition. Elevations or deficiencies of this important mineral can cause problems and, in the extreme, even death. Maintaining consistent levels of potassium in the blood and cells is vital to body function. Therefore, there is no way one should overlook the inclusion of potassium in routine diet plan (O'Shaughnessy, 2006).

Low Potassium Symptoms

Usually symptoms of low potassium are mild. At times the effects of low potassium can be vague. There may be more than one symptom involving the gastrointestinal (GI) tract, kidneys, muscles, heart, and nerves.

- Weakness, tiredness, or cramping in arm or leg muscles, sometimes severe enough to cause inability to move arms or legs due to weakness (much like a paralysis)
- Tingling or numbness
- Nausea or vomiting
- Abdominal cramping, bloating
- Constipation
- Palpitations (feeling your heart beat irregularly)
- Passing large amounts of urine or feeling thirsty most of the time
- Fainting due to low blood pressure
- Abnormal psychological behavior: depression, psychosis, delirium, confusion, or hallucinations.

Loss of potassium through stomach and intestines: Vomiting, enemas or excessive laxative use and diarrhea.

Strategies to Improve NPK Nutrition in Plants, Humans and to Avoid Mal Nutrition

- Soil test based balanced fertilizer application.
- Integrated use of organic and inorganic source of nutrients
- Creating awareness among rural population about intake of balanced diet rich in N,P and K to prevent mal nutrition from locally available cheaper sources
- Intake of protein fortified foods.

- Awareness about safe cooking practices which may help in minimizing the loss of nutrients during cooking.
- Periodical health survey to diagnose malnutrition with respect to N, P and K.
- Effective Government support systems and policies to ensure balanced fertilization

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7 Zinc Deficiency in Soils and Crops and Its Effect on Human Health

K Sammi Reddy

Introduction

Agricultural technologies can be directed towards improving nutritionally-rich food systems, which play an important role in public health. Food systems in many developing countries are now failing to provide adequate quantities of essential nutrients in the people's diet (Welch and Graham, 2005). Cropping systems promoted by the green revolution have increased the food production but also resulted in reduced food-crop diversity and decreased availability of micronutrients. Micronutrient malnutrition is causing increased rates of chronic diseases (cancer, heart diseases, stroke, diabetes and osteoporosis) in many developing nations; more than 3 billion people are directly affected by the micronutrient deficiencies (WHO, 2002).

Unbalanced use of mineral fertilizers and a decrease in the use of organic manures are the main causes of the nutrient deficiency in the regions where the cropping intensity is high (Prasad, 1984). Moreover, agricultural intensification requires an increased nutrient flow towards and greater uptake of nutrients by crops. Until now, micronutrient deficiency has mostly been addressed as a soil and, to a smaller extent, plant problem. Currently, it is being addressed as a human nutrition problem as well. Increasingly, soils and food systems are affected by micronutrients disorders, leading to reduced crop production and malnutrition and diseases in humans and plants (Welch and Graham, 2004).

Among the micronutrients, zinc (Zn) is the most important for activity of various enzymes and proper growth and development of plants, animals and humans (Singh, 2009**)**. Naturally, plant species differ in capacity to grow at low level of soil Zn and to accumulate Zn in the grain. Among different cereal crops, wheat is considered less tolerant to Zn deficiency stress (exhibits significant yield losses due to Zn deficiency) compared to more tolerant species such as peas, carrots and rye. The lecture notes briefly described the strategies which potentially help combating Zn deficiency problems in soil-plant-human continuum.

Zinc in Indian Soils

Zinc deficiency is common on neutral and calcareous soils, intensively cropped soils, paddy soils and poorly drained soils, sodic and saline soils, peat soils, soils with high available phosphorus and silicon, sandy soils, highly weathered acid and coarse-textured soils. Factors such as topsoil drying, subsoil, disease interactions and high cost of fertilizer also contribute to zinc deficiency. The critical soil levels for occurrence of zinc deficiency are between 0.6 ppm and 2mg zinc kg^{-1} depending on the method of extraction used. Calcareous soils (pH>7) with moderate to high organic matter content (>1.5% organic C) are likely to be Zn-deficient due to high HCO^-_3 in the soil solution. A ratio of more than 1 for exchangeable Mg: Ca in soil may also indicate Zn deficiency.

Analysis of over 2,56,000 soil samples from all over India showed that about 50% of the soils were deficient in zinc and that this was the most common micronutrient problem affecting crop yields in India (Singh, 2009). The reasons for the increase of incidences of zinc deficiency include large zinc removals due to high crop yields and intensive cropping systems, less application of organic manures, use of high analysis fertilizers (such as urea and DAP in place of AS and SSP), increased use of phosphate fertilizers resulting in phosphorus induced zinc deficiency and the use of poor quality irrigation water. The soil conditions that commonly lead to zinc deficiency in crops are low total zinc concentrations, such as sandy soils; highly weathered parent materials with low total zinc contents such as tropical soils; high calcium carbonate contents. such as calcareous soils; neutral or alkaline pH, as in heavily limed soils or calcareous soils; high salt concentrations, ie, saline soils; peat and muck, as in organic soils; and high phosphate status; prolonged water logging or flooding, as in rice soils; and high magnesium and/or bicarbonate concentrations in soils or irrigation water. Zinc deficiency in India is expected to increase from the present level of around 50% to 63% in 2025 if the current trend continues. This is also because increasing areas of marginal lands are brought under intensive cultivation without adequate micronutrient supplementation.

About 50% or more soil samples tested were deficient in zinc in Maharashtra, Karnataka, Haryana,Tamil Nadu, Bihar, Orissa and Meghalaya. Increased cropping intensity in marginal lands and less use of micronutrients in the states of Bihar, Tamil Nadu, Maharashtra. Karnataka, Chhattisgarh, Jharkhand and the hill region has further escalated the magnitude of zinc deficiency. The states of Punjab, Haryana and part of Uttar Pradesh have, however, shown a build up of zinc status and decline in zinc deficiency. This likely is due to greater awareness and use of zinc fertilizers by the farmers. This success story needs to be replicated elsewhere in the country.

Zinc deficiency is also widespread in soil types and climatic regions where primarily dryland /rainfed farming is practiced (Rego *et al.*, 2005, Sahrawat *et al.*, 2007). In these rain fed areas, farmers' fields found to be deficient in zinc were: 82% (out of 1926 samples) in Andhra Pradesh. 82% (out of 82 samples) in Gujarat. 74% (out of 1260 samples) in Karnataka, 18%(out of 28 samples) in Kerala, 100% (out of 73 samples)in Madhya Pradesh, 15% (out of 179 samples) in Rajasthan and 61% (out of 1 19 samples) in Tamil Nadu. These data show that zinc deficiency is widespread in the rain-fed fields of the Indian semi arid tropics. In a survey of soils across 21 districts, zinc deficiency was widespread. More than 75% soil samples were found to be deficient in zinc in 43% districts.

There is a high degree of correlation between zinc deficiency in soils and that in human beings. It is estimated that about one third of the world's population suffers from zinc deficiency.

Zinc Deficiency in Humans

Zinc deficiency, especially in infants and young children under five years of age, has received global attention. Zinc deficiency is the fifth leading cause of death and disease in the developing world. According to the World Health Organization (WHO), about 8,00,000 people die annually due to zinc deficiency, of which 4,50,000 are children under the age of five. Globally, around 2 billion people are affected by zinc deficiency. It is also estimated that 60—70% of the population in Asia and Sub-Saharan Africa could be at risk of low zinc intake (Prasad, 2006).It may be surprising to note that 15% of infant deaths are caused by diarrhea compared to 2% by HIV/AIDS. Globally, 1.5 million deaths could be attributed to diarrhea alone. Zinc supplementation could prevent most of the deaths of children due to diarrhea and pneumonia (UNICEF, 2012).

Everyone needs zinc. Children need zinc to grow, and adults need zinc to maintain health. Growing infants, children and adolescents, pregnant women and lactating mothers, athletes, vegetarians and the elderly often require more zinc. The primary source of zinc is food. The major sources of zinc are (red) meat, poultry, fish and seafood, whole cereals and dairy products. Zinc from meat is most available to the human body. The bioavailability of plan-based foods is generally lower due to dietary fibre and phytic acid which inhibit the absorption of zinc. A balanced diet is the best way to provide the body with zinc.

Dietary sources of zinc to meet human health needs along with their average zinc content are oysters (25 mg/100g), meat (especially red meat) (5.2 mg/100g), nuts (3 mg /100g), poultry (1.5 mg/100g), eggs (1.3 mg/ 100g), milk products (1.2 mg/100g), cereals and bread (1 mg/100g), fish (0.8 mg/100g), sugars and preserves (0.6 mg/100g), canned and green vegetables (0.4 mg/100g), potatoes (0.3 mg/100g) and fresh fruits (0.09 mg/ 100g) (Black 2008).

Measures to Overcome Zinc Deficiency

The possible solutions to correct zinc deficiency in humans may be food supplementation, food fortification or bio-fortification. The former two programs require infrastructure, purchasing power, access to market and health care centers and uninterrupted funding, which have their own constraints. In addition, such programs will most likely reach the urban population, which is easily accessible, especially in the developing countries.

Zinc supplementation is an assured and well controlled approach for zinc deficiency intervention in humans, but it has two problems (Shivay *et al.,* 2014):

(1) Zinc supplements are to be used as per medical advice and thus its application is likely to be restricted to urban areas and millions of rural poor will not be able to adopt this approach.

(2) It also involves additional expenditure and about one-third of the Indian population, which cannot afford even two square meals a day, cannot adopt this approach

Alternatively, the latter program, biofortification of crops (especially cereals) with zinc is the best option for alleviating zinc deficiency. It will cater both the rural and urban populations. It could be Crop trials kg/ha Percent achieved through two approaches: (1) genetic biofortification; and (2) agronomic biofortification, there is a developing field of research on biofoitification of plant foods with zinc. This involves both the breeding of new varieties of crops with the genetic potential to accumulate a high density ofzinc in cereal grains (geneticbiofortification) and the use of zinc fertilizers to increase Zinc density (agronomic biofortitication). Although the plant breeding route is likely to be the most cost-effective approach in the long run, the use of fertilizers is the fastest route to improve the zinc density in diets. In order to replenish the zinc taken up by the improved cultivars, higher and sustainable use of fertilizers is inevitable.

Genetic Bio-Fortification

Considering the wide-spread deficiencies of Vitamin A, iron and zinc, especially in the developing world, research on genetic bio-fortification of cereal grains and other foods with these micronutrients is going on in a big way under programmes, such as, Harvest Plus, Golden Rice and African Bio-fortified Sorghum Project (Stein, 2010). These projects involve GM (Genetic Modification) technology. Golden Rice has been engineered to express beta carotene by introducing a combination of genes that code for biosynthesis pathway for the production of pro-vitamin A in the endosperm (Ye *et al.,* 2000). However there are problems in the acceptance of GM crops in several countries. So far no GM plant with denser zinc grains has been developed. In the cultivars so far studied, higher zinc concentration is generally associated with lower grain yield (Fan *et al.*, 2008) and this is contrary to the goal of securing food security in a country. The major disadvantage of this approach is the huge amounts of funds and time required for developing GM crops.

Agronomic Bio-Fortification

Agronomic bio-fortication of cereals and pulses aims at increasing zinc concentration in grains through zinc fertilization. It has also been referred to as ferti-fortification. Zinc fertilizer applications are made on the basis of soil tests for available zinc in soil; the general recommendation for cereals and pulses is soil application of 5 kg Zn/ha as zinc sulphatehepta-hydrate (ZnSHH) at sowing. We have conducted a number of field experiments to compare different sources of zinc and methods of application. In studies on rice and oats, ZnSHH was found to be superior to zinc oxide (ZnO). In rice, the Bio—fortification due to ZnSHH was 41.0% as compared to 35.6% with ZnO, while in oats the values were 34.1% and 30.0% for ZnSHH and ZnO (Shivay *et al.,* 2014), respectively. As regards method of application, foliar application was superior to soil application from the viewpoint of zinc fortification of grains. In corn, zinc fortification of grains was 14.4% with foliar application as compared to 10% with soil application. Further, a combination of soil and foliar application recorded the highest increase of 21.4% in zinc concentration in corn grains **(**Shivay and Prasad 2014). The ZnEDTA, a chelated zinc fertilizer was found superior to ZnSHH for soil application in rice (Shivay et al, 2104a) but not in chickpea. The amount of zinc applied as ZnEDTA was halfthat as ZnSHH. Three foliar sprays of ZnEDTA recorded the highest zinc fortification of grains in rice (42.9%) as well as in chickpea (69.7%). Even when soil application of zinc is made, a foliar application at grain filling stage of the crop is advantageous.

Varieties of a crop also differ in their response to zinc fertilization. For example in an experiment on chickpea, application of 7.5 kg Zn/ha increased zinc concentration in grain by 45.2% in variety ’Pusa 5028’, while it was 33.1% in ’Pusa 2024’ and 30.6% in ’Pusa 372’ (Shivay *et al.*, 2014b). For all the experiments, data on grain yield are also provided to make the point that agronomic Bio-fortification of zinc in grains is made without any sacrifice on the yields. On the contrary zinc fertilization increases grain yield as well as zinc concentration in grain and is thus a win win approach. Further even when GM crop cultivars with denser zinc grains are developed, they will need higher zinc applications.

Response of Crops to Application of Zinc Fertilizers

Crop response to zinc has been observed in all crops under almost all types of soils and agroclimatic zones. Extent of the crop response depends on the status of zinc in that soil. The higher the zinc deficiency in soils, the higher the crop response would be to applied zinc. The effect of zinc on crop yields has been well documented. Since zinc deficiency is widespread, impact of zinc application on increasing crop yields has been recorded on most crops. both under irrigated and rainfed conditions.

Zinc fertilizer recommendations are based on crop-soil-climate specific situations. However, wherever situation-specific recommendations are not readily available, blanket recommendation of 25 kg/ha $ZnSO_4$ heptahydrate, equivalent to 5 kg/ha zinc is generally advocated for every year or alternate years for soil application. For foliar spray, 0.5% $ZnSO_4$ is advocated. In India, agriculture is a state subject. Therefore, fertilizer recommendations are advocated by the Department of Agriculture, State Government.

Major challenges faced by farmers towards use and promotion of zinc fertilizer products are (Das and Green, 2013):

- Unavailability of zinc fertilizers at the time of need of the farmers
- Poor quality of zinc fertilizers available in the market
- Zinc fertilizers under highly unorganized and fragmented sector
- Lack of awareness of the extension and promotional workers
- Lack of awareness of the farmers last mile delivery

Keeping in view the agricultural situation and widespread soil degradation, the time was ripe for ushering in nutrient based subsidy to promote balanced and efficient use of plant nutrients. Such policies encouraged development and use of customized fertilizers. Nutrient based subsidy rather than products based subsidy allows all fertilizers covered under the Fertiliser Control Order to get the subsidy as per their nutrient content. This encourages development and use of new fertilizer products in the country depending upon the requirement of different soils and crops.

Under the Nutrient Based Subsidy Scheme, the role of zinc has been specially targeted through additional subsidy for Zinc fortified products at Rs 500 per ton. The Government of India (G0I) is also promoting the use of zinc under the National Food Security Mission and providing an additional subsidy to the farmers at Rs 500 per hectare for use of micronutrient fertilizers. Inclusion of urea in the Nutrient Based Subsidy Scheme is under consideration by the G0I. Such steps will lead towards balanced fertilization resulting in higher productivity and efficient use of fertilizers. Use of zinc fertilizer is likely to witness an upward trend in the near future.

Conclusions

- Correcting zinc deficiency will improve crop yields and farmers' incomes, while improving nutritional quality of crops and thus human nutrition.
- Balanced fertilizer use with micronutrients including zinc is necessary for higher crop yields.
- Urgent need to increase awareness among farmers and extension workers for increased use ofzinc fertilizers.
- Future research strategy should be 'Soil–crop-animal-human continuum' study on zinc.

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8 Micronutrients in Soils and Crops and Its Implications on Human Nutrition

P Surendra Babu

Introduction

There are about 50 nutrients that are identified as essential for human beings. There are also many well-known nutrients, enzymes, coenzymes, and phytochemicals that are extremely important, but not considered essential in human nutrition. On the other hand, plants/crops take many elements from soils though 18 are identified as essential to plant growth and reproduction. Some of the elements like selenium, chromium, vanadium, cobalt etc., are taken up by plants in small quantities but are essential to animals/humans. Meeting of dietary requirement of human, as depends on crops and or animals, the supply will depend upon consumption of agricultural produce. Sometimes, the supplementation of nutrients like selenium, iodine through fortification becomes essential to meet the human requirement. From crop production point of view 9 micronutrients (including nickel and cobalt) assumes importance both for plant growth and human nutrition. This in turn, depends upon their available status of these nutrients and their external supply to provide required quantities of them to crop growth and subsequently to enter into human nutrition in required quantities. This topic concentrates on these aspects.

The deficiency of any of nutrients (micronutrients) in soils results in poor growth, lesser accumulation of micronutrients in the plant edible parts and thus their access is reduced through human food. In the recent past, increasing concern about the extent of population suffering from lack of optimal or sufficient dietary availability of micronutrients, especially Zn and iron through food across the globe lead to special drive of fortification of these nutrients in food crops. While there are several issues like bio-absorption of micronutrients that is more important to mitigate the shortfall in micronutrient (Zn & Fe) dietary requirement of population, the first and quick intervention is to fortify the food crops to increase the access to these vital micronutrients. Though efforts in this direction through genetic intervention can be a better solution, timeframe for such success and human food consumption & habits would not immediately help to safeguard the suffering population from the malnutrition of these micronutrients. Therefore, micronutrient-ferti-fortification of food crops would be an alternative and best option immediately to bring the suffering population back to normalcy without any interference in their food habits. This approach/intervention also helps in multi-crop fortification with single intervention like say, more but safe soil application of these micronutrient fertilizers or sprays of these nutrients. At the same time, fortification of food crops should be worked out both for deficient and sufficient soils of the nutrient of interest.

In the state of Telangana where rice, maize, pulses and fodder crops are important and are more prominent in diet, research was carried out on these crops about zinc fortification as the soils in the state are deficient to an extent of 28 per cent. Results of experiments conducted at PJTSAU indicated that the mean Zn biofortification in whole paddy grain, brown rice and husk was found to be 8.2, 14.8 and 11.7% higher than their respective controls (without Zn) at Jagtial of Northern Telangana Zone (NTZ) during *kharif* season. Concentrations of Zn in whole paddy grain, brown rice and husk were 6.33, 26.1 and 22.2% higher than no Zn controls, respectively, during the *rabi* season at the same location. This indicates that the zinc content tried for fortification varies with the season. The increase in mean Zn content in paddy grain during *kharif* at the Central Telangana Zone (CTZ) location was found to be similar for whole grain (8.2%), lower in brown rice (7.4%) and higher in husk of paddy grain (17%) compared to those at the NTZ location. The results of this area indicate that the fortification of zinc also varies with place.

The mean Zn biofortification in maize seed at NTZ was lower during *kharif* (6.4%) when compared to that of *rabi* season (18.4%). Within the zones, the maize seed at CTZ location registered lower mean Zn biofortification of 10.9% during *rabi* when compared to that of NTZ. In Pigeonpea, the mean Zn biofortification or increase in Zn concentration over control was found to be 9.5, 8.6 and 9.1%for whole seed, *dal* and hull (seed cover), respectively, at the STZ location during the *kharif* season. Fodder maize experiments conducted during the *rabi* season at STZ resulted in yield in the range of 35.8 to 49 t ha^{-1} with 5.4 to 20.8% increases in Zn in green fodder due to Zn fertilizer application (Table 1).

Table 1. Salient results of Zn biofortification trials conducted for rice, maize and pigeon pea in Telangana State

Details	**Location-I Jagtial(NTZ)**				**Location-II Warangal (CTZ)**		**Location-III Tandur (STZ)**
Season	**kharif**		**rabi**		**kharif (2)**	**rabi (2)**	**Kharif(2)**
Crop	**Rice**	**Maize**	**Rice**	**Maize**	**Rice**	**Maize**	**Pigeonpea**
Variety	JGL11118	DHM117	MTU1001	DHM117	WGL-14	D.Pinacle	Asha
Initial Zn (mg kg-1 soil)	1.02	1.02	1.12	1.08	0.86-1.08	1.47	0.51
Yield range (t ha-1)	5.1-5.6	4.7-5.9	4.9-5.9	10-12.1	3.6-4.5	8.4-9.2	1.9-2.4
Range of Zn content (mg kg-1) in different parts (mean of 2 seasons wherever applicable)							
Whole Grain	16.9-19.8	13.5-15.9	20.3-28.9	13.6-16.9	19.5-22.9	20.2-24.1	18.9-21.2
Brown Rice / Dal (PP)	15.4-19.7	NA	20-28.9	NA	17.4-19.6	NA	19.6-21.9
Husk / Hull of Grain	20.9-25.2	NA	21-30	NA	24.8-33.4	NA	23.5-26.1
Range of extent of Zn enhancement or biofortification (%) over no zinc application							
Whole Grain	2.4-17.1	1-13.2	19-42.6	14.7-24.3	5.4-17.1	4.9-19.5	9.6-12.5
Brown Rice / Dal (PP)	7.5-27.6	NA	17.2-44.5	NA	5.0-12.7	NA	8.2-12.2
Husk / Hull of Grain	5.8-20.8	NA	7.3-43.1	NA	12.3-24.4	NA	7.4-13.5

*Surendra Babu, P., Chandini Patnaik, M and Shankaraiah, M (2014)

It was observed that a single spray of $ZnSO_4.7H_2O$at 60 DAS/DAT/ at tasseling stage (as per the crop) resulted in increases in Zn of 4.1% (over controls) in whole grain and 8.1% in brown rice of *kharif* paddy, 28.5% in whole grain and 21% in brown rice of *rabi* paddy, 9% in *rabi* maize seed, 3.3% in *kharif* maize seed and 7.8 % in *kharif* pigeon pea seed in different agro-climatic zones of Telangana state.

Conclusion

The extent of agronomic Zn biofortification varied among varieties, crops and seasons in different agro-climatic zones of Telangana state. Farmers in the state apply Zn through soil or foliar sprays in the mid season or else will not apply Zn. Therefore, in addition to popularization of Zn usage in crop production, further enhancement of Zn biofortification can be made through a single intervention of foliar spray at 60 DAS across crops. The sum of many small contributions of Zn biofortification from different crops cans result in adequate Zn in the food chain. This will also help in early alleviation of Zn malnutrition and pave the way to overcome other problems associated with genetic biofortification. However, it is important that how much of this fortified food helps in higher bio-absorption of these micronutrients to overcome the malnutrition. Separate research is also underway on these aspects. Some of these issues are discussed during presentation and interaction.

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9 Cropping Systems Strategies for Meeting the Demands of Food Production in Rainfed Areas

G Ravindra Chary, K A Gopinath and B Narsimlu

Introduction

Rainfed agriculture with nearly 55% (78 M ha) of the net cultivated area contributes 40% of the country's food basket. 85% of coarse cereals, 83% of pulses, 70% of oilseeds and 55% of rice is produced from rainfed areas, further, supports livelihoods of 80% of small and marginal farmers, about 68 per cent of rural population, 81 per cent of rural poor and 66% of the total livestock. The relative characteristics of rainfed agriculture vs. irrigated agriculture regions are sown in Table 1. Even after realization of full potential of irrigation, nearly 40% of the net cultivated area will remain under rainfed farming. Much of the acreage under pulses cultivation (84%) is rainfed (DAC, 2014). In view of this, rainfed farming is crucial to country's food security and economy.

The estimated undernourished population would be around 70 m which would account for 5% of the population assuming that dietary energy supply would rise from current 2500 kcal/person/day to 3020 kcal/person/day by 2050.The total cereal demand is projected to grow by 1048 mt (45% from maize; 26% from wheat; 8% from rice; and the rest from minor millets and other coarse grains). The high levels of malnutrition, especially among poor, needs immediate attention as this affects their contribution to the national GDP. Output of cereals has increased at a much faster rate than population during the post green revolution period till mid-1990 speaking to 501 g/day in 1995-96 and then declining slightly. However, output of pulses has remained almost stagnant for a long time resulting in protein malnutrition. Another issue is to meet the growing demand for pulses and oilseeds. With growing affluence, the per capita edible oil consumption is likely to rise sharply leading to further surgein imports (CRIDA Vision, 2050).

Table 1. Relative Characteristics : Rainfed vis-a-vis Irrigated regions

Parameter	Rainfed regions	Irrigated regions
Poverty ratio (%)	37	33
Proportion of agricultural labour (%)	30	28
Land productivity (Rs./ha)	5716	8017
Proportion of irrigated area (%)	15	48
Per capita consumption (kg/year) of		
Cereals	240	459
Pulses	20	12
Total food grains (kg/year)	260	471
Cooperative credit (Rs./ha)	816	1038
Bank Credit (Rs./ha)	1050	1650
Infrastructure development index	0.30	0.40
Social development index	0.43	0.44
Number of Predominant crops	>34	1*, 2**

Note : * Rice-Rice in south India and ** Rice-Wheat or Cotton-Wheat in North India
Source : 1. Source of Estimates of 17th to 48th rounds: NSSO Report No. 407 2. Gol-NSSO 2006, p.18.

Another major development likely to influence rainfed areas is the changing demand profile for different food commodities. With rising incomes, the demand for high energy food (milk, meat, eggs and oils) will increase. For instance, milk and meat demands in India by 2050 are estimated to be around 110 and 18.3 mt respectively meaning more production of livestock and poultry. The major challenge is also for green fodder production. The projected domestic demand indicate that other cereals will be in acute shortage. Out of 59 mt shortfall, most of the produce will constitute maize which would go for animal/poultry feed and the net deficit would be primarily for oilseeds, fruits, vegetables and pulses. There is urgent need for synergy between natural resources endowment and cropping patterns, particularly in rained areas in the country. In rainfed areas, the present cropping patterns do not fit well which are otherwise driven due to changing food habits influenced by urbanization, globalization and accentuated by government policies. Therefore, how these food habits change in the long run will have implications on use of natural resources. For example, increasing consumption of livestock products may lead to higher use of water. Improving water use efficiency and expanding the access to water are critical to achieve the targets. It is an irony that areas with less rainfall are net exporters of agricultural produce to areas with sufficient rainfall and untapped groundwater potential (CRIDA Vision, 2050).

An average food grain yield of 2 t ha^{-1} from the current level of <1.0 t ha^{-1}will be required from drylands to feed the projected population of 1500 million by 2025 AD. More than the calories, ensuring protein security will become an important issue in view of the predominantly vegetarian habits of the populace and the dwindling availability of vegetable (pulses) proteins whose current supply is about 25 g $head^{-1}$ day^{-1} against the minimum dietary need of about 70 g. Based on the present growth in productivity trends, attaining a goal of 2 tonnes of foodgrains ha^{-1} is well within the reach in rainfed areas. The strategies for enhancing food production in rainfed areas lies primarily in increasing the productivity of cereals, pulses, oilseeds and vegetables per unit area through efficient crops, cropping systems, agri-hortisystems and integrated farming systems and through better natural resource management. This will further likely to contribute to enhanced production of fruits, milk, eggs etc.,

Strategies for Enhancing the Food Production in Rained Areas

The coarse cereals, millets, pulses and oilseeds are primarily rainfed crops impacted by intra-seasonal and inter-seasonal weather aberrations, poor soil resource base and poor crop management leading to large yields gaps. Hence, the challenge would be to enhance productivity levels of the rainfed crops/cropping systems, rainfed agri-hortisystems integrated with optimal use of natural resources. The various strategies for enhancing the productivity of rainfed crops are presented in this chapter.

Efficient Crops and Varieties

Sowing of right variety of right crops at right time under right land use conditions makes a significant difference towards attaining higher yields. The choice of crops and varieties is more relevant under highly complex rainfed production systems and areas frequented with weather vagaries. The choice of the crops and variety for an agro-ecosystem could further be narrowed down by matching crop requirements with prevailing location specific climatic and soil information. The analysis of long-term climatic data on onset and withdrawal of monsoon, intermittent dry spells and effective cropping period etc. serve as a good guide to select crops and varieties. While, intrinsic soil properties *viz.*, soil depth, texture, slope and available water holding capacity etc. reflects capability of a soil to mitigate the impact of weather events, and thus are of great use for macro and micro-level crop planning (Velayutham, 1999). Further, few agro-ecosystems frequently experience extreme of moisture (drought or floods), temperature (heat or cold) and wind (cyclone or hail storms). Farming under such situations is highly uncertain and challenging. These events have usually very short life, but long-lasting impact on standing crop and many times results into complete failure of crops. These ecosystems require highly elastic crop and varieties which could give higher yields under normal conditions and also withstand the natural calamities effectively. Understanding their special needs of such agro-ecosystems, a number of crop varieties has been developed and evaluated for their suitability at different parts of the country.

In rainfed production systems, generally, the crop should be of short duration with early vigour, deep root system with ramified roots, dwarf plants with erect leaves and stem, moderate tillering in case of tillering crops and varieties, resistance/tolerance to biotic stresses, lesser period between flowering and maturity so that the grain filling is least affected by adverse weather, resistance/tolerance to abiotic stresses, low rate of transpiration, less sensitive to photo-period and wider adaptability. Thus, under changing climate conditions, introduction of high yielding, drought resistant/tolerant varieties hold the promise for getting higher yields.

As a general rule, rainfed crops are sown early with the onset of monsoon to realize higher yields. And any delay in monsoon beyond normal period affects sowing of many crops of longer duration or narrow sowing window. The crops with wider sowing windows can still be taken up till the cut-off date without major yield loss and only the change warranted could be the choice of short duration cultivars. Beyond the sowing window, choice of alternate crops or cultivars depends on the farming situation, soil, rainfall and cropping pattern in the location and extent of delay in the onset of monsoon. For example, pulses and oilseeds are preferred over cereals with respect to water requirement and for delayed *kharif* sowing. Clusterbean, mothbean and horsegram are better choice for low rainfall areas as compared to other *kharif* season pulses. For cultivation on conserved soil moisture during *rabi* season, chickpea and lentil are preferred over peas and french bean. Similarly among oilseeds, groundnut, castor sesame and niger perform well under rainfed conditions during *kharif* season. In the rapeseed-mustard group, taramira is the best choice for light textured soil with low moisture storage capacity, followed by Indian mustard. Among the *kharif* cereals, coarse cereals (millets, ragi and sorghum) are better choice over maize and rice. Similarly in *rabi* season, barley does well under conserved soil moisture than wheat. Among the millets, setaria is most suited for late sown condition without any serious effect on productivity. The resilient crops and varieties to cope with delayed monsoon in various rainfall and soil zones are given in Table 2.

Table 2. Suitable varieties of rained crops under delayed onset of monsoon

Location/ MCSR (mm)	Crop	Suggested contingency crops and cultivars		
		Delay by 2 weeks	**Delay by 4 weeks**	**Delay by 6 weeks**
Anantapur (Alfisols)/ 352 (*kharif*), 144 (*rabi*)	Groundnut	-	Kadiri- 9, Prasuna, Narayani	Kadiri- 9, Prasuna, Narayani
	Pigeonpea	Palnadu, LRG-41, LRG-30, Lakshmi, PRG-158	Palnadu, LRG-41, LRG-30, Lakshmi, PRG-158	ICTP 8203, ICMV-221, ICMH-451
	Sorghum	PSV-15, 19	CSH-9, 14, CSV-12	CSH-9, 12, 13, 14, CSV-12, NTJ-1, 3
	Castor	Kranthi, Jyothi, GCH-4, 6	Kranthi, Jyothi, GCH-4, 6	Kranthi, Jyothi, GCH-4, 6
	Cotton	Narsimha, MCU-5, LRA-5166, NHH-44, NDLHH-240	Narsimha, MCU-5, LRA-5166, NHH-44, NDLHH-240	Narsimha, MCU-5, LRA-5166
Bangaluru (Alfisols)/ 517 (*kharif*), 241(*rabi*)	Fingermillet	MR-1, 6, L-5	MR-1, 6, L-5, HR-911	Fingermillet: GPU-28 Little millet: CO-2, PRC-3 Foxtail millet: RS-118, K-221-1
	Maize	Deccan-103, NAC-6004, Ganga-11	NAC-6002, 6004	DHM- 2, Ganga-11, Deccan-103
	Groundnut	JL-24, K-134, GPBD-4, K-134	TMV-2, JL-24	JL-24, K-134

	Pigeonpea	BRG-2	BRG-2	K-134, VRA-2
	Cowpea	TVX-944-2E	KBC-1, 2 TVX-944, IT-38956-1	-
Bijapur (Vertisols)/ 388 (*kharif*), 134 (*rabi*)	Pigeonpea	GS-1, BJ-221, Maruthi, Asha, TS-3, ICPC-87	GS-1, BJ-221, Maruthi, Asha, TS-3, ICPC-87	Durga, GC-11,39, WRG-1, Maruthi, TS-3 R, ICPC-87
	Sunflower	KBSH-1, 44, DSH-1, RSFH-1, MSFH-17, SH-41	KBSH-1, 44, DSH-1, RSFH-1, MSFH-17, SH-41	KBSH-1, 44, DSH-1, RSFH-1, MSFH-17, SH-41
Akola (Vertisols)/ 688 (*kharif*), 82.3 (*rabi*)	Soybean	Samrudhi, JS-335, JS-93-05	JS-335, JS-93-05	-
	Pigeonpea	BDN 708, AKT-8811	AKT-8811, Vipula, PKV-Tara, BSMR-736	AKT-8811, Vipula, PKV-Tara, BSMR-736
	Sorghum	CSH – 9, 14	CSH-9, 11, 14, 16, PVK-401, 809	CSH-9, 11, 14, 16, PVK-401, 809
Parbhani (Vertisols)/ 688 (*kharif*), 82.3 (*rabi*)	Pigeonpea	Vaisali	BSMR-736 853, BDN-708, 711	BSMR-736, 853, BDN-708, 711

MCSR: Mean crop seasonal rainfall; *Source:* Annual Reports - AICRPDA-NICRA 2011 to 2015

In addition, the sustainability of few varieties was also tested under various rainfed ecosystems for wider adoption (Table 3).

Table 3. Performance of improved varieties of rainfed crops with high sustainability

AICRPDA Centre	Crop	Variety/ Hybrid	SYI	Agro-climatic zone/ climate /soil type
Arjia	Maize	PEHM-2	0.41	Southern zone of Rajasthan (Semiarid Vertic Inceptisols)
Bangalore	Fingermillet	MR-1	0.77	Southern dry zone of Karnataka (Semi arid Alfisols)
Indore	Soybean	NRCS 37	0.50	Malwa Plateau zone of Madhya Pradesh (Semiarid Vertisols/Vertic Intergrades)
Phulbani	Rice	Vandana	0.79	Easternghat zone of Odisha (Subhumid Oxisols)
Anantapur	Groundnut	Narayani	0.49	Scarcity zone of Andhra Pradesh (Arid to semiarid Alfisols/Aridisols)
Akola	Soybean	JS335	0.55	Western Vidarbha zone of Maharashtra (Semiarid Vertisols)

Source: AICRPDA Annual Reports; SYI- Sustainable yield index

Efficient Cropping Systems

The true concept of cropping system gained momentum during sixties for bring self sufficiency in food through enhanced cropping intensity besides breaking technology and policy barriers. And the advent of high yielding, photo-insensitive, input responsive varieties of rice and wheat totally revolutionized the Indian agriculture in less than a decade and brought paradigm shift in farming with respect to tillage, planting time and method, fertilizer use, irrigation, pest control and harvesting. This resulted in major shift towards cereal based cropping systems by relegating less productive, risk prone legumes and oilseeds to marginal lands especially in irrigated ecosystems. Although, the transformation brought self-sufficiency in food, but caused many second generation farming problems. This necessitated designing alternate cropping systems by considering potential and specific needs of different regions under changing socio-economic and climatic situations. AICRP for Dryland Agriculture (AICRPDA) network centres located across rained agroecologies developed location specific doable cropping systems with higher productivity.

However, many of the conventional cultivation practices and strategies may no longer be relevant under changing climate scenarios. This necessitated need of technologies responding to climate change effects and giving more resilience against such shocks. Under changing climate scenario, many conventional practices and cropping systems are becoming redundant and ineffective, and thus need revalidation and modification in accordance to changing climate and soil-site conditions, This also calls for critical examination of important modifies of cropping systems *viz.*, soil type, rainfall pattern, length of growing season, temperature regimes etc. so that available farm resources are effectively used. Accordingly, identified potential rainfed cropping systems for varying range of rainfalls, soils and agricultural drought situations (CRIDA, 1997) (Table 4).

Table 4. Potential cropping systems based on rainfall and soil types

Mean annual rainfall (mm)	Major soil order	Growing season (weeks)	Suitable cropping system
350-650	Alfisols, shallow Vertisols, Aridisols and Entisols	15	Single rainy season
350-650	Deep Aridisols and Inceptisols	20	Either rainy or post-rainy season crop
350-650	Deep Vertisols	20	Post-rainy season crop
650-800	Alfisols, Vertisols, Inceptisols	20-30	Intercropping
800-1100	Deep Vertisols, Alfisols and Entisols	30	Double cropping
>1100	Deep Alfisols, Oxisols etc	30+	Double cropping

Source: Modified from CRIDA (1997)

Intercropping Systems

Mixed cropping is a widespread traditional practice in rainfed agriculture to distribute the risk of uncertainties among different crops, but the practice is hardly productive. Therefore, mixed cropping was gradually advanced to scientific and rational intercropping systems where two crops of different durations are planted in definite row ratios to minimize the risk and simultaneously enhance the productivity and resource use efficiency. A good intercropping system gives optimum productivity and higher LER in normal/good seasons, while brings reasonable yield for either of the crop in poor seasons as an insurance against weather aberrations (Ravindra Chary *et al*., 2012). Generally, these advantages are more pronounced in stress environments. In addition, it helps to spread labour peaks, maintain soil fertility (with inclusion of legume) and stability in production. It embodies the protective cover of mixed cropping and at the same time increases production. Furthermore, greater efficiency of resource utilization is expected from intercropping in a wide range of environments. In general, intercropping with additive series was found better than replacement series under most of drought situations (AICRPDA, 2003). The mean LER of additive series was 23% higher than replacement series in 54 out of 59 experiments taking sorghum, maize, pearl millet, pigeon pea, safflower and wheat as base crop. However, intercropping systems were more favourable in *kharif* than *rabi* season in Indian rainfed regions probably due to replenishment of soil moisture during *Kharif* season (AICRPDA, 2003). Agroclimatic-zone wise and soil zone wise efficient intercropping systems in major rained production systems are given in Table 5.

Table 5. Agroclimatic zone and soil zone-wise efficient intercropping systems

Soil zone/ Agroclimatic zone/State	Intercropping system
a. Vertisols and Vertic Inceptisols	
Malwa plateau, Madhya Pradesh	Soybean + pigeon pea (4:2)
	Sorghum + pigeon pea (2:2)
Western Vidharbha, Maharashtra	Cotton + greengram (1:1)
Southern Rajasthan	Maize + blackgram (2:2)
	Groundnut + sesame (6:2)
Northern Dry zone, Karnataka	Pearl millet + castorbean (3:1)
	Pearl millet + pigeonpea (4:2)
Northern Saurashtra, Gujarat	Groundnut + castorbean (3:1)
	Groundnut + pigeonpea (3:1)
Southern Tamil Nadu	Cotton + blackgram/greengram (2:1)
b. Inceptisols and related soil zone	
Western plateau, Jharkhand	Pigeon pea + rice (2:3)
	Maize + cowpea (2:2)
Alfisols/ Oxisols zone	
Eastern Ghat zone, Odisha	Maize + pigeon pea (2:2)
	Fingermillet + pigeon pea (4:2)
Alfisols zone	
Southern dry zone, Karnataka	Groundnut + pigeon pea (8:2)
	Fingermillet + pigeon pea (10:2)
Southern zone, Telangana	Sorghum + pigeon pea (2:1)
Scarcity zone, Andhra Pradesh	Groundnut + pigeon pea (7:1)
Aridisols zone	
Northern zone, Gujarat	Castor bean + cowpea (1:2)
	Pearl millet + cluster (2:1)

Source: AICRPDA (2003).

Double Cropping Systems

Traditionally, double cropping including relay cropping is practiced in rainfed regions with sufficient rains (usually >750 mm) and good soil moisture holding capacity (>150mm). However, some more areas could bring under double cropping through use of available dryland technologies *viz.*, rainwater management, choices of crops, short duration varieties and agronomic practices. Out of the two crops, one could be short durations (usually legumes) and another, medium duration (usually cereals) for optimum use of available growing season. For example, a second crop could successfully grown in high rainfall regions of Odisha, Eastern Uttar Pradesh and Madhya Pradesh by replacing medium to long duration (>120 days) rice variety with short duration (<100 days) rice variety; while another crop of chickpea or safflower could be taken in Malwa (MP) and Vidarbha (Maharashtra) regions by substituting sorghum variety of 140-150 days with 90-100 days cultivars. Similarly, relaying a short duration and fast growing crop in standing principle crop provide good opportunity for efficient use of growing period. For example, relay cropping of castor/bean in 40-45 days old greengram crop is practices in about 35000 ha areas of North Gujarat. Castor/bean is either named dibbled sown between two rows of greengram using animal drawn seed drill (Venkateswarlu *et al*., 2009). Some efficient double cropping systems are suggested in Table 6.

Table 6. Efficient double cropping systems

Agroclimatic zone/state	Moisture availability period (days)	Double cropping system
Malwa plateau, Madhya Pradesh)	210-230	Soybean-wheat/wheat, Maize-chickpea/safflower
	190-210	Sorghum – safflower/chickpea, Soybean-safflower
Baghealkhand, Madhya Pradesh)	210-230	Rice-chickpea/lentil
	190-210	Sorghum-chickpea, Blackgram/greengram-wheat Groundnut-chickpea
Bundelkhand, Uttar Pradesh)	190-220	Sorghum-chickpea, Blackgram- mustard/safflower, Fodder cowpea- mustard
Vidarbha,Maharashtra	190-210	Groundnut-safflower, Sorghum-safflower
	170-190	Green gram-safflower
Southern Maharashtra	160-180	Greengram- sorghum/safflower
Southern Rajasthan	160-180	Greengram – safflower
Central Karnataka	130-150	Cowpea – sorghum, Greengram – safflower

Source: AICRPDA Annual Reports

Pulses in Rice Fallows

On an average, 30% of the area under rice production during *kharif* season in India remains fallow in the subsequent *rabi* due to number of biotic, abiotic and socio-economic constrains. A large area (11.6 m ha) of rice fallows under rainfed conditions can be brought under pulses provided available land and water resources (soil moisture, crop residue, water harvesting structures, etc) are scientifically and innovatively managed (Kumar *et al*., 2013a). Out of 10.5 m ha rice fallows of eastern (Uttar Pradesh, Bihar, West Bengal, Assam), Central (Chhattisgarh) and southern states (Andhra Pradesh, Karnataka, Tamil Nadu), 2.5 m ha can be utilized by expanding lentil, Greengram and blackgram cultivation (Ali and Gupta, 2012). Pulses are the ideal crops that can be grown in the areas vacated after rice, because of their property to establish with the surface seeding and suitability for relay/para cropping and resistance against soil moisture and temperature stress. Pulse crops suitable for rice fallow areas are lentil, lathyrus, urdbean, mungbean and chickpea.

Cropping Systems Management

Crop planning as per climate-soil-site suitability

Agriculture is mainly a land based activity, and thus requires better land resource management for higher productivity and conservation of resources. Efficient resource management has become more relevant in recent time to address the twin problems of unabated land degradation and impact of changing climate on land productivity. Further, the natural resources have profound influence on cropping pattern and crop productivity. Since each plant species need specific soil-site conditions for its optimum growth. As a result, soil-site based land use planning has capacity to double the yield under many rainfed conditions. Therefore, soil-site suitability for crops needs to be determined to grow most suitable crop(s) in each land use types. Plant requires a reasonable moisture and nutrient supply, linked to a sufficient rooting depth and a good energy regime for photosynthesis and biomass production. And the adaptability of crops in an area is the interaction between existing edaphic conditions and fitness of the cultivar under those conditions. Further, the productivity and profitability of agriculture are largely determined by field preparation and harvesting conditions, while workability and traffic ability factors may also have to be considered for some land utilization types.

Planting Techniques

Traditionally, pulses are sown on flat seedbeds under rainfed conditions. In eastern Uttar Pradesh, Bihar, West Bengal, Odisha and part of central India, pigeonpea crop often suffers due to water stagnation during rainy season which ultimately reduces productivity. With promotion of paddy cultivation, compartmental bunding also increased, which led to poor drainage and thus a challenge to successful cultivation of *kharif* pulses in these areas (Ali *et al*., 2012). Raised land configurations such as broadbed and furrow (BBF), broad furrow and ridge (BFR), raised and sunken beds etc help in efficient conservation of rainwater in Vertisols thereby enhance the productivity of pulses. Ridge planting of pigeonpea was conceptualized and evaluated under AICPIP/ AICRP on pigeonpea which showed very encouraging results in maintenance of optimal plant populations and consequently higher productivity due to proper drainage. Ridges are made at 60-75 cm distance leaving 30 cm wide furrows for drainage of rain water. Two to three rows of short-duration legumes such as mungbean/urdbean can be successfully planted on ridges.This system helps in reducing quantity of irrigation water, and also minimizes incidence of Phytophthora blight in pigeonpea. Raised bed system of planting has similar beneficial effect (Ali *et al*., 1998). Ridge planting of pigeonpea, and raised-bed planting of *kharif* and *rabi* pulses have proved to be important techniques for raising productivity (Ali and Gupta, 2012). Enhancement in *kharif* pulses yield up to 33% and 25% saving of costly inputs (seed and fertilizers) was recorded under raised bed planting system in comparison to flat seedbed (Kumar *et al*., 2012).

RCTs for *in Situ* Moisture Conservation

The RCTs for *in situ* conservation of rainwater and ensuring its uniform distribution within the field and throughout the crop growth period assume paramount importance in enhancing the productivity of rainfed pulses. These technologies include land levelling and bunding, tillage, conservation furrow, set furrow, broad bed and furrow system, mulching, compartmental bunding, inter plot rainwater management etc.

Tillage: Off-season tillage has been found to be useful in increasing rainwater infiltration and minimizing water evaporation by a 'mulching' effect. Deep ploughing plays an important role in stabilizing the productivity of rainfed pulses through *in situ* soil moisture conservation (Table 6; AICRPDA, 2003). Summer tillage with two-bottom mouldboard plough utilizing residual moisture or pre-monsoon showers is recommended to make the land ready for planting in eastern Uttar Pradesh. This practice helps in greater retention of rainwater (36% higher than conventional method) and enhances the yield of pigeonpea by 86% compared to farmers' practice (Venkateswarlu *et al.*, 2009). In another experiment at Arjia (Bhilwara district, Rajasthan), *in situ* moisture conservation system involving summer deep ploughing with raised bed of 40 cm width gave highest black gram yield (1243 kg/ha), rainwater use efficiency and lowest runoff and soil loss compared to farmers' practice of flat bed (AICRPDA, 2011b). It is evident from several experiments that the effects of deep tillage could last for 2 to 5 years depending upon the soil texture and rainfall. On Alfisols, the problem of crusting and sealing is encountered during early stages of crop growth resulting in uneven germination and plant stand. Under stress conditions, shallow tillage as an additional intercultivation has been found to be effective in breaking up the crust, improve infiltration, and reduce moisture losses through evaporation by creating dust mulch.

Compartmental bunding: It is the *in situ* moisture conservation practice in medium to deep vertisols in post-monsoon predominant cropping areas like northern Karnataka. Dividing the field into parcels of 4.5 x 4.5 m and 3 x 3 m on lands having slopes of 2% and 3% respectively is called compartmental bunding (Guled *et al.*, 2003). The seed yield of chickpea with compartmental bunding was 450 kg/ha with a yield advantage of 50% and additional net returns of Rs. 2850/ha compared to flat sowing.

Conservation furrows: Conservation furrows are the opening of furrows parallel to rainfed crop rows across the land slope, with a country plough, 3 to 4 weeks after the germination of the main crop (Venkateswarlu *et* *al*.,2008). Large scale demonstrations in 56 farmers' fields in Karnataka proved that finger millet + pigeonpea intercropping system (8:2) with staggered moisture conservation furrow gave higher net returns (Rs. 14198/ha) with a B:C ratio of 2.26 as compared to farmers' practice (Ramachandrappa *et al*., 2010).

Mulching: Mulching is useful for achieving higher rainfall infiltration, reduced soil erosion, structural stability and minimize soil moisture losses through evaporation. Different materials such as crop residues, green manure, sand, polyethylene and pebbles can be used as mulch. Soil water content under sand mulch at any point of time in a year could be 85-98% compared to no mulch.

Rainwater Harvesting and Its Efficient Utilization

It may not be possible to conserve all the rainwater *in situ*, in spite of adopting different soil and water conservation measures. The soil topographic features and climatic factors prevailing in most dryland areas are highly conducive to generation of runoff. This inevitable runoff may be collected in small and medium reservoirs that can be utilized for providing supplemental/ life saving irrigation to the crop at critical growth stages. Rainwater harvesting is a centuries old strategy, but relegated to background in many areas because of availability of modern irrigation technology (Singh, 1998). The traditional rainwater harvesting structures commonly found in different regions of India are *nadi, tanka* and *khadin* in Rajasthan, *bhandaras* in Maharashtra, *bandhis* in Madhya Pradesh and Uttar Pradesh, and *ahars* in Bihar. Several studies conducted in different parts of the country have revealed the benefits accruing from supplemental irrigation to pulses from stored rainwater during prolonged periods of dry spells. The results of supplemental irrigation in medium deep black soils at Bijapur indicated that seed yields with one life saving irrigation could be enhanced by 32.5% in chickpea and 92.4% in pigeonpea (Guled *et al.*, 2003). In another experiment at Solapur, one protective irrigation at flowering of chickpea enhanced the yield by 39.1% (Bangar *et al.*, 2003). Similarly, trials conducted at farmers' fields in Vidarbha region of Maharashtra showed that pigeonpea yield increased by 66% with one supplemental irrigation. In chickpea, the yield increased by 166% with two supplemental irrigations (Taley, 2012). At Rewa, one pre-sowing irrigation to chickpea gave about 50% higher yield than rainfed crop (AICRPDA, 2010).

Recycling of harvested water from the *Nadis* (small water harvesting structures) ensures double cropping (maize followed by chickpea) resulting in higher productivity of land and water. About 5.5 to 7.0 t/ha of chickpea green pods can be harvested with a net income of Rs. 25000 ha^{-1} (Venkateswarlu *et al*., 2009). The post-monsoon crops suffer from the progressive increase of stress due to receding soil moisture status. Under these conditions, supplemental irrigation helps in overcoming moisture stress and achieve better crop yields (Pramanik, 2009).

Foliar Nutrition

Mid- and terminal season drought/soil moisture stress is a common feature in rainfed in both rainy and winter season pulses. In pulses, reproductive stage (flowering to pod filling) is most critical for soil moisture stress. The limited movement of nutrients from soil to plant root and shoot restrict the photosynthetic activities in leaves and pod filling. Under this situation, foliar application of 2% urea or DAP twice at flowering and pod filling stage can increase the seed yield by up to 15% (Venkatesh and Basu, 2011; Ali *et al*., 2012; Singh *et al*., 2014). Similarly in rice-fallow pulses, foliar application of 2% DAP + 0.5% $ZnSO_4$ + 1% Fe twice (pre-flowering + flowering) had shown significant highest values of all yield attributes and yield in mungbean and urdbean (Ganapathy *et al*., 2008). Similar results were also obtained with foliar application of 0.2% borax and 0.1% NH_4-molybdate in chickpea (IIPR, 2009). At Babulgaon village (Parbhani district, Maharashtra), foliar spray of 19:19:19 (0.5%) in pigeonpea recorded higher seed yield (484 kg/ha) and net returns (Rs.16422/ha) compared to farmers' practice of no foliar spray (436 kg/ha) (AICRPDA-NICRA, 2016).

Real Time Contingency Planning

During 1972-73, large scale scarcity of rainfall was experienced all over the country, particularly in the scarcity region of Maharashtra, Karnataka and Andhra Pradesh. Roving seminars were organized by the ICAR at different locations, at the end of which *new phrases* were coined *viz. contingent crop planning and mid-season* *correction*. As a follow up, the AICRPDA centres at Solapur and Bijapur collected data on these two aspects and after analysis of weather data for the past 100 years, listed the weather aberrations: (*i*) delayed onset of monsoon, (*ii*) early withdrawal of monsoon (*iii*) intermittent dry spells of various durations, (*iv*) prolonged dry spells causing changes in the strategy and (*v*) prolonged monsoon (AICRPDA, 1983).Contingency plans, for each region, was a conceptual approach unique from AICRPDA project in developing location specific contingent crop strategies which were first published in 1977 (Ravindra Chary *et al.*, 2012) and with further refinements and updating in crops and varieties, the first document was brought out by AICRPDA in 1983 on "Contingent crop production strategy in rainfed areas under different weather condition". The AICRPDA network centers developed crop contingency plans for each centre's domain (Subba Reddy *et al.*, 2008; Ravindra Chary *et al*., 2012). Further, during 2009-10, AICRPDA centres prepared contingency measures considering weather aberrations, seasons, and the predominant *kharif* and *rabi* crops with appropriate crop management strategies. Central Research Institute for Dry land Agriculture (CRIDA)with information available at AICRPDA centres and SAUs, prepared district level agriculture contingency plans for more than 614 districts in collaboration with Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, GoI, ICAR institutes, State Agricultural and allied universities, Krishi Vigyan Kendras (KVKs), and the State line departments. These plans essentially suggest coping strategies/measures in agriculture, horticulture, livestock, fisheries and poultry sectors in the event of delayed onset of monsoon, seasonal drought, unseasonal rainfall events, floods, cyclones, hail storm, heat/cold wave (Venkateswarlu *et al*., 2011).

In view of the frequent weather aberrations impacting agricultural production round the year in some part of the country, the need was felt to implement contingency measures on real-time basis to minimize the losses in agriculture and allied sectors and to improve the efficiency of the production systems,. Thus, Real Time Contingency Planning is considered as "Any contingency measure, either technology related (land, soil, water, crop) or institutional and policy based, which is implemented based on real time weather pattern (including extreme events) in any crop growing season" (Srinivasarao *et al*., 2013).The real-time contingency measures aim to (*i*) to establish a crop with optimum plant population during the delayed onset of monsoon; (*ii*) to ensure better performance of crops during seasonal drought (early/mid and terminal drought) and extreme events, enhance performance, improve productivity and income; (*iii*) to minimize damage to horticultural crops/produce; (*iv*) to minimize physical damage to livestock, poultry and fisheries sector and ensure better performance) to ensure food security at village level and (*vi*) to enhance the adaptive capacity and livelihoods of the farmers. Some of the methods/measures to be adopted as real-time contingency plan implementation during various weather aberrations are presented in Table 7.

Table 7. RTCP measures for various climatic aberrations in arable crops

Climatic aberration	RTCP measures
Delayed Onset of monsoon Early season drought	• Beyond the sowing window, choice of alternate crops or cultivars depends on the farming situation, soil, rainfall and cropping pattern in the location and extent of delay in the onset of monsoon. • Re-sowing within a week to 10 days with subsequent rains for better plant stand when germination is less than 30%. • If the plant population is 50 to 75% of the optimum population (gaps in rows and also in between rows), sow the same crop of shorter duration variety in the gaps either within or in between rows. If less than 50% optimum population, sow suitable contingent crop as per the remaining effective growing season e.g. pearl millet in place of sorghum up to 1stweek of July. • Thinning in small-seeded crops. • Interculture to break soil crust and remove weeds and create soil mulch for conserving soil moisture.

	• Avoid top dressing of fertilizers till favourable soil moisture. • Opening conservation furrows at 10 to 15m intervals. • Ridge and furrow across the slope for effective moisture conservation as well in as
Mid-season drought	• If symptoms such as drying of leaves, wilting of plants and cracking in black soils are observed, blade harrowing in rows during dry spell in coarse cereals, oilseed and pulse crops helps in creating dust mulch and closing of cracks in black soils. After relief of dry spell, open conservation furrows at 1.2 m distance, spray with 2% urea, particularly in pulse crops, castor and sunflower. Apply additional 10 kg N/ha. • Plant protection. • Supplemental/protective irrigation, if available. • Repeated interculture to remove weeds and create soil mulch to conserve soil moisture. • Avoid top-dressing of fertilizers until receipt of rains. • Opening conservation furrows for moisture conservation, Foliar spray of 2% KNO3 or 2% urea solution or 1% water soluble fertilizers like 19-19-19, 20-20-20, 21-21-21. • Opening of alternate furrows. • Surface mulching with crop residues.
Terminal drought	• Providing life-saving or supplemental irrigation, if available. Harvesting crop at physiological maturity with some realizable yield or harvest for fodder. • Prepare for winter (rabi) sowing in double-cropped areas. • Ratoon maize or pearl millet or adopt relay crops as chickpea, safflower, rabi sorghum and sunflower with minimum tillage after soybean in medium to deep black soils in Maharashtra. • Prefer contingency crops (horsegram/cowpea) or dual-purpose forage crops on receipt of showers under receding soil moisture conditions.
Unseasonal heavy rainfall events	• Re-sowing. • Providing surface drainage. • Application of hormones/nutrient sprays to prevent flower drop or promote quick flowering/fruiting and plant-protection measures against pest/disease outbreaks with need based prophylactic/curative interventions. • At crop maturity stage, prevention of seed germination and harvesting of produce. • If untimely rains occur at vegetative stage, the contingency measures include: • Draining out the excess water as early as possible. • Application of 20 kg N + 10 kg K/acre (0.4 ha) after draining excess water. • Application of 50 kg urea+ 50 kg murate of potash /acre (0.4 ha) after draining excess water. • Gap filling either with available nursery or by splitting the tillers from the surviving hills in rice.

	• Weed control. • Suitable plant protection measures in anticipation of pest and disease out breaks. • Foliar spray with 1%KNO3 or water-soluble fertilizers like 19-19-19, 20-20-20, 21-21-21 at 1% to support nutrition. • Need-based fungicidal spray with Copper oxychloride 0.3% or Carbendazim 0.1% or Mancozeb 0.25% 2 to 3 times by rotating the chemicals. • Interculture at optimum soil-moisture condition to loosen and aerate the soil and to control weeds. • Earthing up the crop for anchorage etc.

AICRPDA-NICRA-Annual Reports:2013-14; 2014-215; 2015-16; *Source:* Srinivasa Rao *et al.*, 2016

Pulses as Contingency Crops for Delayed Onset of Monsoon

In rainfed areas, as a general rule early sowing of crops with the onset of monsoon is the best-bet practice that gives higher realizable yield. Major crops affected due to monsoon delays are those crops that have a narrow sowing window and therefore cannot be taken up if the delay is beyond this cut-off date. Beyond the sowing window, choice of alternate crops or cultivars depends on the farming situation, soil, rainfall and cropping pattern in the location and extent of delay in the onset of monsoon (Table 8; AICRPDA-NICRA, 2016).

Table 8. Pulse crops and varieties as contingency crops for delayed onset of monsoon

ACZ	Crop	Variety	Seed yield (kg/ha)	Yield advantage (%)	Net returns (Rs/ha)
Western plateau zone of Jharkhand	Pigeonpea	ICPH-2671	1527	87	41345
		Birsa Pigeonpea-1	1367	68	35745
	Horsegram	Madhu	1149	65	19672
		GHG-19	1100	58	18300
Bastar plateau zone of Chattisgarh	Pigeonpea	UPAS-120	1000	70	24000
Eastern ghat zone of Odisha	Pigeonpea	Laxmi	1000	25	16000
Southern zone of Rajasthan	Blackgram	T-9	1042	29	-
	Horsegram	AK-22	671	32	-
Eastern/Central/ Southern Dry zone of Karnataka	Rice bean	RBL-1	1385	21	17797
	Horsegram	PHG-1	1395	34	20863
	Field bean	HA-1	997	17	23548
	Cowpea	IT-38956	1293	63	38822
South-western semi-arid zone of Uttar Pradesh	Cluster bean	RGC-1003	492	7	6412
	Greengram	GM-4	510	19	18716
	Cluster bean	GG-2	355	27	12838
	Blackgram	GU-1	590	23	41701
Northern dry zone of Karnataka	Pigeonpea	TS-3R	2400	37	102300
	Mothbean	KBMB-1	475	19	31125
	Horsegram	GPM-6	350	27	16500
Scarcity zone of Maharashtra	Pigeonpea	Vipula	1060	39	27780

	Blackgram	TPU-1	700	26	20900
Malwa plateau of Madhya Pradesh	Pigeonpea	ICPH-2671	1268	9	52400
Keymore plateau and Satpura hill zone of Madhya Pradesh	Blackgram	LBG-20	900	29	32500
	Pigeonpea	Asha	1700	21	77500
Central Maharashtra plateau zone	Pigeonpea	BDN-711	638	35	23572
	Greengram	BM-4	532	9	12700

Productive Farming Systems

Productive farming systems are identified for drought prone regions based on rainfall; land capability and soil order (Vittal *et al.*, 2003). Land use based farmstead plan state-of-the-art based agroforestry models linked to livestock and watershed management for soil and water conservation including water harvesting. Some of the subjects are hedge fencing, multipurpose tree species, bush farming, cereals/millets. Pulse/oilseeds/ , parkland horticulture, olericulture, floriculture cum IPM, home remedies, water harvesting, livestock, poultry, fisheries, apiary, etc. are some of the models suggested (Fig 1). Diversification in to higher value agricultural crops (medicinal, aromatic, dye yielding crops, etc.), and non-farm activities like value addition to agricultural products offer good scope for sustained increase in per capita income. Part of the farmstead could also be used for generating seed spices. For the development of commons, these may be divided into small plots of 5-10 ha and can put on long lease of about 19 years to the user groups. The combination of systems such as fruit trees, silvipastures, multipurpose trees, or even pastures may be adopted on commons. Maximum number of trees per hectare may be limited by quantum of annual rainfall (product of rainfall in m and area in m^2) divided by volume of water one full grown tree transpires annually (a product of canopy area, surface area in m^2, and potential evapotranspiration in m per annum). Improved variety or new plant species suitable for the ecosystem and rejuvenation of social fencing of improved plant species may be attempted. In tree farming, the general cleanliness of the area is lost thus, encouraging new diseases and pests. Therefore, it is important to carry out weeding and form basins for the trees and furrows for *in-situ* rainwater harvesting in the case of shrubs, grasses and fodder legumes. Diversification strategies should be based on low external input strategies.

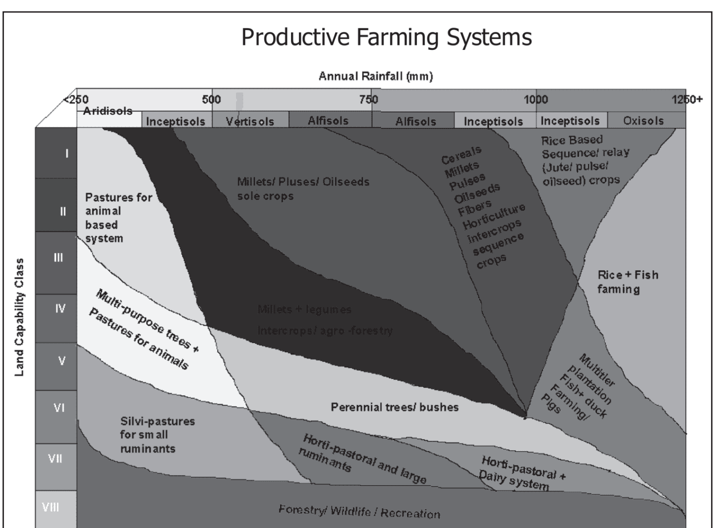

Fig. 1. Productive farming systems matrix in rainfed agriculture

Conclusion

There is a growing demand for food in the country besides changing food demand profile. Since rained areas contribute 40 % of country's food basket, there a need for enhancing the productivity of rained crops from this region. Besides this, the climate change risks and impacts on agriculture production and productivity are evident in rainfed araes. The focus thus would be on upscaling of doable cropping systems technologies and real-contingency measures in target domains. A well-planned complementary cropping systems and intercropping have great potential to reduce the risk and uncertainties in production through effectively exploiting differential performance of crops to moisture and temperature stresses, intermittent and terminal droughts in different agro-ecological settings. In addition, the sustenance of small and marginal land holdings will also depend on better integration and utilization of resources from unit piece of land. Similarly, double and relay cropping systems with suitable component crops/varieties with resource conservation technologies have greater scope for climate resilient agriculture. Further, breeding resilient crop varieties that fits in emerging cropping systems is very important for enhancing adaptation capabilities. Resilient varieties not only cope with multiple weather aberrations but also enhance crop productivity. Thus, it is essential to characterize agroecology/resource domain (climate and soil) of these varieties for wider adoption. However, all these efforts will have little significance if it is not supported with real-time strategies to handle farming emergencies emerging due to enhanced weather vagaries. The important issues include developing rainfed agroecology specific resilient cropping systems along with associated management practices; agroforestry based cropping systems, evaluation of crop varieties in cropping system mode and demonstration of proven systems in cluster approach for large scale adoption.

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10 Current Trends in Food Grains Production and Food Security

BMK Raju, CA Rama Rao, Josily Samuel, N Swapna and D Yella Reddy

Introduction

Agriculture is the source of livelihood for nearly two-thirds of population in India and contributes 14% of GDP. India's agricultural performance over years has been remarkable, as food grain production increased by more than four times after Independence. The growth of food grains production is ahead of population growth rate which is key to our national food security. During the decades after green revolution, not only has the dependence on imports of farm products, especially of food grains, declined, but also the exports have been increasing. India's capabilities for management of droughts and famines have also been laudable. The growth in agriculture contributed to the reduction in incidence of rural poverty (Parthasarathy, 1994). The present study intends to bring out the details in these lines and assess state-wise food security in India.

Trends in Food Grains Production in India

The production of food grains in India was about 60 million tons from about 100 million tons ha in 1950s. The productivity was as low as 500-600 kg/ha (Fig 1). The country was to import food grains to feed its population. Green revolution caused a jump of about 25% over the then existing production of 80 million tons with a productivity of 800-900 kg/ha in early 1970s. On the other hand population in India increased from 36 crore in 1951 to 55 crore in 1971. Area under food grain crops has become stabilised after 1970 at about 120-125 mil ha. But production increased from 100 million tons in 1970s to 250 mil ton in the present decade. Technology development, creation of irrigation potential and encouraging public policies may be attributed to this phenomenal growth. The country has transformed itself from a begging bowl image to one which occupies the first or second position in terms of production and area in several major crops and achieved self sufficiency in food grains production and maintains buffer stocks according to our population needs.

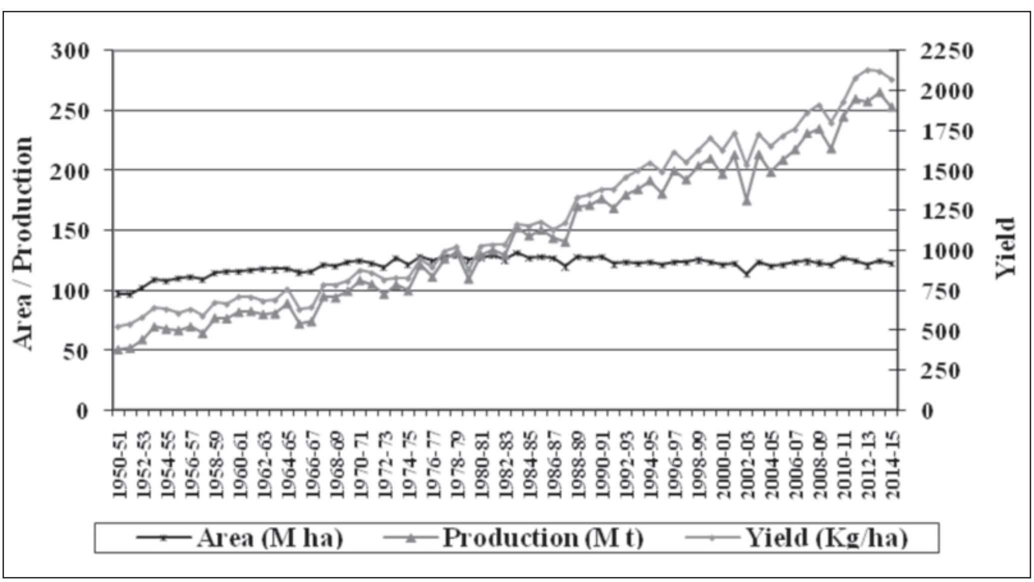

Fig. 1. Area, production and yield of food grains in India

Source of data: Dept. of Agriculture, cooperation & Farmers Welfare (DAC&FW), GoI

Food grains production in India is largely dependent on monsoon. However recent trends reveal some signs of resilience to rainfall variability in south-west monsoon (Fig 2). There is one to one correspondence between deviation in food grains production from mean during kharif season (June to September) and deviation in rainfall from mean during south-west monsoon from 2000-01 to 2007-08. The dependency of the production on rainfall is evidenced by the large correlation coefficient (0.9) between the two variates. The correlation between the two variates became weak (0.53) after 2008-09 which indicates the resilience of food grains production to south-west monsoon.

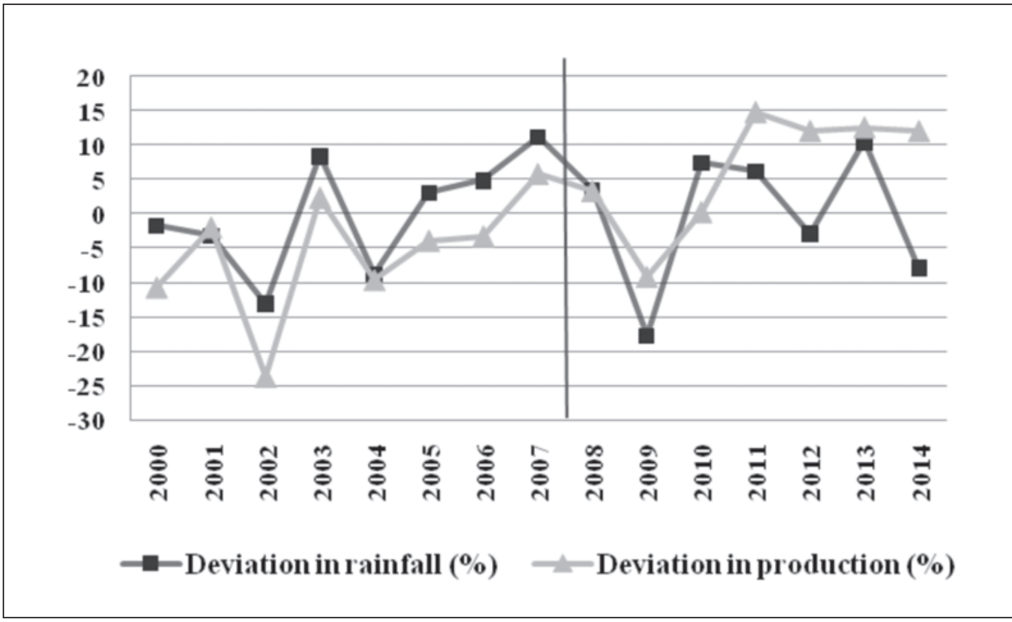

Fig 2. Rainfall (Jun-Sep) Vs Food grains production in *kharif* season in India

Source of data: Dept. of Agriculture, cooperation & Farmers Welfare (DAC&FW), GoI

Crop-wise Production Trends

Cereals and pulses together constitute food grains. The important cereal crops viz., rice, wheat, sorghum, peral millet and maize and major pulse crops viz., pigeon pea and chick pea are considered for providing trends in area sown, production and productivity from the beginning year of 21st centuary i.e. 2000-01 (Tables 1, 2 and 3).

Table 1. Area sown under major food grain crops (m ha) in India

Year	Rice	Wheat	Sorghum	Pearlmillet	Maize	Pigeonpea	Chickpea	Cereals	Pulses	Foodgrains
2000-01	45	26	10	10	7	4	5	101	20	121
2001-02	45	26	10	10	7	3	6	101	22	123
2002-03	41	25	9	8	7	3	6	93	21	114
2003-04	43	27	9	11	7	4	7	100	23	123
2004-05	42	26	9	9	7	4	7	97	23	120
2005-06	44	26	9	10	8	4	7	99	22	122
2006-07	44	28	8	10	8	4	7	101	23	124
2007-08	44	28	8	10	8	4	8	100	24	124
2008-09	46	28	8	9	8	3	8	101	22	123

2009-10	42	28	8	9	8	3	8	98	23	121
2010-11	43	29	7	10	9	4	9	100	26	127
2011-12	44	30	6	9	9	4	8	100	24	125
2012-13	43	30	6	9	9	4	9	98	23	121
2013-14	44	30	6	8	9	4	10	100	25	125
2014-15	44	31	5	7	9	4	8	101	23	122

Source of data: Dept. of Agriculture, cooperation & Farmers Welfare (DAC&FW), GoI

Table 2. Production of major food grain crops (m t) in India

Year	Rice	Wheat	Sorghum	Pearlmillet	Maize	Pigeonpea	Chickpea	Cereals	Pulses	Foodgrains
2000-01	85	70	8	7	12	2	4	186	11	197
2001-02	93	73	8	8	13	2	5	199	13	213
2002-03	72	66	7	5	11	2	4	164	11	175
2003-04	89	72	7	12	15	2	6	198	15	213
2004-05	83	69	7	8	14	2	5	185	13	198
2005-06	92	69	7	8	15	3	6	195	13	209
2006-07	93	76	7	8	15	2	6	203	14	217
2007-08	97	79	8	10	19	3	6	216	15	231
2008-09	99	81	7	9	20	2	7	220	15	234
2009-10	89	81	7	7	17	2	7	203	15	218
2010-11	96	87	7	10	22	3	8	226	18	244
2011-12	105	95	6	10	22	3	8	242	17	259
2012-13	105	94	5	7	22	3	9	239	18	257
2013-14	107	96	6	9	24	3	10	246	19	265
2014-15	105	89	5	9	24	3	7	235	17	253

Source of data: Dept. of Agriculture, cooperation & Farmers Welfare (DAC&FW), GoI

Table 3. Yield (kg/ha) of major food grain crops in India

Year	Rice	Wheat	Sorghum	Pearlmillet	Maize	Pigeonpea	Chickpea	Cereals	Pulses	Foodgrains
2000-01	1901	2708	764	688	1821	620	744	1844	544	1626
2001-02	2079	2763	771	869	2000	679	852	1980	607	1734
2002-03	1744	2610	754	610	1679	652	717	1753	543	1535
2003-04	2079	2713	716	1141	2041	668	811	1983	636	1727
2004-05	1984	2602	796	859	1907	668	815	1903	577	1652
2005-06	2102	2619	835	802	1938	765	808	1968	598	1715
2006-07	2131	2708	844	885	1914	649	845	2020	612	1756
2007-08	2202	2802	1022	1042	2335	826	763	2151	625	1860
2008-09	2178	2907	962	1015	2414	671	895	2183	659	1909
2009-10	2125	2839	860	731	2024	709	916	2075	630	1798
2010-11	2239	2988	949	1079	2542	654	894	2256	691	1930
2011-12	2393	3177	957	1171	2478	661	928	2415	699	2079
2012-13	2462	3117	850	835	2566	776	1036	2449	789	2129
2013-14	2416	3146	957	1184	2675	813	960	2462	764	2120
2014-15	2389	2872	953	1271	2556	749	875	2331	744	2070

Source of data: Dept. of Agriculture, cooperation & Farmers Welfare (DAC&FW), GoI

Area sown under food grains was more or less constant in last 15 years except for drought years 2002-03, 2009-10, 2012-13 and 2014-15 (Table 1). The loss in area as well as productivity in rice and wheat, which forms the bulk of food grains, in these years caused dips in production. However the overall trend in production of food grains was positive (Table 2 and 3).

Per Caipita Production of Food Grains

The growth in population of India from 1951 to 2011 is seen to follow exponential model (Fig 3). The growth in food grains production in the country was considered for comparison to growth in population in India. NIN (2011) gave a recommended dietary allowance (RDA) of 480 grms of food grains/day/person (400 g cereals and 80g pulses for moderately active person) which is equivalent to 175 kg/year. Therefore per capita food grains production in India was examined from 1951 to 2011 (Fig 4) with reference to the norm of 175 kg. It revealed that per capita food grains production was more than 175 kg in all (census reference) years except 1950-51. It indicates that the country became self reliant by producing the food grains required to feed the population from 1960s. Per capita production during 2010-11 was more than 200 kg, which would be sufficient to meet the RDA of the population even after accounting for demand of seed and wastage.

State-wise per capita food grains production in 2010-11 was also compared to the demand of 175 kg/year/person (Fig 5). The per capita production was found to be 1000kg and 657kg in Punjab and Haryana respectively, which are much above the norm of 175 kg. The per capita production was found to be less than 100 kg in Delhi, Kerala, Mizoram, Meghalaya, Jharkhand and Goa states and it was more than 100 kg but less than 175 kg in Bihar, Tamil Nadu, Jammu & Kashmir, Maharashtra, Gujarat, Assam, Odisha and West Bengal states. But it doesn't imply that these are food insecure states. A state that produces little grain, such as Kerala, is not for that reason food insecure. There is an all-India market for grain. Restrictions on the movement of food grain have been removed and grain can move freely from one part of the country to another. Consequently, the states of Kerala or Delhi do not have to be concerned with the extent of their own production of food grains (IHD, 2011). As long as the country's per capita production is not grim, these states can meet their requirement from the states like Punjab, Haryana etc. which are having surplus. But the question is do the people in these states have power to purchase the grains from states having surplus? Keeping this rationale in mind, the next section attempts to assess food security state-wise.

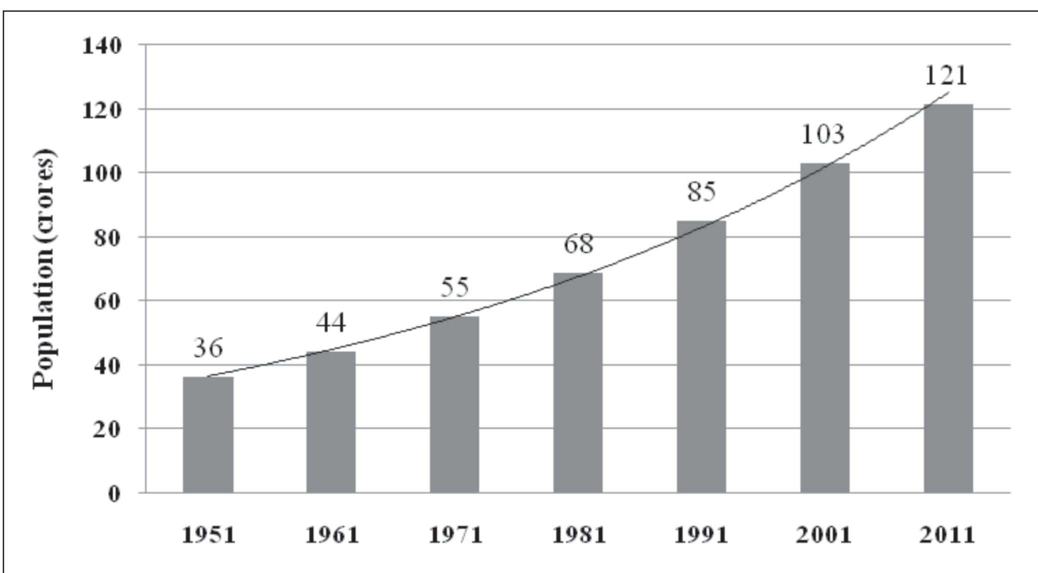

Fig. 3. Population in India

Source of data: Population Census of India

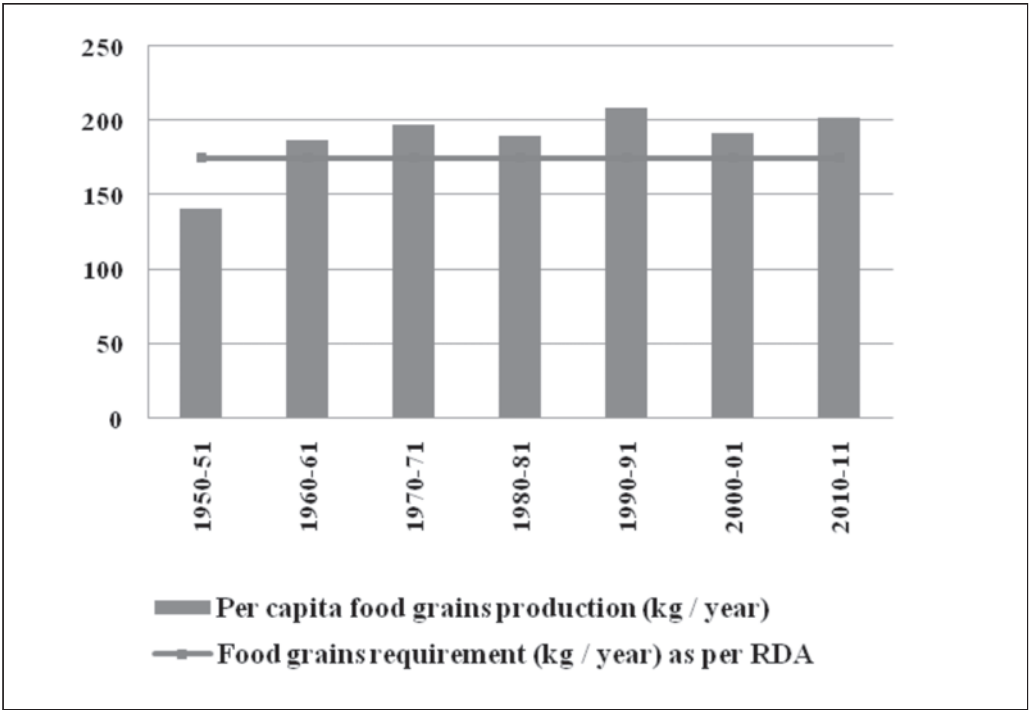

Fig. 4. Food grains production per capita in India 1951 to 2011

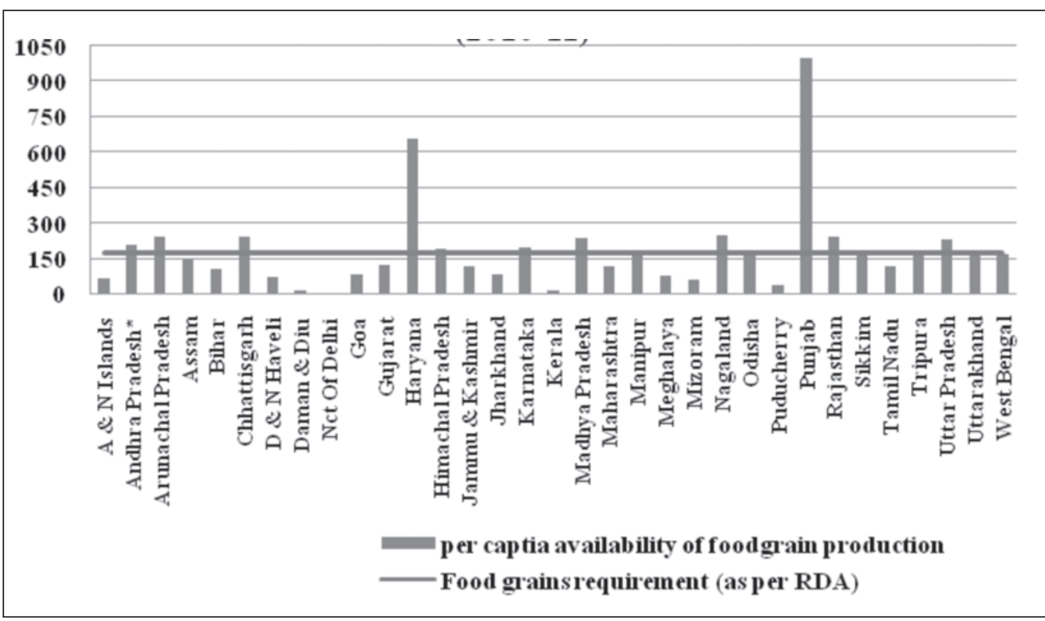

Fig. 5. Per capita food grains production (kg) in India (2010-11)

* includes Telangana, Source of data for Population: Population Census of India- 2011

Food Security

FAO (2002) defined food security as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

From this definition, four main dimensions of food security are identified:

Physical Availability Of Food: Food availability addresses the "supply side" of food security and is determined by the level of food production, stock levels and net trade. In the present study the dimension of availability is considered as fulfilled for all states in India on account of self sufficiency achieved at country level (as described in previous section).

Economic and physical ACCESS to food: An adequate supply of food at national level does not in itself guarantee household level food security. Due to lack of purchasing power (poverty) access to food may get restricted. The present study considered per cent population below poverty line (Planning Commission, 2013) to quantify the dimension of access of food security.

Food Utilization: Utilization is understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, food preparation and diversity of the diet. Combined with good biological utilization of food consumed, this determines the *nutritional status* of individuals. As suggested by FAO, WFP and IFAD (2012), the indicator - access to safe drinking water is considered to reflect the dimension.

Stability of the other three dimensions over time: Inadequate access to food on a periodic basis risking deterioration of nutritional status is considered food insecurity. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on food security status. As suggested by FAO, WFP and IFAD (2012), the indicator percentage arable land equipped with irrigation has been considered to reflect this dimension.

The state/UT is considered as unit of analysis in the present study. For food security objectives to be realized, all four dimensions must be fulfilled simultaneously. Therefore a composite index was built by assigning equal weightage to the above four dimensions and combining them linearly to quantify food insecurity at state level in India. The results of the same are as provided in Table 4.

Table 4. State-wise indicators used and food insecurity index

State/UT	Non-availability of food	% BPL Population	% Households using untreated drinking water	% Rainfed area to arable land	Food Insecurity Index
Andaman & Nicobar Islands	0	1	31	99	33
Andhra Pradesh	0	9	51	68	32
Arunachal Pradesh	0	35	74	87	49
Assam	0	32	91	95	54
Bihar	0	34	97	54	46
Chandigarh	0	22	6	39	17
Chhattisgarh	0	40	88	75	51
Dadra & Nagar Haveli	0	39	74	83	49
Daman and Diu	0	10	45	100	39
Delhi	0	10	25	58	23

Goa	0	5	18	79	26
Gujarat	0	17	60	67	36
Haryana	0	11	44	17	18
Himachal Pradesh	0	8	16	87	28
Jammu & Kashmir	0	10	65	70	36
Jharkhand	0	37	90	97	56
Karnataka	0	21	59	73	38
Kerala	0	7	77	82	41
Lakshwadeep	0	3	91	100	48
Madhya Pradesh	0	32	84	54	42
Maharashtra	0	17	44	85	36
Manipur	0	37	74	82	48
Meghalaya	0	12	72	94	44
Mizoram	0	20	61	97	44
Nagaland	0	19	94	88	50
Odisha	0	33	90	81	51
Puducherry	0	10	9	49	17
Punjab	0	8	59	4	18
Rajasthan	0	15	68	72	39
Sikkim	0	8	71	85	41
Tamil Nadu	0	11	44	64	30
Tripura	0	14	80	79	43
Uttar Pradesh	0	29	80	30	35
Uttarakhand	0	11	46	78	34
West Bengal	0	20	79	46	36

Source of data: BPL population from Planning commission, Drinking water data from Population Census of India-2011, Arable land and rainfed area from DAC&FW

The states namely Jharkhand, Assam, Odisha, Chhattisgarh and Nagaland were found to have very high food insecurity (more than 50) (Fig 6) due to poor facility of treated drinking water and larger share of rainfed area to arable land (as per the data in Table 4) which reflect poor utilization and instability respectively. On the other hand the state/UTs *viz.*, Chandigarh, Puducherry, Punjab, Haryana, Delhi, Goa, Himachal Pradesh and Tami Nadu were found to have very low food insecurity (less than 30) due to availability safe drinking water facilities and low percentage of population below poverty line.

Conclusion

The state/UTs having food insecurity more than 40 need to be accorded priority for improving the conditions. Governments in the states are already working on 'access to food' dimension through public distribution system and corrected the situation to a large extent. The state administration need to target the dimensions *viz*., utilization and stability, where most of these states are lagging behind, to further improve the conditions. More concentrated efforts towards creating irrigation potential brings in stability in food grains production and building infrastructure to provide safe drinking water and sanitation improves absorption/ utilization of food consumed.

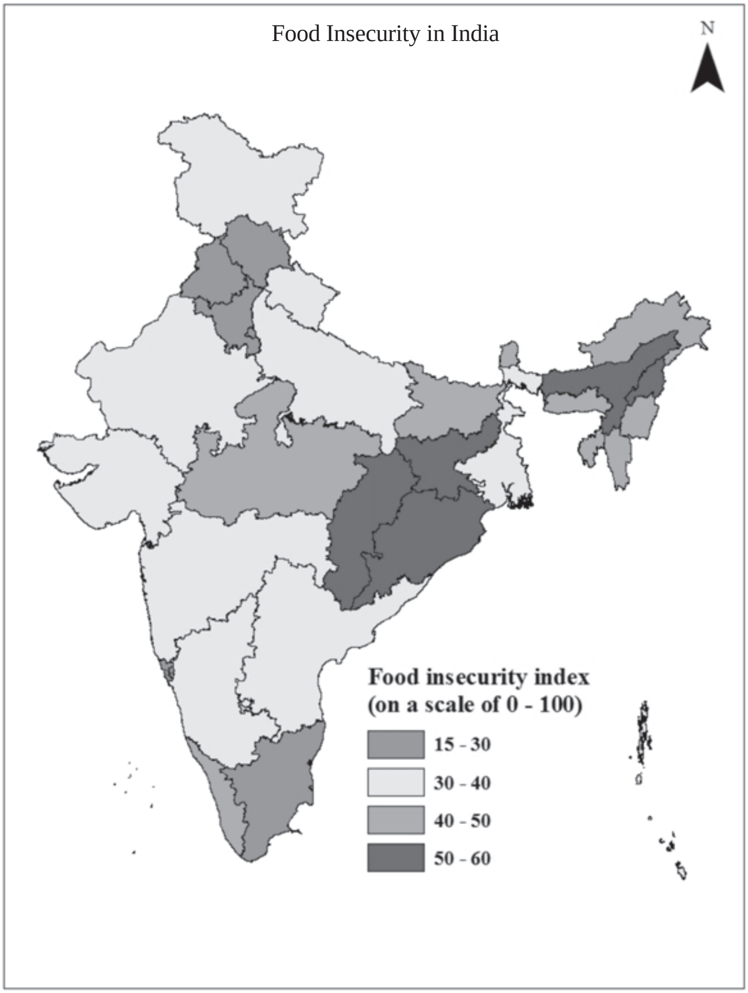

Fig. 6. Food Insecurity in India

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11 NICRA Experience for Food and Nutrition Security

M Prabhakar

Introduction

Climate change has become an important area of concern for India to ensure food and nutritional security for a growing population. To meet the challenges of sustaining domestic food production in the face of changing climate and generate information on adaptation and mitigation in agriculture to contribute to global fora like UNFCC, it is important to have concerted research on this important subject. With this background, ICAR launched a major project '*National Initiative on Climate Resilient Agriculture*' (NICRA) during XI Plan in February 2011 and now during XII Plan it is referred as '*National Innovations in Climate Resilient Agriculture*' (NICRA).

Objectives

The Major objective of NICRA is to enhance the resilience of Indian agriculture, covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies; to demonstrate the site specific technology packages on farmers' fields for adapting to current climate risks; and to enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application.

Components

During XII Plan, the scheme involves 4 major components, viz., Strategic Research (40 ICAR Institutes), Sponsored and Competitive Grants, Technology Demonstration (121 KVKs), Capacity Building and Knowledge Management.

Strategic Research

In the strategic research, both short term and long term research programs with a national perspective have been taken up involving adaptation and mitigation covering crops, horticulture, livestock, fisheries and poultry. The main thrust areas covered are (i) identifying most vulnerable districts/regions, (ii) evolving crop varieties and management practices for adaptation and mitigation, (iii) assessing climate change impacts on livestock, fisheries and poultry and identifying adaptation strategies. In XII Plan 19 institutes have been included in addition to the ongoing 21 research institutes.

Significant achievements of the project include extensive field phenotyping of germplasm of target crops (rice, wheat, maize, pigeonpea, tomato) to multiple abiotic stresses, preparation of first ever Vulnerability Atlas of India at district-level for all the 572 rural districts, Technology development for climate resilient horticulture including inter-specific grafting of tomato, NRM in adaptation – Biochar, CA, water foot prints and emission reduction through efficient energy management, quantification of carbon sequestration by agroforestry, quantification and techniques for measurement of GHG emissions in the rice-based system and marine ecosystem; quantification of carbon sequestration potential through agro-forestry systems across the country, Unique traits for thermal tolerance in livestock mapped, heat care mixture for poultry ready for commercialization, Relationship established between increase in SST and catch and spawning in major marine fish species. The theme areas viz., phenotyping/breeding programs in crops, horticulture and livestock, simulation modeling to understand the impacts at regional/national level, address crops and regions which could not be covered in the XI Plan such as onion, cotton, sugarcane and temperate horticulture etc. are being emphasized.

Technology Demonstration Component

Technology Demonstration Component (TDC) is being implemented in a farmer participatory mode in 121 vulnerable districts of the country through 121 Krishi Vigyan Kendras (KVKs) spread across the country in 28 States & one Union Territory. About 7 sites implemented by premier ICAR research institutes. TDC aims at demonstration of proven technologies to enhance the adaptive capacity and to enable farmers cope with current climatic variability. Location specific technologies which are developed by the national agricultural research system which can impart resilience against climatic vulnerability are being demonstrated. TDC is being implemented in 100 climatically vulnerable districts of the country through Krishi Vigyan Kendras (KVKs) spread across the country. During the XII Plan, 21 more districts are being added along with 25 AICRIPAM, 23 AICRIPDA villages. A representative village in each climatically vulnerable district was selected for implementation. The interventions are broadly divided in to four modules, natural resource management, crop production, livestock and fisheries and the creation of institutional structures for sustaining the activities envisaged and scaling up of interventions.

NRM interventions included site specific rainwater harvesting structures in drought affected areas; recycling of harvested water through supplemental irrigation to alleviate moisture stress during midseason dry spells; improved drainage in flood-prone areas; artificial groundwater recharge and water saving micro-irrigation methods. *In-situ* moisture conservation through ridge and furrow and raised bed planting in soybean, cotton, maize, pigeonpea, short duration pulses, vegetables, wheat, mustard, sugarcane, potato and vegetables resulted in higher benefit: cost ratios (2.6 to 4.7). Adoption of in-situ moisture conservation measures in crops was helpful to improve the soil moisture availability at the root zone (30-40 days) and eventually increased the productivity of crops by 15-20% in dry regions of the country in comparison to the traditional practices of farmers. Over 500 Rain Water Harvesting structures were constructed/renovated/repaired, while 80000 m^3 additional rainwater storage capacity was created through farm ponds alone and the cropping intensity was increased by about 20% in several NICRA villages.

Under the crop production module, demonstrations consists of drought and flood tolerant varieties, community nurseries for delayed monsoon, water saving paddy cultivation methods (SRI, aerobic, direct seeding), advancement of planting dates of *rabi* crops in areas with terminal heat stress, frost management in horticulture through fumigation, popularization of location-specific and risk-reducing intercropping systems with high sustainable yield index. Under the livestock & fishery module demonstrations on fodder production, especially under drought/flood situations, improved shelter for reducing heat stress in livestock, silage making methods for storage of green fodder and feeding during the dry season, breed selection and stocking ratios for fish production in farm ponds and monitoring of water quality in aquaculture and Integrated farming system models in diverse agro ecosystems are being taken up. Village level institutional mechanisms such as Village Level Climate Risk Management Committees (VCRMC), custom hiring centers are created for managing infrastructure created and to improve the timeliness of operations during the limited window periods of moisture availability in rainfed areas and to promote small farm mechanization for adoption of climate resilient practices. These interventions helped farmers to reduce the yield losses and enhanced their adaptive capacity against climatic variability.

Several Small Millets have been known for their tolerance to weather extremes, more so to moisture stress. Under NICRA several attempts have been made to make best use of millets to meet the future climate change in the country. Some of the examples are here under:

Stress Tolerant Bajra as an Alternate to Maize and Cotton in Drought Prone Ranga Reddy District of Telangana

Cotton, maize and sorghum are the major crops grown in the district under rainfed conditions. However, due to frequent droughts and erratic distribution of rainfall, farmers there are frequent crop failures resulting in severe financial loss to farmers in general, and in particular crops like maize and hybrid bt cotton are more vulnerable for water stress. During the past few years there is continuous water stress or drought in the district where in maize crop suffered total wilting and yield loss was almost 80%. Similarly jowar crop also suffered yield loss during the same period with 50% damage.

Bajra is best crop for drylands during water stress or drought situations. Krishi Vigyan Kendra, Ranga Reddy District, CRIDA, Hyderabad conducted field demonstrations of bajra crop with the hybrid PHB-3 released from RARS, Palem, Proffesor Jayashankar Telangana State Agriculture University. This hybrid is high yielding, downy mildew tolerant and stress tolerant. Demonstration was carried out at different locations over a period of two years. The hybrid performed better in all the locations during the water stress conditions prevailed in the *kharif* season. The average crop yield and net returns over a period of two year trials during *kharif* is given below (2013 and 2014).

Table 1. Performance of Bajra Hybrid hybrid PHB-3

No of trials	Area (ha)	Crop Yield (kg/ha)		Net Returns (Rs)	B:C
		Farmer's local variety	Bajra hybrid		
5	0.5	1,050	2,650	22,600	2.65

Table 2. Performance of other crops

Other crops	Yield (kg/ha)		B:C
	Normal	Actual	
Cotton	800-1000	350-450	1.14
Maize	1500-2000	300-400	Loss
Sorghum	1000-1200	200-250	Loss

The farmers harvest good crop yield compared to local variety and obtained highest net returns of Rs. 22,600 with benefit cost ratio of 2.65. During the period there was a total crop loss of maize and Jowar crops (50 to 80%) due to drought. The farmers benefitted with bajra crop, which was introduced as alternate crop to maize and jowar (Table 1 and Table 2).

Similar attempts have been made demonstrating feasibility of using several millet crops across several KVKs in the country under Technology Demonstration Component of NICRA. Millets in addition to grain yield also provide Stover which has potential use as fodder.

Millets Sprouts for mitigating heat stress in poultry: Experiments by DPR, Hyderabad proved that by using sprouts on millets like bajra, ragi and korra as feed supplement improved anti-oxidant activity in broilers thereby improving their ability to withstand heat stress.

Identification of climate resilient pearl millet genotypes: ICAR – Central Arid Zone Research Institute at Jodhpur identified genotypes and hybrids (CZP2K-9, CZH226 & CZH227) that can withstand extreme temperatures and severe drought. These lines have been used in breeding programmes for developing new varieties/hybrids of bajra that can withstand extreme weather conditions.

Use of bajra Stover for silage making: Studies at ICAR-Central Sheep and Wool Research Institute, Avikanagar showed bajra mixed with jungle cholai (50:50) improved palatability in sheep as evidenced from higher body weight. Silage making technology is one of the important climate resilient technology being implemented across several KVKs under Technology Demonstration Component of NICRA.

Isolation of drought tolerant gene from finger millet: ICAR – National Research Centre for Plant Biotechnology at New Delhi has successfully isolated and characterized the heat stress responsive genes for from finger millet, gene constructs were developed and ready for transformation into wheat. This will enable to develop thermo tolerant transgenic wheat.

Conclusion

Climate change is an eminent phenomenon and the preparedness to face the consequences takes many years of concerted efforts. A good beginning has been made through NICRA Project. However it is important to sustain these efforts in the years to come. A huge infrastructure created at several research institutes need to be put to use. Therefore, continued emphasis is needed for enhancing the resilience of Indian agriculture to climate variability and change. In this endeavour, millets play an important role in bringing nutritional security and sustainability under changing climate.

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12 Changing Climatic Conditions on Uptake and Utilization of Major Nutrients of Crop Plants

M Vanaja

Introduction

Climate change induced, with a consequence of increasing concentration of atmospheric greenhouse gases such as carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O) has very much altered the biogeochemical cycles of several elements. Of the several anthropogenic greenhouse gases, CO_2 is the most important agent of global warming because of its current contribution and projected increase in future as well as its long persistence in the atmosphere. The concentration of atmospheric CO_2 increased from about 280 ppm at the beginning of the nineteenth century to 367 ppm at the end of the twentieth century by human activities, and the concentration is estimated to reach 490 to 1,260 ppm by 2100. Increases in CO_2 concentration will likely have a profound impact on plant growth. Elevated atmospheric CO_2 increases the photosynthetic rate, stimulating increases in biomass, yield, water content and carbon-to-nitrogen ratio (C: N) in most C_3 plants.

The increasing anthropogenic atmospheric CO_2 concentration stimulates plant growth, which increases C storage on land. The studies have shown that elevated CO_2 increases net photosynthesis rate in C3 plants because higher CO_2 suppresses ribulose-1,5-bisphosphate oxygenase activity, decreases photorespiration, and increases carbon assimilates for plant growth and development and as a consequence, generally increase the biomass of C3 plants. It was demonstrated that cotton plants (*Gossypium hirsutum*) grown under 550 ppm CO_2 had a 35% higher biomass, 40% higher fruit weight, and 60% higher yield than plants grown under 350 ppm CO_2.

The extent to which elevated CO_2 increases plant growth, however, can be controlled or modified by available mineral elements in soil. Elevated CO_2 often increases carbohydrates in plants and might logically be expected to lead to a decrease in the mineral element concentrations in plant tissues. The nutrient dilution may preclude the positive effects of elevated CO_2 on plant growth. Consequently, the interaction between CO_2 and nutrient status in plants has significant implications to the responses of growth and yield of crop plants. In general, it was observed that plants grown under elevated CO_2 typically have reduced tissue concentrations of N, the changes of other mineral element concentrations under elevated CO_2 were much more complex. Using a meta-analysis method, it was suggested that mineral elements were clearly different in response to elevated CO_2. Some studies revealed that N and P concentrations in plants were not decreased by elevated CO_2 in subtropics, and instead P concentrations in plants positively responded to elevated CO_2.

Many studies on plant mineral elements in response to elevated CO_2 focused on leaves. However, different plant organs have different responses to elevated CO_2 and N application. The leaves are highly metabolically active, the strength of regulatory control over elements would be stronger in leaves than in roots. Many studies have reported that the responses of terrestrial plants to elevated CO_2 were species-specific, potentially driving a shift of the inter-specific competitive interactions and inducing species composition changes.

Carbon dioxide is just one of many inorganic substrates that are required by plants, and the long-term response of photosynthesis and growth to elevated CO_2 will depend, for two basic reasons, on the availability of mineral nutrients and the way in which they are utilized by the plant. Firstly, the higher rates of growth in elevated CO_2 will lead to an increased demand for mineral nutrients. This could be met by using nutrients more efficiently and/or by increasing the rate at which minerals are absorbed and assimilated by the plant. To understand the response of plant metabolism and growth to elevated CO_2 one need to consider how mineral nutrients are acquired and used in the plant. It can be expected that the response will vary, depending on the species involved, the level of nutrition the plant is receiving, and the mineral is a question. Secondly, the acceleration of growth and increase of biomass in elevated CO_2 may change the nutrient status in the plant. This is a very real possibility, unless the nutrient supply is super-optimal or is increased in parallel with the rate of plant growth.

The enhancement of plant growth by elevated CO_2 will also increase their demand for nutrients. For example, the study with growth response of Japanese red pine (*Pinus densiflora*) seedlings to phosphate (PO_4) revealed that it was saturated at 0.1 mM PO_4 in ambient CO_2 (350 ppm), whereas in the elevated CO_2 (700 ppm), the growth response to Pi supply did not saturate even at 0.2 mM PO_4 supply. Iron (Fe) is an essential micronutrient for plant growth and development. Although the total Fe content in soil regularly exceeds plant requirements, its bioavailability to plants is often limited, particularly in calcareous soils, which represent 30% of the earth's surface. Therefore, Fe nutrition in plants is likely to be affected by the continued elevation of atmospheric CO_2, which, in turn, will affect crop production. It was demonstrated that both ferric reductase activity and Fe uptake capacity of the marine alga *Chlorococcum littorale* cultured in Fe-limited medium were significantly enhanced by extremely high concentrations of CO_2. However, little is known about how elevated CO_2 influences Fe nutrition in higher plants, which undergo specific morphological and physiological changes in response to Fe deficiency and these changes were classified as strategy I and strategy II mechanisms. Strategy I occurs in non-graminaceous monocots and dicots, and strategy II occurs in graminaceous monocots. For strategy I plants, Fe deficiency enhances the activity of the plasmalemma NADPH-ferric chelate reductase increases acidification of the extracellular medium, and increases the sub apical development of root hairs.

Although the initial stimulation of net photosynthesis is sometimes retained during long-term exposure to elevated CO_2, it is often partially reversed or abolished in a process termed the 'acclimation' of photosynthesis to elevated CO_2. Acclimation is usually accompanied by alterations in the gas exchange characteristics that are indicative of a decreased carboxylation capacity and decrease of Rubisco activity or Rubisco protein in many species. Acclimation of photosynthesis to elevated CO_2 is usually more marked in nitrogen-limited plants than in well-fertilized plants. Analysis of the gas exchange characteristics indicates that the shift to a decreased carboxylation capacity in elevated CO_2 is more marked in nutrient limited than in well-fertilized plants and that elevated CO_2 leads to a larger decrease of Rubisco in nitrogen-limited plants than in well-fertilized plants. The decrease of Rubisco may reflect a general decrease of leaf protein, due to reallocation of nitrogen to younger leaves or earlier leaf senescence in nitrogen-limited plants. These processes may be accelerated in elevated CO_2, because the plants are larger and therefore experience a more acute nitrogen limitation.

The studies have also reported that the nitrogen use efficiency (the rate of growth per unit of nitrogen in the plant) increases in elevated CO_2. This increase of the nitrogen use efficiency is, in part, due to the lower nitrate content in elevated CO_2. However, the organic nitrogen use efficiency usually also increases in elevated CO_2. The decreased nitrogen concentration frequently observed in elevated CO_2 indicates that nitrate uptake and assimilation often fail to keep pace with photosynthesis and growth in elevated CO_2. The effect of elevated CO_2 on whole plant net nitrogen uptake is revealed more directly by comparing the change of the nitrogen concentration with the change of plant biomass. In some studies, the nitrogen content per plant still increased in elevated CO_2 even though tissue nitrogen concentration or the nitrogen/carbon ratio decreased.

Plants growing in elevated CO_2 possess larger root systems, at least in absolute terms, which should allow them to exploit a larger soil volume and might be expected to promote nitrate and ammonium uptake. However, the beneficial effect of an increased root volume might be counteracted by the effects of elevated CO_2 on water flow. Increased CO_2 usually leads to partial closure of stomata, resulting in lower transpirative water flow. This may be advantageous under water-limiting conditions because it leads to a higher water use efficiency, but it will decrease the mass flow of water in the soil to the roots and might therefore decrease the root surface concentrations of soil-mobile minerals, including nitrate. This is unlikely to lead to nitrate becoming limiting in well-fertilized soils, but could decrease access to nitrate when the soil nitrate solution is very dilute. Increased exudation of carbon and trapping of nitrogen in the soil microflora might also modify soil nitrogen availability, especially when overall concentration is low. To understand the mechanisms that govern the response to elevated CO_2, detailed analysis of nitrogen metabolism is required. As increased rates of plant growth in elevated CO_2 may lead to plants becoming nitrogen limited or exacerbate an existing nitrogen limitation, and some of the changes in metabolism and physiology in elevated CO_2 might be indirect effects, due to the plants becoming more nitrogen limited. It will therefore be important to analyze nitrogen metabolism in parallel with changes in photosynthesis, carbon metabolism and growth to identify conditions in which complicating effects due to changes in the nitrogen status are absent or minimized, and to distinguish between direct effects of elevated CO_2 and an increased supply of photosynthate, and indirect effects due to nitrogen limitation. A detailed analysis of nitrogen metabolism is needed to identify changes in specific pools in nitrogen metabolism which might be of significance for the regulation of metabolism, development and growth in elevated CO_2. This could include factors which increase nitrogen uptake and assimilation, or the allocation of nitrogen in the cell and the plant.

The dilution effect of the extra plant biomass produced by the aerial fertilization effect of atmospheric CO_2 enrichment may reduce the plant tissue concentrations of a number of micro-nutrients, many of which are important to human health and are currently present in common food plants in what are believed by some to be insufficient quantities. Hence, it was suggests that the increase in the air's CO_2 content that has occurred over the industrial era may have caused an elemental imbalance in some of earth's plants, contributing to the problem of micro-nutrient malnutrition and harming the health and economy of over half the world's population, which was describes as the problem of "hidden hunger."

The majority of conclusions were based on data obtained from plants grown under artificial growth conditions hence the extent of dilution was probably exaggerated in these studies and the potential for elevated CO_2 to exacerbate micro-nutrient deficiencies were overestimated. Hence, scientists analyzed the elemental concentrations of archived grain samples from temperate rice crops they had grown previously in a fertile agricultural field, where an approximate 200-ppm increase in the air's CO_2 concentration increased rice grain yields by about 14%. Of the five macro-nutrients they measured (N, P, K, Mg, S), only N showed a decrease in concentration with elevated CO_2 while all six of the micro-nutrients studied (Zn Mn, Fe, Cu, B, Mo) exhibited concentration increases. For Zn and Mn, in particular, there was a strong tendency to increase, while the same could also have been for Fe.

Conclusion

Hence, it may be concluded that as long as there is a readily available supply of nutrients and that the nutrient uptake capacity response to elevated CO_2 is equal or greater than the whole plant biomass response (except for N), then no dilution should be observed.

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13 Effect of Elevated Atmospheric CO_2 Concentration on Nutrient Quality of Food Crops

K Sreedevi Shankar and M Vanaja

Introduction

Carbon emissions related to human activities have been significantly contributing to the elevation of atmospheric CO_2 and temperature. More recently, carbon emissions have greatly accelerated, thus much stronger effects on crops are expected. The physiological responses of crops suggest that they will grow faster, with slight changes in development, such as flowering and fruiting, depending on the species. There is growing evidence suggesting that C3 crops are likely to produce more harvestable products and that both C3 and C4 crops are likely to use less water with rising atmospheric CO_2 in the absence of stressful conditions. Changes in food quality in a warmer, high CO_2 world are to be expected, e.g., decreased protein and mineral nutrient concentrations, as well as altered lipid composition. We point out that studies related to changes in crop yield and food quality as a consequence of global climatic changes should be priority areas for further studies, particularly because they will be increasingly associated with food security.

Elevated CO_2 Experiment in Open Top Chambers (OTCs)

The seeds of maize, black gram, pigeon pea and amaranthus were sown in open top chambers (OTCs) of 3 × 3 m diameter lined with transparent PVC (polyvinylchloride) sheet, which had 90% transmittance of light. The studies on were conducted at ICAR - Central Research Institute for Dryland Agriculture Hyderabad, Telangana.

Physicochemical and Cooking Characteristics of Legumes

100-seed weight (g): Average weight of two random samples of 100 seeds from each plot.

Hydration capacity (HC) (g water per seed): 50 seeds were transferred to 200 ml Erlenmeyer flask and 100 ml demineralized water was added. The flask was tightly stoppered and left overnight (16h) at room temperature. Next day the seeds were drained, superfluous water was removed with help of a paper towel and seeds were reweighed. HC = (weight after soaking – weight before soaking)/50.

Hydration index (HI): the ratio between HC and original weight (HC per seed/Original weight per seed [g])

Swelling capacity (SC) (ml per seed): After reweighing, the soaked seeds were transferred to 200 ml measuring cylinder and 100 ml water was added. SC = (volume after soaking-volume before soaking)/50.

Swelling index (SI): the ratio between SC and volume (SC per seed/volume per seed [ml]).

Cooking time (min): 25 seeds of each sample were soaked in 100 ml of demineralized water for 12 h. After 12 h, the samples were cooked in 100 ml water at 100°C. The temperature was maintained constant throughout, until the samples were cooked. Seeds were cooked until soft when pressed between the fingers to check for softness (Tripathi *et al*., 2013) .

Effect of Elevated Atmospheric CO_2 Concentration on Nutrient Quality of Maize Crop

The response of different phytochemical content to elevated carbondioxide concentrations in three different maize crop genotypes i.e., DHM 117, Harsha and Varun grown showed mixed results. Protein content (%) of Harsha genotype of maize was significantly higher compared to DHM 117 genotype at 550 ppm of elevated CO_2 concentration. Varun variety found to contain significantly higher protein content compared to Harsha variety at elevated CO_2 level (Fig 1).

DHM 117 genotype showed significantly higher 100 seed weight at 550 ppm elevated CO_2 compared to ambient concentration of CO_2. The 100 seed weight of Varun genotype was found to be significantly higher compared to DHM 117 at ambient levels and 550 ppm of CO_2 concentrations. Harsha genotype was found to contain significantly higher 100 seed weight grown at 550 ppm compared to ambient concentrations. The mean 100 seed weight of varun genotype was possessed to have significantly higher seed weight compared to Harsha grown under both ambient and 550 ppm levels CO_2 concentrations (Fig 2).

Total mineral content (g/100g) of DHM 117, Harsha and Varun genotypes grown at 550 ppm was significantly higher compared to 380 ppm levels of CO2 concentration (Fig 3). Zinc content (mg/100g) of DHM 117 recorded significant increase in DHM 117 genotype grown in chamber control compared enriched CO_2 levels of 550 ppm. DHM 117 and Varun genotypes found to contain highly significant zinc content compared to Harsha genotype grown at ambient conditions (Fig 4). The effect of elevated CO_2 on iron, copper, manganese, magnesium and crude fibre found to be non significant among the three maize genotypes (Sreedevi *et.al.,* 2014).

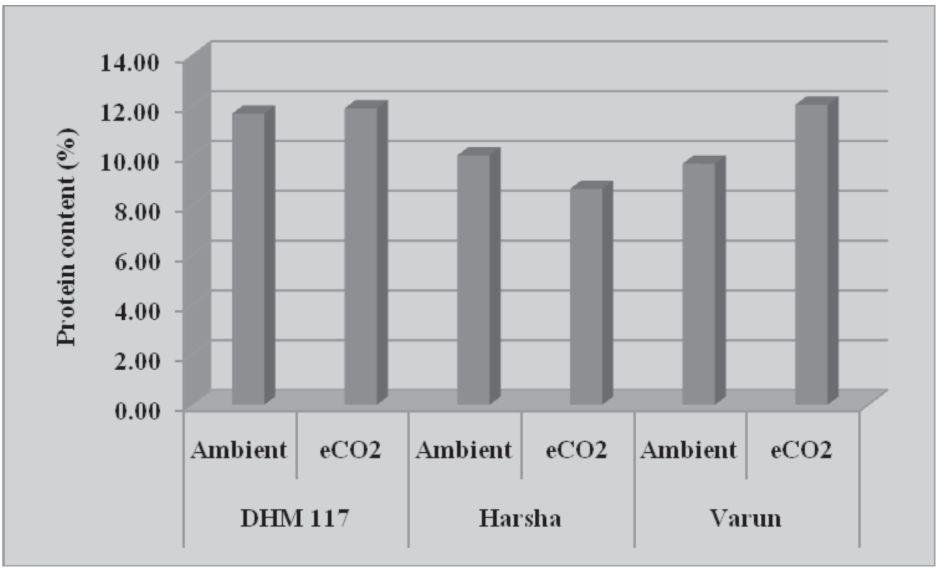

Fig. 1. Protein content (%) in different maize genotypes at elevated CO_2 concentration compared to ambient conditions

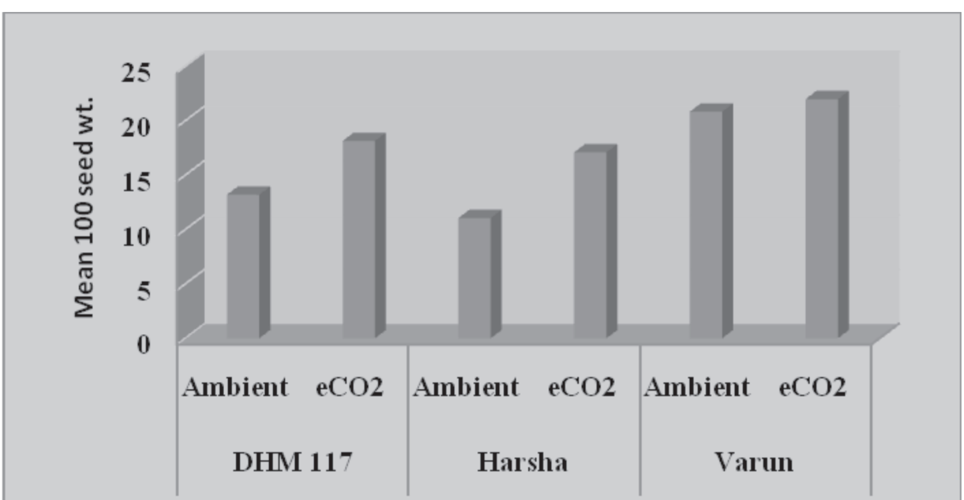

Fig. 2. Mean seed weight (g) in different maize genotypes at elevated CO_2 concentration compared to ambient conditions

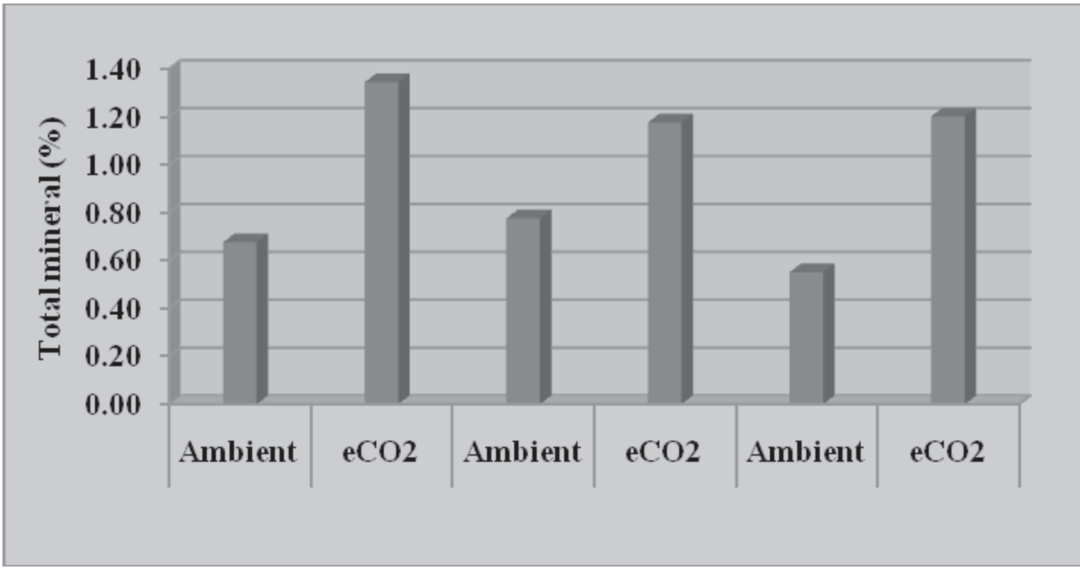

Fig. 3. Total mineral (%) in different maize genotypes at elevated CO_2 concentration compared to ambient conditions

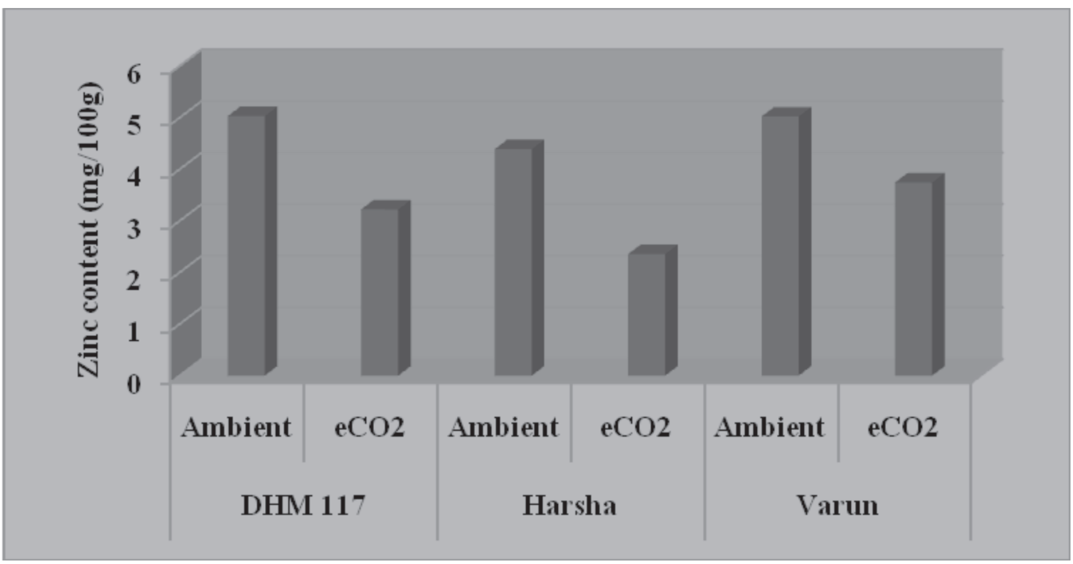

Fig. 4. Zinc content (%) in different maize genotypes at elevated CO_2 concentration compared to ambient conditions

Effect of Elevated Atmospheric CO_2 Concentration on Nutrient Quality of Amaranthus Crop

Green leafy vegetables are important sources of essential nutrients for human nutrition. Amaranthus with its dark green leaves, is one of the richest sources of minerals and Vitamin C content which is easily and abundantly available for consumption. A study on *Amaranthus tricolor* was conducted in Open Top Chambers (OTCs) using 550 ppm of elevated carbondioxide concentration and ambient conditions.

Amaranthus tricolor grown under elevated CO_2 concentrations was subjected to phytochemical quality analysis for different essential nutrient composition in edible amaranthus leaves. The calcium iron, zinc and magnesium content of amaranthus leaves was found to be significantly higher at 550 ppm of eCO_2compared to chamber control. Vitamin C (mg/100g) content of freshly harvested amaranthus leaves grown under elevated CO_2 conditions also showed significantly higher content at 550 ppm.

Effect of Elevated Atmospheric CO_2 Concentration on Nutrient Quality of Black Gram Crop

Blackgram (*Vigna mungo (L.) Hepper* is an important source of protein and is cultivated as short duration rain fed crop in semi arid areas of south asian countries. Field experiment was conducted in open top chambers (OTCs) at the elevated CO_2 levels (550 and 700 ppm) to compare the nutrient profile minerals *viz*; iron, zinc, copper, manganese, magnesium, total ash (mineral), crude fibre and protein of black gram seeds harvested at two levels on CO_2 and compare with the ambient (390ppm) chamber control treatments. The black gram seeds cv.T9, CN-9078 and KDRS-251 were sown in pots in three open top chambers (OTCs). Three pots for each variety were maintained per chamber. Recommended dose of fertilizer was used and standard agronomic practices were adopted. At maturity, pods were harvested and seed was used for estimation of quality parameters.

Desired CO_2 concentration of 390 ppm, 550 ppm & 700 ppm were maintained and monitored continuously throughout the experimental period as illustrated by Vanaja *et al*., (2006). Elevated CO_2 levels of 550 and 700 ppm were maintained in two OTCs throughout this study. The third OTC without any additional CO_2 supply served as a control chamber with 390ppm (ambient level).

Nitrogen content was estimated by micro-kjeldal method as described by (Dhyan Singh *et al.*, 2005), and crude protein was calculated (N X 6.25). Crude fiber content was determined by Fibertech method as described by Sadasivam and Manickam 2004. Nutrient profile minerals iron, zinc, copper, manganese, magnesium, total ash (mineral) was analyzed by Atomic Absorption Spectrophotometer. All analysis was carried out in triplicates and the results were calculated on dry weight basis. Analysis of variance was carried out as described by Snedecor and Cochran (1989).

Protein, Crude Fiber Content in Black Gram

Protein content was analysed in three genotypes of black gram. T9 variety showed a significantly increased protein content to elevated CO_2 levels and was observed that the response to enhanced CO_2 levels was higher at 700ppm (Table 1). Blackgram crop grown under elevated atmospheric CO_2 concentration would probably show positive impact on protein content, when as it is N fixing legume. The most influential factor in reducing grain nitrogen concentration was determined to be low soil nitrogen and under this conditions atmospheric CO_2 enrichment further reduced grain nitrogen and protein concentrations, although the change was much less than that consumed by low soil nitrogen. When soil nitrogen was not limiting however, increases in the air CO_2 concentration did not affect grain nitrogen and protein concentrations (Leimball *et al*., 2001). Literally thousands of studies have assessed the impact of elevated levels of atmospheric CO_2 on the quantity of biomass produced by agricultural crops, but only a tiny fraction of that number have looked at any aspect of food quality. From what has been learned about protein substances that have been investigated in this regard, however, there is no reason to believe that these other plant constituents would be present in any lower concentrations in a CO_2 enriched world of the future than they are currently. Indeed, there is ample evidence to suggest they may well be present in significantly greater concentrations, and certainly in greater absolute amounts. (Idso, *et al.*, 2003). The effects of atmospheric CO_2 enrichment reported on plant constituents of significance to human health by Idso and Idso (2001) cited a number of studies that indicated elevated levels of atmospheric CO_2 may at times increase, decrease or have no effect upon the protein contents of various foods.

Crude fibre content of black gram was analysed in three genotypes i.e., T9, CN-9078 and KDRS-251 under elevated CO_2 concentrations, where it was found to be increased in T9 and CN-9078 variety with increased CO_2 concentration i.e. 550 ppm and 700 ppm (Table 1). Increase in the crude fibre content and total ash is supported by Vanaja *et.al*., (2007) where the total biomass of black gram increased with increase in CO_2 concentration.

Table 1. Protein (%) and crude fiber content (%) of black gram crop grown under two elevated CO_2 concentrations

CO_2 levels	Protein (%)				Crude fiber (%)			
	390ppm	550 ppm	700 ppm	CD Value (0.05)	390ppm	550 ppm	700 ppm	CD Value (0.05)
T9	19.71	20.16	20.66	0.77*	4.99	5.44	5.57	0.196*
CN-9078	20.20	20.63	20.39	NS	4.75	4.99	5.44	0.52*
KDRS-251	20.20	20.21	19.53	NS	5.22	5.82	6.41	NS

*- Significant NS- Non significant

The response of manganese content had lower effect due to enriched CO_2 concentration from 550 to 700ppm and the trends was also repeated in the case of iron content, where a decreasing tendency was showed from chamber control to 550 ppm and 550 ppm to 700 ppm in the crop. The total ash content of black gram crop enriched with elevated CO_2 concentration was positive and significant at control and 550 ppm levels. The copper content of black gram under elevated CO_2 concentration followed a deceasing trend and found to be significantly lower in 550 ppm and 700 ppm compared to control. With impact to the concentrations of mineral nutrients in the edible part of blackgram, the contents of iron, copper, and manganese content showed a decreasing trend (Table 2). However, it is suggested that such mineral deficiencies would also probably be relieved by larger fertilizer inputs in intensive agriculture practices

Table 2. Micronutrient content of black gram crop (T9 variety) grown under two elevated CO_2 concentrations

Elevated CO_2	Mn (mg/100g)	Zn (mg/100g)	Cu (mg/100g)	Ca (mg/100g)	Fe (mg/100g)	Total Ash (%)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
550	0.09±0.02	0.94±0.25	0.07±0.02	38.55±2.57	0.61±0.18	4.23±0.05
700	0.06±0.06	1.08±0.30	0.15±0.01	63.15±17.16	0.42±0.35	4.22±0.05
Ambient	0.55±0.00	0.56±0.27	0.59±0.10	77.95±34.83	2.59±0.75	3.97±0.04
CD (0.05)	0.15*	NS	0.21*	NS	1.15*	0.12*

*- Significant NS- Non significant

Screening of Black Gram Genotypes for Nutritional Proximates Grown Under Control

Eighteen lines of different black gram genotypes grown under control conditions were analysed for quality parameters i.e., crude protein (percent) and total phenol content (percent). Protein was high in KDRS-251 and SKN-158 high yielding and stable varieties and CN-9013 was low yielding and stable variety and Total phenols were high in CN-9078 and KARS-269 which were medium yielding and stable varieties (Figs 5 and 6).

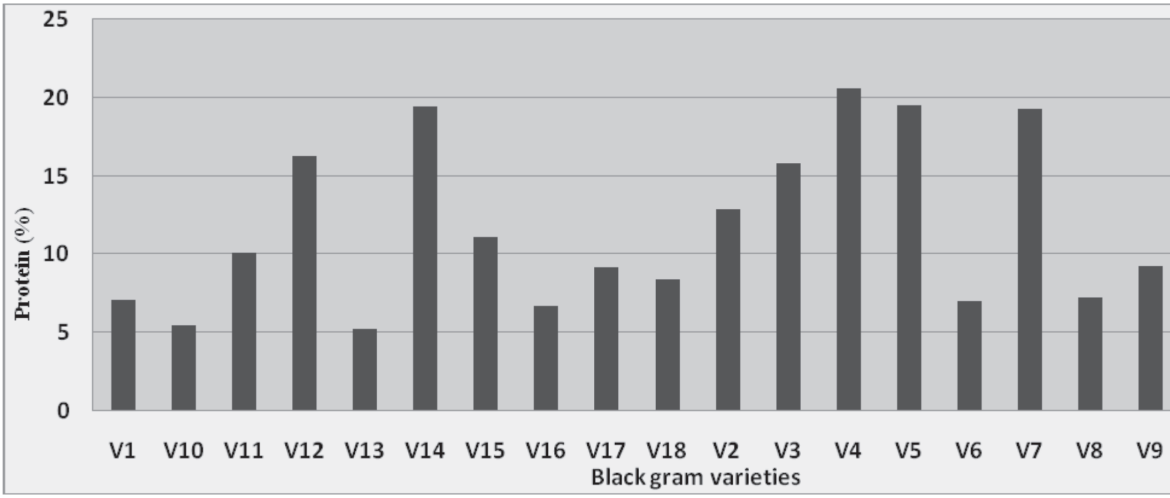

Fig. 5. Crude protein (%) in different black gram varieties

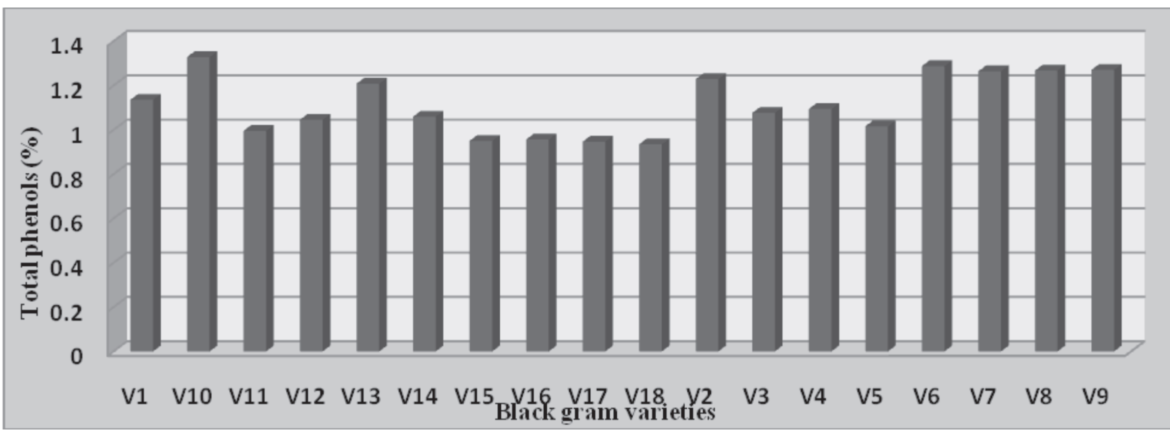

Fig. 6. Total phenol content (%) in different black gram varieties grown under control

Effect of Elevated Atmospheric CO_2 Concentration on Nutrient Quality of Pigeon Pea Crop

Three varieties of pigeon pea whole seeds (GT-1, Pusa-991 and WRG-27) grown under elevated CO_2 concentration and control were evaluated for mean 100 seed weight (g 100 seed^{-1}). Mean 100 seed weight of the three pigeon pea genotypes ranged from 9.97-12.73 g 100 seed^{-1} under 390 ppm and 10.60-12.03 g 100 seed^{-1} under 550 ppm. Mean 100 seed weight of GT-1 and Pusa 991 pigeon pea varieties (12.03 g & 10.03 g 100 seed^{-1} respectively) was found to be decreased with increased CO_2 concentrations at 550 ppm and WRG-27 pigeon pea genotype alone showed an increasing trend of mean 100 seed weight (g 100 seed^{-1}) from 390 ppm to 550 ppm (Fig 7).

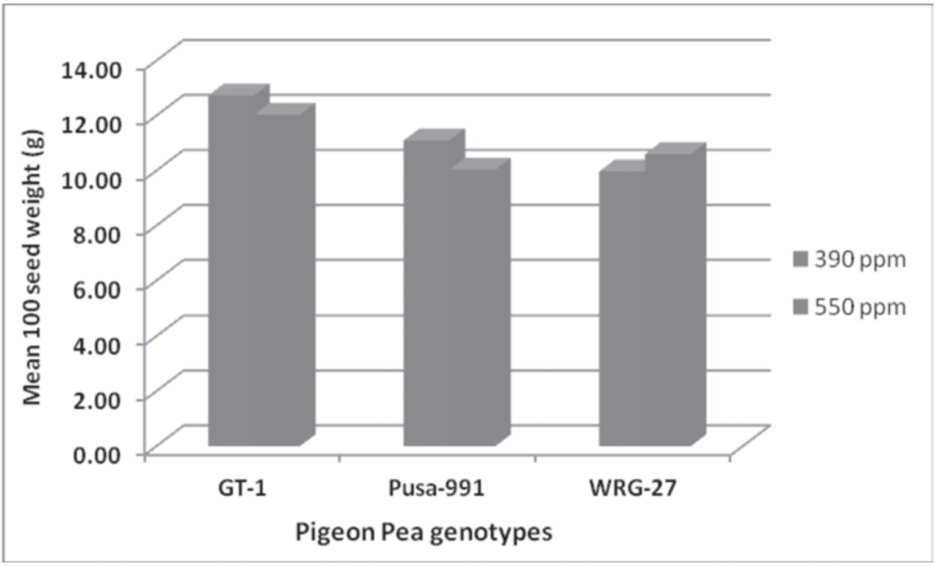

Fig. 7. Mean 100 seed weight (g) of pigeon pea seeds grown under elevated CO_2 concentration and compared with control

Nine varieties of pigeon pea whole seeds (AKP-1, AL-201, VIPULA, ICPL-8039, WRG-27, GT-1, PRG-158, PT-002-02 and Pusa-991) were evaluated for Hydration capacity, Hydration index, Swelling capacity, Swelling index, Cooking time (min) were studied by soaking of the pigeon pea seeds in water for 16 hours at room temperature.

Hydration capacity of the pigeon pea genotypes ranged from 0.109-0.146 g water $seed^{-1}$. Highest Hydration capacity was found in GT-1 (0.146 g water $seed^{-1}$) and the lowest in PRG-158 (0.109 g water $seed^{-1}$) pigeon pea varieties, whereas Hydration Index was recorded highest in PT-002-02 (1.21 g water $seed^{-1}$) followed by GT-1 (1.19 g water $seed^{-1}$) and the lowest in PRG-158 (0.99 g water $seed^{-1}$) pigeon pea varieties (Fig 8 and 9). Swelling capacity and Swelling index of the genotypes ranged between 0.207-0.273 ml water $seed^{-1}$ and 1.20-1.71 ml water $seed^{-1}$ respectively (Fig 8 and 9).

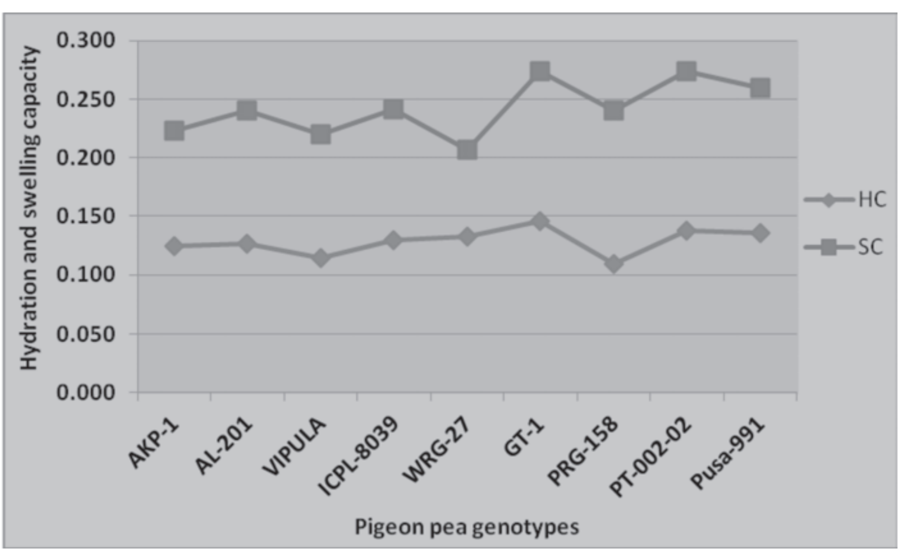

Fig. 8. Hydration Capacity (HC) and Swelling Capacity (SC) of pigeon pea seeds

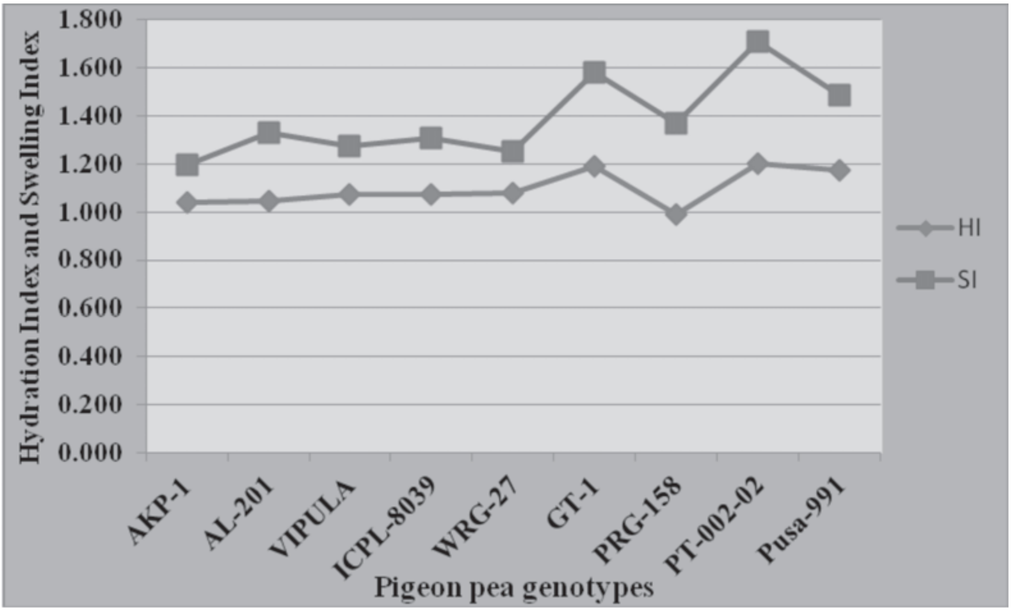

Fig. 9. Hydration Index (HI) and Swelling Index (SI) of pigeon pea seeds

Cooking time (min.) of pigeon pea genotypes was found to be higher in Pusa-991 (5.33 min.) and the lowest cooking time was found in PRG-158 (3.5 min.) after soaking of the pigeon pea seeds in water for 16 hours at room temperature (Fig 10). Volume expansion (after soaking in water) and cooking time are important cooking quality traits. Cooking time is generally assessed by the softness of the cooked seeds by applying pressure of the fingers.

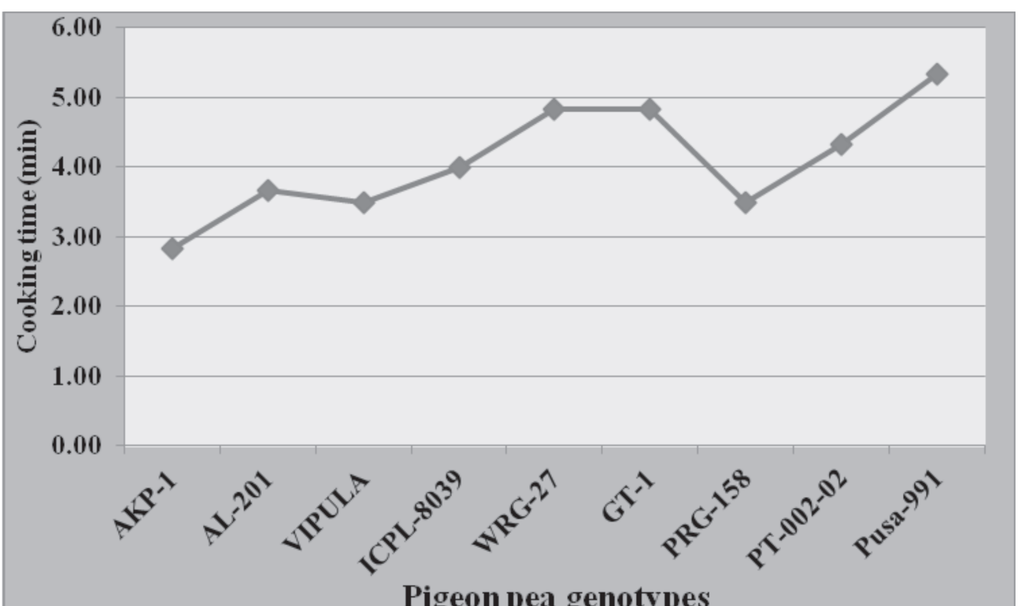

Fig. 10. Cooking time after 16 hours of soaking of pigeon pea genotypes

Nutritional quality analysis was carried on nine pigeon pea genotypes grown under control and nutritionally better varieties of pigeon pea will be selected and then subjected to elevated CO_2 treatments at Open Top Chambers (OTCs) comprising ambient and elevated CO_2 treatment of 550 ppm. Nine genotypes of pigeon pea were collected for estimation of nutrients. The genotypes are AKP-1, AL-201, Vipula, ICPL-8039, WRG-27, GT-1, PRG-158, PT-002-2 and Pusa-991. Nutrient analysis was carried on for estimation of total carbohydrates, crude fiber, iron, zinc and â-carotene in all the genotypes in triplicate. Nine varieties of pigeon pea genotypes were analysed for total carbohydrates (%). AKP-1, AL-201 and WRG-27 found to contain significantly higher total carbohydrates ranging from 39.5-50 g/100g compared to other pigeon pea genotypes (Fig 11).

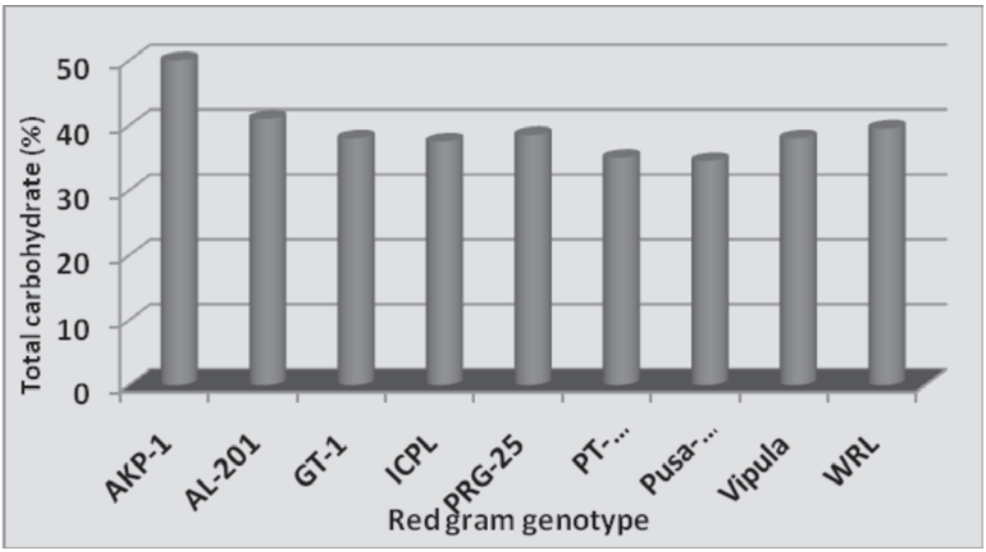

Fig. 11. Total carbohydrate content (g/100 g) of different red gram genotyes

Pigeon pea genotypes PRG-158, GT-1, AL-201and PT-002-2 were significantly found to possess higher crude fiber (%) content ranging from 8. 69-8.71g/100 g compared to other genotypes. Pigeon pea genotype WRG-27 found to contain significantly lower content of crude fiber content compared to all other genotypes (Fig 12).

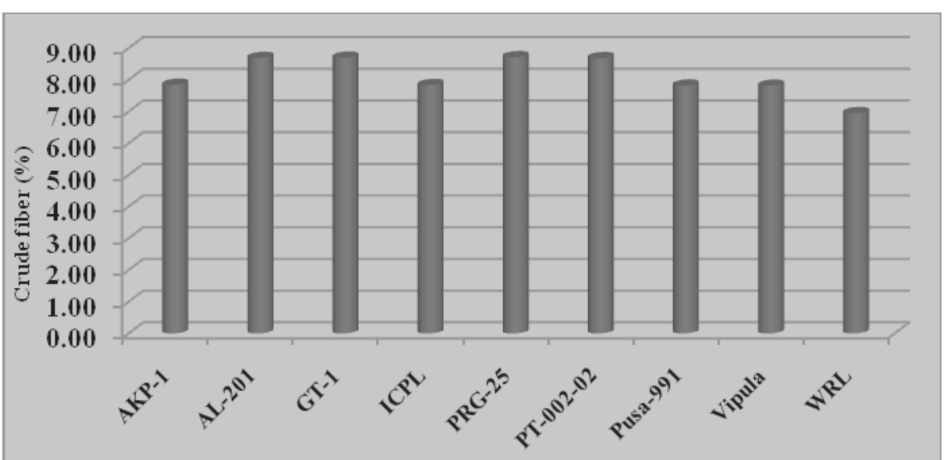

Fig. 12. Crude fiber content (mg/100 g) of red gram genotypes

AKP-1 and ICPL-8039 were found to possess significantly higher iron content (Fig 13) compared to other genotypes of pigeon pea.

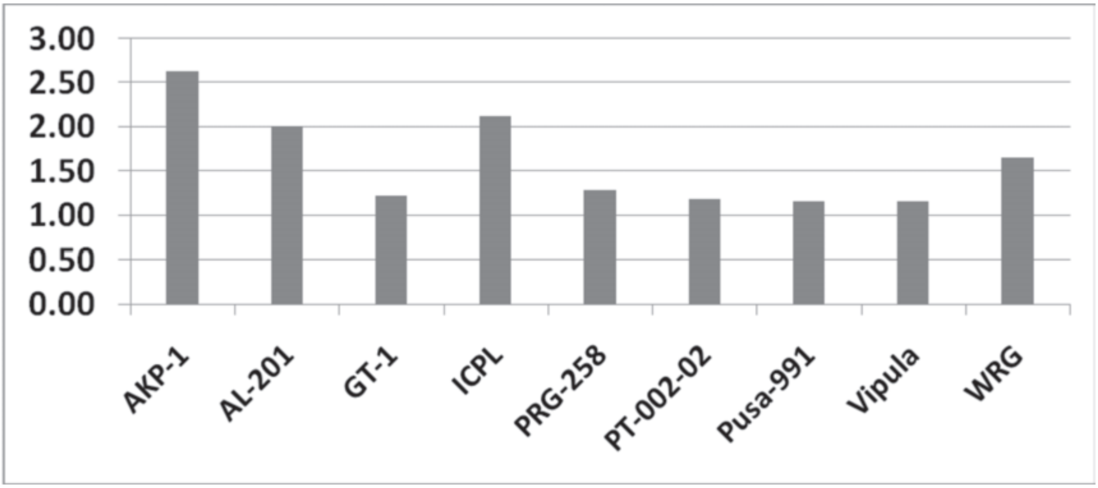

Fig. 13. Iron content (mg/100 g) of red gram genotypes

The zinc content was found to be higher in GT-1 and WRG -27 genotypes of pigeon pea (Fig 14)

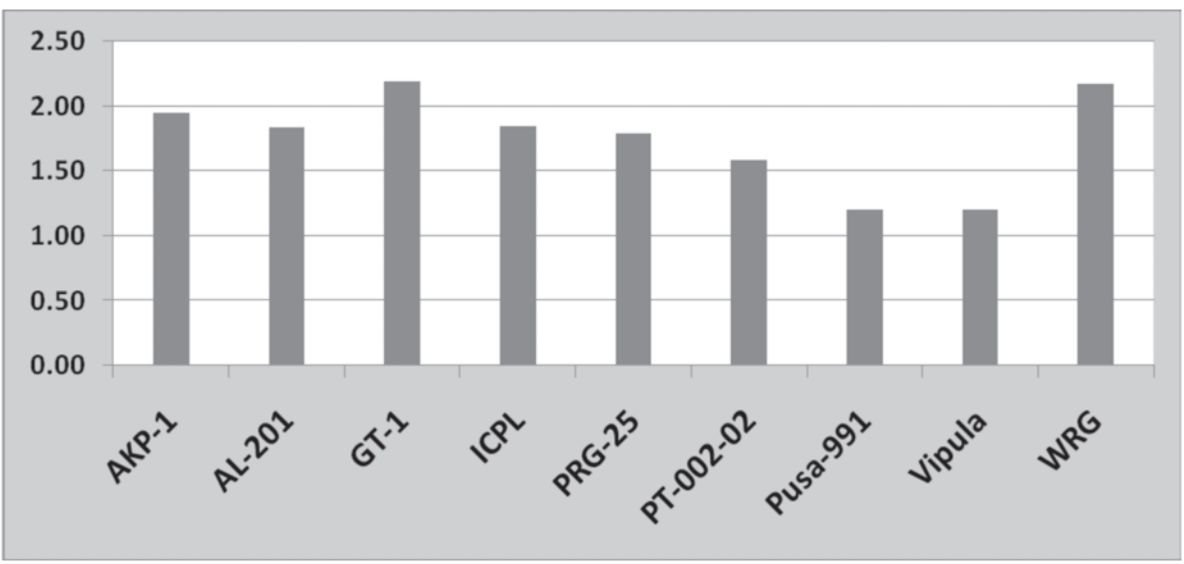

Fig. 14. Zinc content (mg/100 g) of red gram genotypes

β -carotene content is found to be higher in Vipula, WRG-27 and AKP-1 compared to other genotypes of pigeon pea (Fig 15).

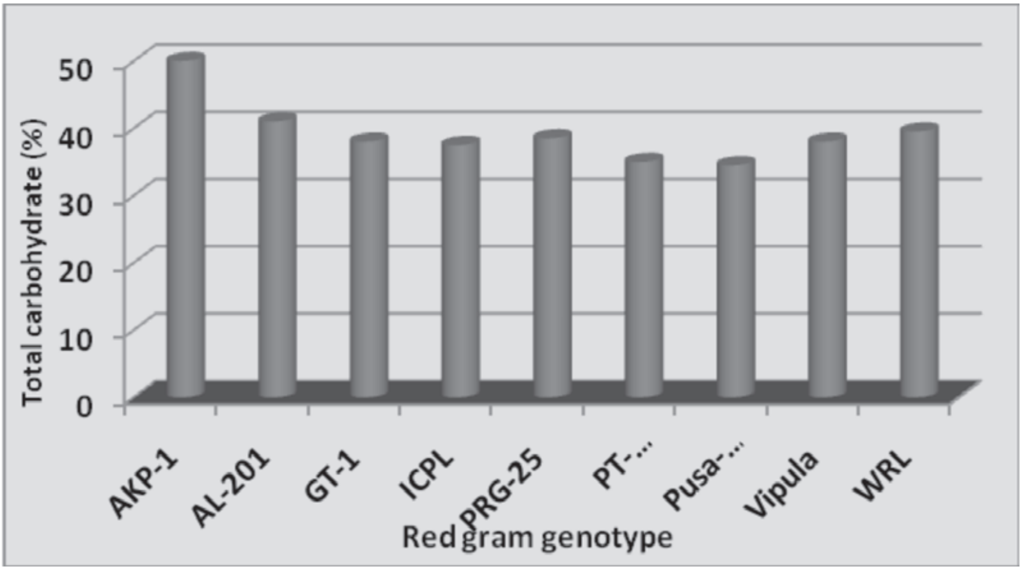

Fig. 15. β-Carotene content (mg/100 g) of red gram genotypes

Conclusion

Atmospheric gas plays an important role in determining many nutritional aspects of food crops. Atmospheric CO_2 enrichment specifically altering, the concentrations of food crop constituents is unknown, related to human health. Rising atmospheric CO_2 is likely to increase or reduce the protein concentration for many plant crops. The magnitude of this effect is difficult to estimate, due to the sensitivity of this effect to experimental conditions. Nonetheless, decreases in mineral content are seen consistently in these studies. Several other food crops has to be studied across a wide range of experimental techniques and environmental conditions. The effect of atmospheric CO_2 on crop protein and minerals therefore seems likely to be of genuine importance for human nutrition in and beyond the 21st century.

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14 Policy Imperatives for Enhancing Agricultural Growth for Ensuring Nutritional Security

Josily Samuel, C A Rama Rao and BMK Raju

Introduction

Ensuring nutrition security is one of the important issues that are receiving the attention of global community. Various forms of malnutrition manifested in the form of stunting, wasting, infant mortality, obesity continue to impede the capacity of human beings to lead a quality life. In spite of significant growth achieved in agriculture in the country, the development goals related to nutrition and hunger continue to major obstacles.

Although the share of agriculture to GDP declined to less than 15 per cent, the agriculture's share in employment continues to be more than 55 per cent. This indicates that majority of Indian population still depends on agriculture for their livelihood. Agriculture as whole is facing problems such as declining availability of land, decreasing farm sizes, land degradation; depletion of soil nutrients, pollution leading to unhealthy soils and which in turn affects the quality of food produced. There is need to revive agricultural growth in order to meet the nutrition requirements also. Enhancing productivity and profitability of agriculture is a potent tool for enhancing human welfare and well being. Any strategy for accelerating agricultural development will do well to consider the issue of ensuring nutrition security to the growing population in a sustainable way.

According to FAO (2015), food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and their food preferences for an active and healthy life. From this definition, four food security pillars can be identified:

- Food availability;
- Economic and physical access to food;
- Food utilization; and
- Stability over time of food availability, access and utilization.

There has been noticeable growth in the economic condition and food production and poverty reduction in the recent decades especially in the Asian countries. However, the progresss was not as impressive in terms of reduction in inequity. The rise in inequality can be linked at least in part to slow growth in agriculture, which continues to employ some of the region's poorest people and pays lower wages than industry or services. Furthermore, when workers exit from agriculture, they often find employment in low-productivity services with little job security.The inequality in agriculture can weaken the link between agriculture and nutrition. The share of small and marginal farmers in Indian agriculture is 41 percent and they belong resource poor areas with low incomes where under nutrition in concentrated (Dev, 2012)

Global rates of hunger have fallen and now affects around one in ten people and the percentage of children who are chronically undernourished has declined to around one in four. However, despite these gains, malnutrition in all its forms currently affects one in three people worldwide. There will be 653 million calorie-deficient people (down from 795 million in 2015). Most of the reductions in calorie insufficiency are from Asia, while Africa will see a levelling off. Asia and Africa will still be grappling with significant levels of undernutrition in 14 years' time (Global Panel, 2016).

Agriculture and Nutrition : India

The Food and Agriculture Organization of the United Nations (FAO) estimates that 22% ofIndia's population is undernourished.Moreover, India's malnutrition problem is of global proportions. UNICEF in 2008 estimated that India was home to 42% of the developing world's children who were underweight (low weight-for-age) and

32% of those who were stunted (low height-for-age) (Figs 1 and 2; Table 2). Malnutrition comes in many guises: stunting, wasting, deficiencies of essential vitamins and minerals, and obesity. In order to tackle problem of malnutrition we need to look into the relationships between agriculture and nutrition, nutrition and income levels.

The issue of food security is to be addressed in its wider connotation. Food security also implies, in addition to just having enough to eat to keep away hunger, nutritional security and ability to assimilate what one eats and this is dependent on the intake of not just calories but also other nutrients such as minerals and also on sanitation, drinking water availability and primary health care. Millets as already mentioned are rich in minerals and their consumption leads to a more balanced and healthier diet. It was observed that body-mass-index was found to be higher in case of people whose diet included millets than those whose diet did not include millets (Rama rao, 2011). Table 1 gives the agriculture and nutrition status across states in India. According to Dev and Kadiyala (2011), "Inclusiveness and equity in agriculture can be achieved by increasing agricultural productivity in rainfed and resource-poor areas, thereby raising the productivity and income of small and marginal farmers." The bulk of the rural poor, as well as small and marginal farmers, lives in such resource-poor areas, where under nutrition is also concentrated. The move of consumption patterns toward non-cereals presents a good opportunity for small farmers to diversify their cropping patterns in order to improve both income and nutrition.

Table 1. Agricultural growth and area occupied by small holders

State	(1) Agricultural Growth, 1992-2000 to 2008-09	(2) Area occupied by small and marginal farmers, 2005-06	(3) Incidence of rural poverty, 2004-05	(4) underweight, 2005-06
Andhrapradesh	6.27	48	32.3	32.7
Bihar	4.38	73	5.7	56.1
Chhattisgarh	6.60	37	55.1	47.6
Gujarat	11.61	27	39.1	44.7
Haryana	3/86	22	24.8	39.7
Himachal Pradesh	5.42	52	25.0	36.0
Jammu and Kashmir	3.81	70	14.0	29.0
Karnataka	0.12	37	37.5	37.6
Kerala	0.55	76	20.2	22.7
Madhya Pradesh	3.45	29	53.6	59.8
Maharashtra	5.76	40	47.9	36.7
Orissa	3.67	58	60.8	40.9
Punjab	2.62	9	22.1	24.6
Rajasthan	4.89	14	35.8	40.4
Tamilnadu	2.77	59	37.5	30.0
Uttar Pradesh	2.18	63	42.7	42.3
West Bengal	2.27	80	38.2	38.5
All India	2.68	41	41.8	42.5

In terms of production, small and marginal farmers also have a larger share in the production of high-value crops. They have a major share in production of fruits and vegetables and small farmers will remain the major part of Indian agriculture.

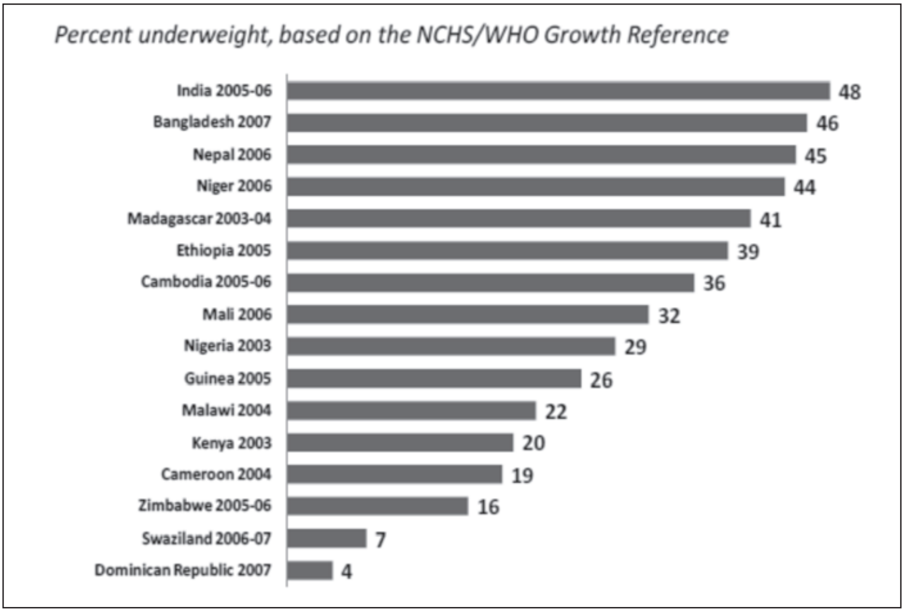


Fig. 1. Under nutrition among children under five years in selected countries
(Source: Ministry of Health and Family Welfare, GOI)

Table 2. Under nutrition in India

Nutrition indicator	NFHS-2 (1998/99)	NFHS-3 (2005/06)
(percent)		
Stunting (children < 3)	51	45
Wasting (children < 3)	20	23
Underweight (children < 3)	43	40
Anemia (< 11.0 g/dl) (children 6–35 months)	74	79
Vitamin A deficiency (children < 5)	n.a.	57
Women with BMI < 18.5	36	33
Men with BMI < 18.5	n.a.	28
Women with anemia	52	56
Men with anemia	n.a.	24

(Source: Ministry of Health and Family Welfare, GOI)

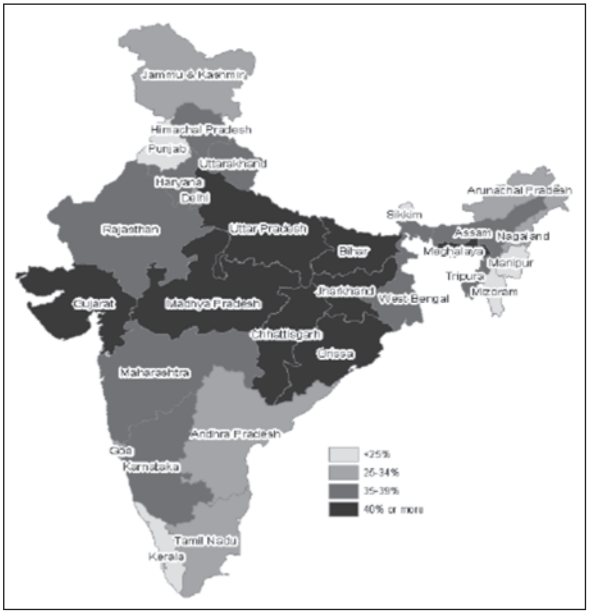


Fig. 2. Percentage of children under five who are under weight
(Source: NFHS -3)

Table 3. Average calorie intake per capita and per consumerunit in 2011-12: major States

State	calorie intake (kcal)per day per capita		calorie intake (kcal)per day per consumer unit	
	rural	urban	rural	urban
Andhra Pradesh (undivided)	2365	2281	2926	2789
Assam	2170	2110	2617	2574
Bihar	2242	2170	2731	2625
Chhattisgarh	2162	2205	2661	2697
Gujarat	2024	2154	2497	2627
Haryana	2441	2443	2992	2988
Jharkhand	2138	2175	2645	2647
Karnataka	2164	2245	2675	2753
Kerala	2162	2198	2749	2784
Madhya Pradesh	2234	2209	2711	2676
Maharashtra	2260	2227	2802	2722
Odisha	2215	2191	2750	2665
Punjab	2483	2299	3066	2822
Rajasthan	2408	2320	2959	2832
Tamil nadu	2052	2112	2560	2619
Uttar Pradesh	2200	2144	2717	2622
West Bengal	2199	2130	2710	2624
all-India	2233	2206	2752	2700

Source: NSS Report No.560: Nutritional Intake in India, 2011-12

Table 3 shows that all the major States had average levels of calorie intake in 2011- 12 within + or -11% of the all-India average for the sector (2233 Kcal per capita for rural and 2206 for urban). Though the overall magnitudes of deviation of average calorie intake of the states from the all-India average do not tend to change substantially when per consumer unit estimates are used instead of per capita estimates, there are situations where state averages do shift from below national average to above, and vice versa (Madhya Pradesh and Bihar are examples of the latter kind). This suggests that there is some inter-State difference due to difference in age-sex composition between states. Deviations from the all-India average are a little wider in the rural sector than in the urban. At the all-India level, in both rural and urban sectors, calorie intake per consumer unit is about 23% higher than intake per capita

Table 4. Mean per capita consumption of calories, protein and fats (per capita per day)

Year	Calories (kcal)		Protein (gms)		Fat (gms)	
	Rural	Urban	Rural	Urban	Rural	Urban
1983-84	2240	2070	63.5	58.1	27.1	37.1
1987-88	2233	2095	63.5	58.6	28.3	39.3
1993-94	2153	3\2073	60.3	57.7	31.1	41.9
1999-00	2148	2155	59.1	58.4	36.0	49.6
2004-05	2047	2023	59.3	58.8	43.1	53.0

Source : NSSO reports (various rounds)

Pattern of calorie and protein intake for rural and urban householdsshows a dissimilar trend during the period 1983-84 to 2009-10. while per capita calorie intakedeclined from a level of 2240 kcal per day in 1983-84 to 2147 kcal per day in 2009-10 for therural population, the per capita protein intake for the rural population declined from 63.5 gm to 59 gm per day during the same period (Table 4). The per capita calorie intake for the urban population however increased marginally from 2070 kcal per day to 2123 kcal per day and per capita protein intake from 58.1 gm per day to 58.8 gm per day in the period between 1983-84 and 2009-10. Onthe other hand the per capita intake of fat increased steadily over time for both rural and urbanpopulation.In rural India as a whole, protein intake per person per day has definitely declined since 1993-94. However, the decline at the all-India level shows signs of flattening out, being only 0.5 gm less in 2011-12 compared to 2004-05. The decline in rural protein intake since 1993- 94 has been prominent in Rajasthan (a fall of 11gm), Haryana (about 10 gm), and Punjab (8 gm). In the urban sector the decline between 1993-94 and 2011-12 is less marked than inthe rural area. In both sectors, all the southern States except Karnataka show slight increases inprotein intake per person during this period (NSSO, 2014) (Table 5).

Table 5. Percentage break up of calorie consumption over nine food groups: 1993-94 to 2011-12

Year	cereals	roots & tubers	sugar & honey	pulses, nuts & oilseeds	veg. & fruits	meat,eggs & fish	milk & milk proucts	oils & fats	misc. food, etc.
Rural									
1993-94	71.03	2.65	4.8	4.92	2.02	0.68	6.15	5.34	2.41
1999-2000	67.55	3.25	5.14	5.46	1.97	0.77	6.17	7.37	2.32
2004-05	67.54	2.95	4.78	4.98	2.23	0.76	6.42	7.36	2.98
2009-10	64.16	2.78	4.61	4.54	1.84	0.72	6.79	8.53	6.04
2011-12	61.1	3.01	4.9	5.2	1.85	0.82	7.07	9.01	7.04
Urban									
1993-94	58.53	2.54	6.21	6.05	3.26	1.02	8	8.79	5.6
1999-2000	55.05	2.9	6.15	6.86	2.94	1.12	8.23	11.24	5.52

2004-05	56.08	2.82	5.69	6.68	3.17	1.05	8.61	10.58	5.32
2009-10	55.01	2.59	5.66	5.94	2.62	1	9.37	11.92	5.87
2011-12	51.64	2.73	5.62	6.41	2.62	1.13	9.07	12.17	8.61

Source: NSSO Reports

The table shows that over the 18-year period from 1993-94 to 2011-12, the share of cereals in total calorie intake has declined by nearly 10 percentage points in the rural sector and nearly 7 percentage points in the urban. On the other hand, the share of oils and fats has risen by about 3½ percentage points in both sectors.

Phases in Indian Agriculture

Pre-reform period (until 1990s)

- **Pre-green revolution (until; the mid 1960s)**
- Imbalances between demand for food and domestic supply
- *1950*s: Institutional reforms: Abolition of *zamindari*system; enactment of tenancy laws and ceilings on landholdings
- **Green revolution period**
- There was shift in the policy from institutional to technologicalfactors
- *1970s*: intra- and interregional and intercrop imbalances in crop yields
- Operation Flood
- *1980s:* Regional spread of agricultural growth and crop diversification
- Shift from cereal to other food crops
- Green Revolution technology mainly benefited high-potential and irrigated areas and had less impact on dryland and rainfed areas.
- Shift from food to non-food crop production (such as cotton)

Post reform period (1992 onwards)

- Decline in growth of the agriculture sector
- Shift in policy emphasis to liberalizing trade in agriculture
- *1990s:* Decline in annual growth rate of agriculture to 3.6 percent
- *1990s* onward: Rise in relative cereal prices amid rising buffer stocks
- Rapid growth in non-food crop cultivation (Bt cotton) and contract farming
- End of all quantitative restrictions

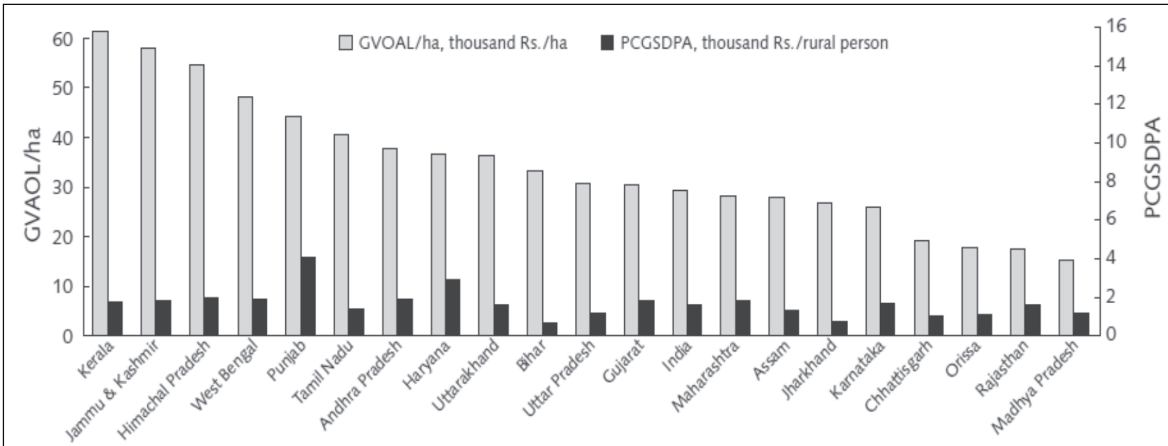
Factors Affecting Nutrition

Economic and agricultural growth

Studies have shown that increase in agriculture growth /GDP impacts the poor of the country. Growth in agriculture can reduce poverty especially in Asian countries which are dependent on agriculture. Overall agricultural growth and food-grain production growth are not a necessary condition for nutritional improvement in India. Improvement in gross domestic product per capita from agriculture was seen to have brought about more than proportional improvement in the incomes of the lowest quintile (DFID, 2004). Declining share of agriculture in the GDP, without a commensurate decline in the population dependent on agriculture leads to per worker productivity gaps between agriculture and non-agriculture (Timmer *et al*., 2008).

In India, rice and wheat production and consumption increased significantly, but pulse production and consumption declined. These changes were influenced by the adoption of high-yielding varietiess and other technologies, which made rice and wheat more profitable to produce relative to pulses. Ever since then, in India the per capita availability of pulses has declined, prices have risen, and consumption has declined.The greater availability and lower prices of rice and wheat is evident and they displaced other widely consumed coarse grains (Gopalan, 1999). Likewise, breeding of oilseeds has contributed to the rapid increase of global vegetable oil availability in the last 40 years (Hawkes, 2007). In India in the last two decades, the introduction of newer oilseeds has led to increased production of groundnut, soybean, rapeseed, and mustard oils.

A large proportion of the poor and malnourished live in rural areas where agriculture remains the primary occupation. From this perspective, augmenting incomes from agriculture is one of the most critical avenues through which agriculture can impact nutritional outcomes of farm households via increased access to quality food. Improvements in agricultural performance can also increase food availability at the local and national levels (home production, local markets, and national food availability), bring down food prices, and stimulate the development of the rural nonfarm sector (Gulati *et al*., 2012)



Grass Value of Output from Agriculture and Livestock per hectare (GOVAL/ha) is in 1,000 Rs/ha at 1999/00 prices. Per Capita GSDPA (PCGSDPA) is in 1,000 rs at 1999/00 prices. States are arranged in descending order of GVOAL/ha.

Fig. 3. Agricultural performance status across states for 3 years ending 2005-06

Source : Central Statistical Organisation

An analysis of agricultural performance and income measures (GVOAL/ha and PCGSDPA) show high and significantly negative correlations with Combined Normalized Malnutrition Index (CNMI) (Fig 3). Indicators of the level of agricultural performance or income show a strong and significant relationship with the indices of undernutrition among adults and children. This suggests that improvement in productivity can be a powerful tool to reduce undernutrition among the vast majority of the population, especially in countries where a large proportion of the population is dependent on agricultural livelihoods. Improvement in productivity commonly occurs with faster growth in yield (driven by better inputs and technologicaladvances) and/or diversification into high-value agriculture(fruits and vegetables, fisheries, and livestock). Punjab and Haryana are typical examples of the firstinstance: i.e., higher growth in yield of key cereal cropsresulting in a high level of agricultural prosperity. Stateswith high GVOAL/ha driven by a significant proportionof high-value agriculture include Kerala, Himachal Pradesh, West Bengal, and Andhra Pradesh. At the other end are states like Madhya Pradesh, Chhattisgarh, and Rajasthan, with low agricultural performance and high rates of undernutrition (Gulati *et al*., 2012).

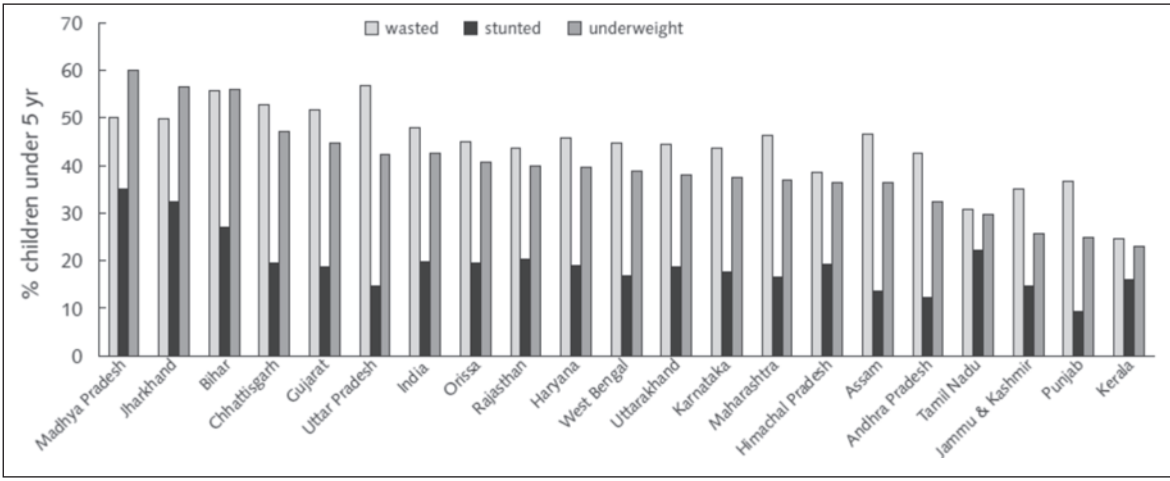


Fig. 4. Child nutrition indicators across states, NFHS -3. The states are arranged in descending order of percentage of children under 5 years old age who are under weight.

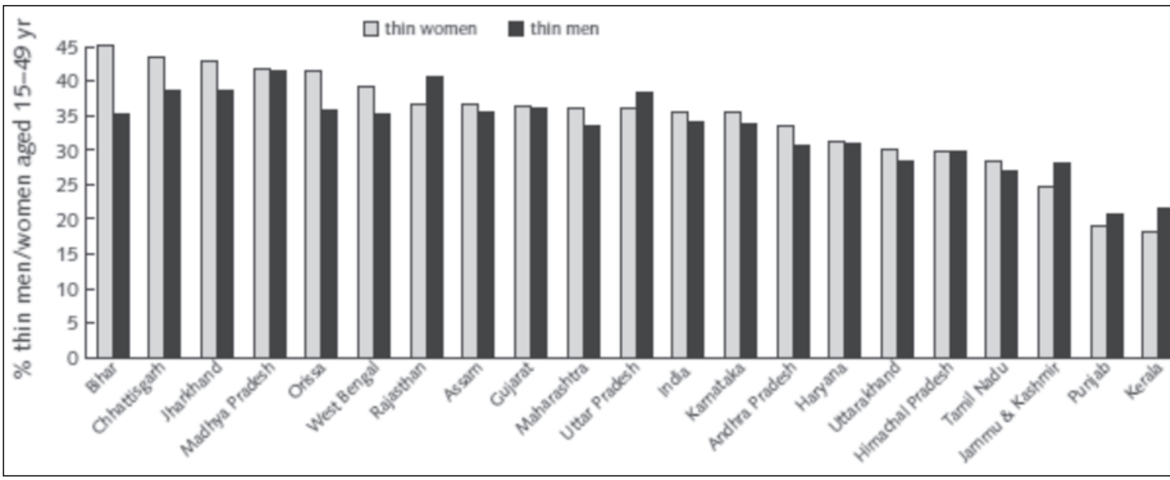


Fig. 5. Adult malnutrition indicators, NFHS -3. States are arranged in descending order of percentage of women 15 to 49 years of age who are thin

The figures 4 and 5 show the status of agriculture and malnutrition indicators across states in India. Agriculture could influence positive child nutrition outcomes based on the pattern of growth and percolation of benefits via land productivity and worker productivity to the poor. Probably as agriculture get prosperous with high wages, women‘s income access leads to positive nutrition outcomes for children. The agriculture-child-nutrition linkages do exist at the macrolevel in the Indian context, though agricultural growth per se would not help, especially if the levels are low (Swarna *et al*., 2014)

Linkages Between Agriculture and Nutrition

Agriculture has significant potential for driving improvements in nutrition as nearly 58% of the Indian work force lists agriculture as their primary source of employment (over 80% for the rural female labor force) and agriculture still generates more than half of total rural income.The Fig 6 shows the agriculture-nutrition linkages. Like other productive sectors, agriculture is a source of household income and expenditure on nutrition-enhancing goods and services (pathway 2), although agriculture is generally amore important source of income for the poor and undernourished, both directly, and through so called multiplier effects on other sectors.

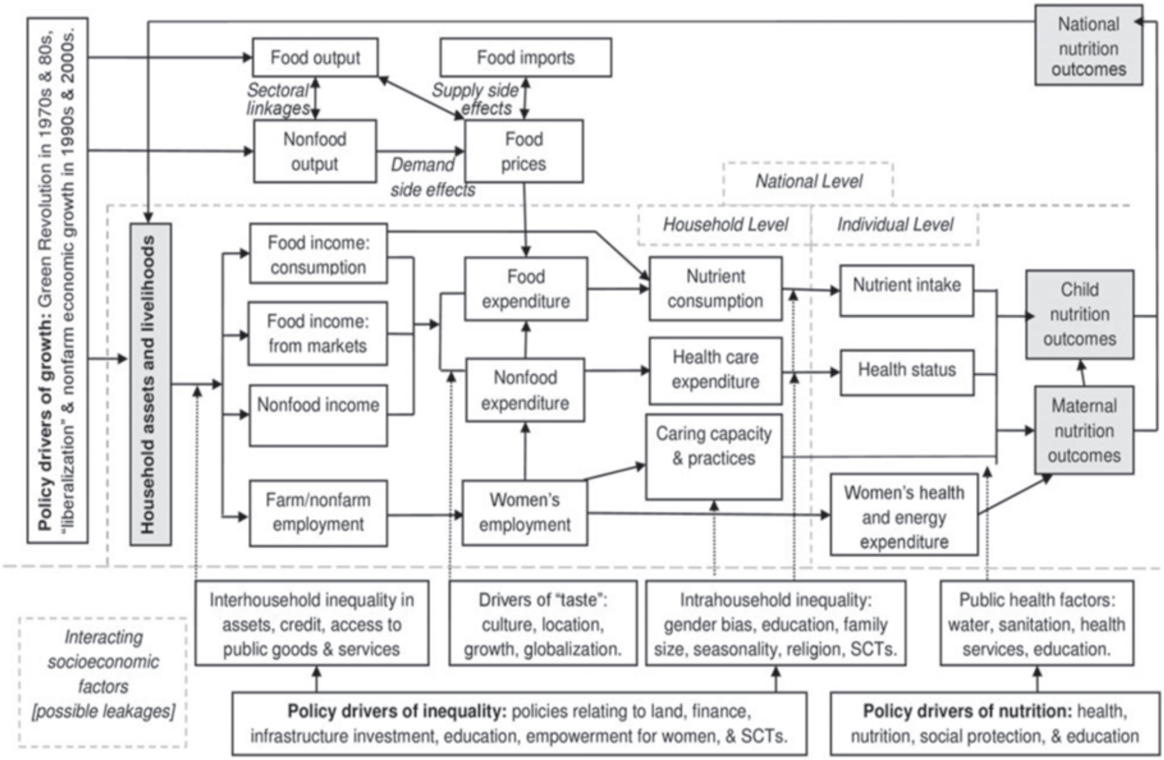


Fig. 6. The agriculture-nutrition pathways in India

Pathway 3, which posits that agricultural production conditions can determine the relative prices of food in general as well as specific foods, potentially also makes agriculture a special sector because it influences the composition of diets through macro economic linkages.The next three pathways focus on linkages between child undernutrition and maternal socioeconomic and nutritional status. Pathway 4 acknowledges that agricultural production conditions can influence the empowerment of women and household decision-making outcomes for nutrition-relevant resources, particularly food and health care.

Pathway 5 focuses more specifically on whether large female workloads in Indian agriculture influence childcare outcomes through inadequate childcare practices. Pathway 6 addresses the possibility that the often arduous and hazardous conditions of agricultural labor in India pose substantial risks for maternal nutritional status and an intergenerational transmission of undernutrition (Kadiyala *et al*., 2015)

Access to Food and Nutrition

Food security means that they have access to the required food either throughtheir own production, through the market, and through the government's transfer mechanism. Food security requires the poor to have adequate purchasing power apart from physical access tothe required food. Very often the poor cannot afford to obtain the available food due to the highlevel of market prices. The poor needs an employment intensive pattern of growth wherein remunerative work is provided.

Employment: The sustained creation of employment goes a long way in effectively increasing access and ensuring the right to food. The increase in employment opportunities especially for the poorenables them to obtain the purchasing power to increase their food consumption. The overallgrowth in employment in the country is thus closely related to the ability to improve access tofood particularly for the poor in both rural and urban India.

According to researchers the capacity to benourished (for the body to absorb food) depends crucially on other characteristics of a person thatare influenced by non-food factors such as medical attention, health services, basic education,sanitary arrangements, provision of clean water, eradication of infectious epidemics and so on (Dreze, J. and A. Sen, 1989). This inability to absorb the food intake or where the body isincapable of absorbing the nutrients from the food consumed can be termed absorption food insecurity.

Access to the Public Distribution System: The operation of the PDS is supplementary in nature and doesnot meet the entire food requirements of any household. However it does effectively protect thehousehold by providing a basic entitlement at affordable prices and at convenient locationsthrough its wide network of Fair Price Shops.

Growth in Incomes: Growth in incomes not only enhances greater access to food but can improve nutrition aswell. The decline in malnutrition comes about with therise in per capita incomes. However, this will only happen ifgrowth is equitable. In recent times we have witnessed the GDP growing in India at 6 to 7 percent, however the percentage decline in child malnutrition has declined by only 0.5 percent perannum. Income growth is thus necessary but not a sufficient condition in the effective reduction in malnutrition. As incomes increase, food scarcity diminishes but the cost of many nutritious foods remain high and the ability to purchase foods that do not support high quality diets increases. Currently, income growth is a double edgedsword when it comes to improving diets (Global Panel, 2016).

Public Health: It suffers from significantregional, social disparities, and gender disparities reflecting low levels of health indicators, which have hardly improved over the years. The quality of delivery systems is very poor. The unaffordable and expensive private health services impact the poor who are as a result forced to compromise other essential expendituresuch as on food and education.

The low standards of health, hygiene, safe drinking water andsanitation play a very adverse role by inhibiting the absorption of essential nutrients by childrenwho are sick and ailing.

Empowerment of Women: The improvement in the status of women, and their well-beingwould in turn significantly improve the well-being of children. The mechanisms through which women's empowerment is effectively transferred to the well being of the child are maternaleducation, economic empowerment, and the power to make decisions within the household andempowerment of women in the community. Better child related services could be demanded by educating women.

Multi-Sectoral Interventions: There is a pressing need to ensure coordinated interventions on several fronts such asprocesses for improving clean drinking water, sanitation and public hygiene, elementaryeducation, immunization, antenatal care and nutritional supplementation. A package of suchinterventions will bring about lower child mortality and child nutrition. The need to achieve a high level of synergy between sectors is thus most essential.

Agricultural Growth and Development: Among the other indirect or institutional factors that impact the level of nutrition is thediversified growth and development of the agricultural sector. This sector not only ensures betterfood availability but can also increase access to food and nutrition. It is seen that agricultural growth is slow in states where malnutrition is high in the central and eastern states. The increasedinvolvement of women in raising home gardens and the incorporation of nutritional elements incrop production and diversification can tackle the problems of malnutrition to a significant extent.

Policy Imperatives

Agricultural policies and production practices affect diet through their influence on food availability, price, and nutrient quality, which, in turn, affect food choices available to consumers. Agricultural policies amenable to intervention include input, production, and trade policies; agricultural production practices amenable to intervention include crop breeding, crop fertilization practices, livestock-feeding practices, and crop systems diversity (Nugent, 2004; Hawkes, 2007).

Vast areas of India have tropical agroclimatic conditions, which are well suited for the cultivation of horticulture and plantation crops. In addition to providing nutritional and livelihood security and helping poverty alleviation and employment generation, this subsector can sustain a large number of agro-industries, which can generate huge additional non farming employment opportunities. These factors have led to a greater area being brought underhorticulture and a consequent increase in the production of fruits and vegetables.

Direct nutrition intervention through the Special Nutrition Programme under the Integrated Child Development Scheme (ICDS; now called the Supplementary Nutrition Programme) and the Mid-Day Meals Scheme (MDMS) was launched to address the nutritional needs of children and women. Other than these, relevant schemes include food-based safety nets such as the Food for Work Programmeunder the National Rural Employment Scheme and state-specific schemes and initiatives. By the 1990s, the main initiatives to address nutritional security were via the food management system (buffer stocks and the Public Distribution System (PDS) network), food supplementation through the ICDS and MDMS, nutrition education through the Nutrition Board and ICDS, and health interventions to address the physical symptoms of malnutrition, micronutrient deficiencies, and maternal health.Although these schemes are important and have much potential, they are still poorly implemented.

A successful future nutrition reduction strategy ought to be integrated and dovetailed with certain aspects of agricultural development strategies. This can be done at many levels. “One option at the sowing stage is biofortification of crops with essential nutrients such as iron, zinc, and vitamin A, after suitable research, quality testing, and trials. This can directly improve the quality of food intake and diets and improve nutritional outcomes in the immediate term and at the individual level. Research under the Harvest Plus Initiative in 12 countries in Africa, Asia, and Latin America indicates that developing and disseminating biofortified crops is a highly cost-effective means of reducing micronutrientmalnutrition in the developing world” (Gulati *et al.*, 2012). The adoption of fortified foodought to be integrated with larger production andcropping strategies to make the food widely availableand cost-efficient.

Growth in productivity via diversification intohigh-value agriculture (fruits and vegetables, fisheries,and livestock) can also promote nutritional security. First, high-value agriculture can be instrumental inboosting incomes of farmers, especially smallholdersand woman-headed households. Special focus on the vulnerable, such as woman farmers and cultivatorsand woman-headed households, in providing accessto credit, special training and extension programs, etc.can be useful. The resultant income growth can emergeas one of the most sustainable means to improve nutritionaloutcomes, as households whose income has increased tend to invest in better quality and quantity of food as well as housing and essential household amenities. It also provides more nutritious food for short-run self-consumption purposes.

Homestead production of fruits and vegetables and livestock rearing, combined with nutrition education, was launched to combat vitamin A deficiency from the early 1990s onwards (especially targeting households represented by women). The intakes of nutritional food increased, especially among women and children. High-value products like fruits and vegetables are perishable, postharvest activities, such as handling, transport, storage, processing, quality control and testing and marketing, are criticalto preserve and even enhance their nutritional value.

Dietary diversification can be instrumental in improving nutritional outcomes. A large partof the Indian diet still depends on cereals (especiallyin poorer households), which do not always offer the best-quality nutrients. (Gulati *et al.,* 2012). It is estimated that rural Indians obtain 66% and urban Indians 56% of theirproteins from cereals, which are of poorer quality thanproteins from pulses, meat, fish and eggs. The bottom 30% of the population in terms of mean per capita.

The Indian government has recognized malnutrition as a serious problem in every plan document. However, a pressing issue is the absence of a comprehensive and functioning National nutrition Strategy.

During the 1950s and 1960s, because of the food shortages, nutritional security was seen as dependent on first making food available to the masses by increasing grain production. The first nutrition specific intervention scheme was launched under the department of food like nutrition education and fortification of some food items, such as iodization of salt and the Applied Nutrition Scheme under the Ministry of Rural Development (in selected blocks, nutrition education activities and assistance in production and preparation of foods through community gardens, poultry farming, fish culture, etc.,).

More innovative steps need to be taken by the government to tackle the problem as suggested by Gulati *et al.*, 2012 that to tackle the protein deficit, a more cost-effective and nutritious option is to use soybean meal (which has 40% protein compared with 20% to 25% in pulses) in food-based safety nets. India has witnessed relatively high growth in the soybean crop. The increased output has been used by the feed industry or exported. Reconstituted soybean flour (*dhal*) can be sold through the public distribution system, as well as distributed in the Mid-Day Meals Scheme and Integrated Child Development Scheme in cooked meals to enrich dietary intake.

The following specific agro-food strategies for priority consideration would be as below : (1) increased production and lowered cost of pulses to enhance their consumption; (2) improvement in the perennial availability of vegetables and fruits at an affordable cost; (3) increased production of coarse grains, which could also be used to meet the energy requirements of below-poverty-line families at lower cost; (4) taxation of unhealthy (non-communicable-disease-promoting) vegetable oils and fats and possibly, after careful consideration of trade-offs, taxation of all edible oils; (5) taxation of sugar added to beverages; (6) regulatory measures to control the amount of sugar, oil/fat, and salt in processed foods, coupled with their nutritional content labelling; and (7) regulatory measures to restrict the marketing of unhealthy foods, particularly through advertisements. It would be prudent to caution that these possibilities would need detailed research and analyses prior to considering interventions, preferably on a pilot basis.

Inclusive growth in agriculture is important for strengthening the linkages between agriculture and nutrition. The shifting consumption patterns toward non-cereals provide an opportunity for small farmers to diversify their agriculture. Inclusiveness and equity in agriculture can be achieved by having policies for increasing agricultural productivity in lagging areas like rainfed areas and raising productivity and income of small and marginal farmers. Therefore, inclusive, climate smart, efficient and sustainable policies are needed to strengthen the agriculture-nutrition linkage.

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15 Agri Food Value Chain Markets for Nutrition

Anurag Chaturvedi

Introduction

South Asia has experienced rapid economic growth, yet it still has the highest rate of child malnutrition in the world, and half the population is undernourished. Besides children, under nutrition among women and adolescent girls is also a major concern. The lack of progress in solving under nutrition, in all its guises, reflects in part the complexity of factors involved.

There is increasing interest in the links between agriculture and nutrition outcomes in consumers who derive some or all of their food through markets. Seeing that many households rely on food purchases for all or part of their nutrient intake, attention is being given to the scope for developing and improving the functionality of agri-food value chains for better nutrition. Also, many households in South Asia rely on market purchases seasonally or year round, for some or all of their dietary needs. For these people, access to food depends upon how the food markets function. At the same time, it is being increasingly recognized that private sector players (at all scales, from large -scale food processors to informal sector traders and processing operations) have a critical role to play, not only because they operate at scale and bring know-how and financial and other resources, but also because of their existing involvement in markets for food.

Agri-food businesses, medium-scale and small-scale processors of staple foods, and private health networks now have an active involvement in the production, marketing, and consumer choice in the purchase of food and other nutrition-relevant goods and services. The key outcomes that value chains need to achieve in order to bring about improvements in the micronutrient intake of those who are currently deficient, through sustained increased consumption of nutrient-dense foods.

The conceptual framework specifically focuses on understanding the effectiveness of interventions in enhancing the performance of food markets in terms of the availability, affordability, acceptability and consumption of nutritious foods by the poor on a sustained basis, with particular emphasis on infants and women of child-bearing age. The ultimate aim is to identify the most effective strategies for ensuring that nutritious foods get to the poor and are eaten.

Nutrition Goals

- Increase the supply of accessible (available and affordable) nutritious foods for the poor all year round
- Increase the demand for and acceptability of nutritious foods for the poor
- Increase coordination among value-chain actors and activities
- Address the trade-offs between economic returns and nutritional benefits from agriculture in the value chain

Limitations of Value-chain Approaches for Nutrition

- The focus on value addition and differentiated products may leave out poor consumers.
- Consumers are not actors in the chain.
- “Value” means economic value. The focus on single food commodities neglects dietary diversity.
- The focus on competitive markets leaves out other markets.

Overall the potential of value chains for nutrition is considerable. Yet the limitations to value-chain approaches to nutrition are real and should be recognized in order to guide the effective development of value chains for nutrition. In a value chain, value is added to the product along the supply chain through certain activities including storage, distribution, and processing and the work of many actors. Conceptually, there are three main channels for value chains to improve nutrition: (1) through increased consumption of nutritious foods (a demand side pathway); or (2) through increased incomes from value chain transactions (a supply side pathway) or (3) through increased nutrition value-addition in the chain transactions. These three pathways are interlinked and involve complex dynamics that are not straightforward to understand

Agriculture in India is poorly configured towards positive direct impacts on food security. Food security is not an end in itself, of course, but is a means to other ends, such as nutritional sufficiency and finally health. The ability of the poor to access a varied diet comprised of nutritious foods is critical , but nutritional outcomes are also decisively affected by caring practices, health, sanitation, and empowerment of women, among other things. There is clearly a need for investments to boost agricultural productivity, to prevent the global and regional escalation of food prices in the face of demand expansion due to population growth and rising incomes, and to boost farm incomes by addressing these issues is through the adoption of "value-chain" concepts. Value-chain approaches are already used in international development to enhance the livelihoods of food producers, but they rarely consider diet quality and nutrition.

A Sustainable Food Value Chain (SFVC) is Defined as

The full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources.

Two core elements are embedded in definition of a value chain: chain and value. The chain component of value chain refers to a supply chain the processes and actors that take a product from its conception to its end use and disposal (this chain can also be seen as the life cycle of the product). For a single food or commodity product, a supply chain comprises the processes and actors that take a food from its production on the farm including the inputs into that production to the consumer and to its disposal as waste.

Key Value-Chain Concepts

Value chain: A supply chain in which value is added to the product as it moves through the chain. It is described by the series of activities and actors along the supply chain, and what and where value is added in the chain for and by these activities and actors.

Value-chain analysis: The analysis of where, how, and why value is added and created along the chain. Its objective is to understand why the value chain is structured as it is and how it could be leveraged for change.

Five Different Types of Upgrading in a Value Chain

Process upgrading: Improving processes, such as increasing the efficiency of internal processes, improving client management, or reducing waste.

Product upgrading: Introducing new products or improving old products to give them greater unit value, complying with standards for those products, or shifting away from high-value markets to gain more value from bulk markets.

Volume upgrading: Producing more of the product.

Functional upgrading: Changing the mix of activities conducted to gain more value from the chain, such as taking on a new function in the chain (for example, farmers involved in processing as well as growing) or offloading such a function.

Improving value-chain coordination: Improving coordination in the chain to improve performance. The value-chain approach to economic development is thus a market-based framework focused on private sector development in the activities and sectors in which poor people are concentrated (for example, labor-intensive industries, natural products, agriculture, and small enterprises). It often involves linking informal to formal markets. The U.S. Agency for International Development (USAID), for example, takes a value-chain approach in its work supporting the development of microenterprises in developing countries. The United Nations Industrial

Development Organization (UNIDO), a technical cooperation agency, takes a value-chain approach to capacity building for market access and development in developing countries, including for agro-food chains. As part of its Job Creation and Enterprise Development Department, the Inter-national Labour Organization (ILO) has a Value Chain Development Program that seeks to develop value chains that "channel more benefits to the poor and create more jobs effectively"

Requirements of an Effective Value Chain

Food must be safe to eat on a sustained basis: Microbiological contaminants, Naturally-occurring toxicants such as mycotoxins, high levels of residues, heavy metals.

Food must be nutrient-dense at the point of consumption: The potential loss of nutrients along the value chains during processing, storage, distribution and/or preparation due to spoilage, adulteration, inappropriate handling or preparation methods, etc. should be avoided

Food must be consumed in adequate amounts on a sustained basis to bring about the desired nutritional outcomes: The target food has to be actually consumed by those that need it and in sufficient quantities over time to meet their nutritional needs on an ongoing basis.

The emphasis here is on the viability of market approaches in enabling the purchase and consumption of foods that will reduce under-nutrition by the population groups most in need of them. These outcomes are dependent on conditions like the households in which the target population must choose to eat the target food. Second, the business/supply-side there must be incentives for actors along the value chain to produce, process and distribute the food in such a way that the target consumers are able and willing to choose the target food. While it might be possible to make nutrient-dense foods physically available in markets frequented by the poor, this might require the use of new and more costly distribution systems.

Making safe, nutrient-rich foods more accessible to people on low-incomes is one way to reduce micronutrient under nutrition (the lack of essential nutrients and minerals required by the body for healthy development). Efforts to integrate better agriculture and nutrition are focused on this goal, and many initiatives target low-income farm households. Examples of this approach include promotion of home gardens and schemes to increase the production and consumption of nutrient-rich foods (fish, fruit and vegetables, chickens) by farm households. In South Asia, a large proportion of the poorest people depend on agriculture for their livelihoods, so farm-based initiatives are important. However, it is increasingly recognized that most low-income households buy some or all of their food in markets. Even farm households frequently buy some of their foods in markets and dependence on markets for obtaining food is even greater for rural non-farm, landless and urban households. In addition, public agencies often acquire food for distribution to low-income households through markets.

Research teams in Bangladesh, India and Pakistan are investigating the effectiveness of different routes for delivering good quality nutrient-dense food to low-income and undernourished people. The potential routes are many and varied. They include:

- Promoting local markets for nutrient-rich foods (millets, dairy, vegetables, etc.)
- Food distribution programmes (such as the Public Distribution System in India)
- Mandatory fortification programmes for staple foods (such as adding vitamin A to cooking oil, or cereal-based products, to reduce the incidence of blindness)
- Marketing of products enhanced with vitamins and minerals aimed at particular population groups. For example the Grameen Danone shoktidoi yoghurt for children was targeted at families in low-income communities.

As well as requiring a better understanding of food systems and how undernourished people buy their food, they also raise issues relating to:

- Gender. Who makes household decisions about food purchases? Whose workload is affected by decisions to buy and/or process different foods? Do female infants and women of childbearing age have access to the food they need?

- State capacity. How can States in South Asia make food-based strategies for reducing under nutrition more effective? Their willingness and ability to intervene in the ways that are required?
- Innovation. Delivering foods to populations beyond the farm by collaboration and coordination between multiple actors, private and public sectors.

Initiatives based on market incentives typically face two overlapping sets of market constraints that inhibit them from marketing nutrient-rich foods to these groups:

- Constraints related to nutrition: low awareness/demand, poor information and difficulties in targeting products at priority groups infant children, adolescent girls, and pregnant and breastfeeding women;
- Constraints related to the characteristics of markets serving low-income groups: high costs of distribution, low population density and low spending power.

Reviews of all three types of value chain interventions in Bangladesh, India and Pakistan showed that all different interventions face challenges in distributing their products to undernourished consumers.

The success of such interventions relies heavily on well-functioning markets and distribution systems, and on consumer awareness of the value of nutrition; characteristics which are often lacking. As no successful examples exist it is necessary to study the *potential* of market-based interventions in enhancing the consumption of nutrient-dense foods by low-income, undernourished populations. Interventions promoting naturally nutrient dense foods and foods of enhanced nutritional value struggle to ensure that the product is affordable and accessible to those who most require it. In addition, consumers need to have a certain level of nutritional awareness to prioritize purchasing such foods. For food distribution programme ensuring a consistent supply of produce and ensuring it is actually being consumed by the targeted populations, are essential to their success. The diversity of these supply, distribution, marketing, and consumption challenges necessitates the involvement of multiple sectors in order to overcome them.

This makes public-private partnerships important in ensuring that nutritious food is delivered to and consumed by undernourished people. In addition, people affected by under nutrition belong disproportionately to lower income groups, who buy food in the informal sector. This makes it important to identify market-based solutions in both the formal and informal sectors.

Policy Implications

These initial findings help identify some broad implications for policy:

Some agricultural development initiatives could expand the benefits of their programmes to improve nutrition outcomes for low-income rural non-farm, landless and urban households.

Agricultural development initiatives are still largely being used as a tool to improve livelihoods, not nutrition outcomes. To the extent that there is a nutrition focus, this is largely confined to promoting improved consumption on beneficiary farms.

How agri-food value chains function beyond the farm, and how policy interventions can make these chains more effective in reducing undernutrition, is a critical area not yet sufficiently examined

There needs to be more focus on the informal sector, but providers in this sector need to improve safety and nutritional quality.

Agri-food value chain interventions which have a focus on providing nutrient-dense foods to low-income consumers typically work to modernize existing value chains. They do this through improving technology, linkages, processing, investment and training. However, such interventions typically do not work with informal sector food businesses and industries, which are the source of much of the food bought by low-income households. Informal sector providers tend to be competitive on cost, and have good knowledge of local needs. However, these providers need to improve the safety, nutritional quality and consistency of their products if this sector is to play a significant role in reducing undernutrition amongst low-income groups

Fortified staples have a strong potential to address undernutrition amongst target populations, but require the right processes and policy in place.

Food fortification has the advantage of reaching very broad swathes of the population at a relatively low cost. Fortificants can be selected to address particular health problems and the associated nutrient deficiencies (anaemia, zinc deficiency, etc.,). However, the effectiveness of such interventions depends on two factors. The first is ensuring that the correct levels of fortification are achieved and products reach households without undue degradation of quality. This requires effective government regulation of food fortification businesses. The second is to ensure that the fortified foods are accessible and affordable for the poorest households; otherwise, they will continue to use non-fortified alternatives.

Businesses in South Asia do market fortified non-staple foods. These products are marketed to a range of consumers, and in some cases sales to higher-income groups subsidize sales to low-income groups. When sold to low-income people, affordability is a critical issue, and so packaging in small quantities is important. Brands like Gro Aur in Pakistan advertise to households who already have some nutrition awareness, a strategy which could potentially exclude many low income households. Particular efforts have to be made to ensure these products reach poor consumers. This may be through directed and subsidized marketing programmes targeted at the poor (for example, GrameenDanone yoghurt, which is produced in the size and at a price point that low-income households can afford), or a combination of private production and public distribution (Tiger Brand biscuits).

Conclusion

Building more effective linkages between agriculture and nutrition requires initiatives on multiple fronts. Some of these initiatives will focus on improving farm inputs and the diets of farm households. Equally, however, improving the flow of food along value chains from farms through to consumers in both urban and rural areas should improve the diets and contribute to reducing nutritional deficiencies amongst larger undernourished and low-income households. Understanding how food value chains work and the role of both public and private actors in making them work more effectively should enable better policy interventions to improve agriculture-nutrition linkages.

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16 Scope of Insect Farming and Entomophagy

M Srinivasa Rao

Introduction

In 2050 the world population is estimated at more than 9 billion people, resulting in an additional need for food of half the current needs. This will demand increased output from available agroecosystems. Greater pressure on the environment, agricultural land, water resources, forests, fish supply and biodiversity, as well as an increased need for nutrients and non-renewable energy, is predicted (FAO, 2015). There is an urgent need for innovative solutions. Conventional protein sources may be insufficient and we will have to focus on alternative sources, which may be edible insects.

Insects are included in the human diet in most parts of the world, with Europe and parts of North America being two exceptions (FAO, 2013). In Africa, Southeast Asia and the northern parts of Latin America, this large group of animals is a popular delicacy and an interesting assortment of food enrichment. Edible insects contain high quality protein, fat, vitamins and minerals (Rumpold and Schluter, 2013; Makkar *et al*., 2014) and are also considered tasty and even delicious by those accustomed to eating them (De Foliart, 1999).

What is Entomophagy?

The practice of eating insects is called entomophagy. The word “entomophagy” derives from the Greek term “entomos” or “entomon” - “insect” and “phagein”- “to eat”. It literally means “insect eating”.

Before humans had tools to hunt or farm, insects may have represented an important part of their diet. Evidence has been found analyzing coprolites from caves in the US and Mexico. Coprolites in caves in the Ozark Mountains were found to contain ants, beetle larvae, lice, ticks, and mites. Evidence suggests that evolutionary precursors of *Homo sapiens* were also entomophagous (https://en.wikipedia.org/wiki/Entomophagy).

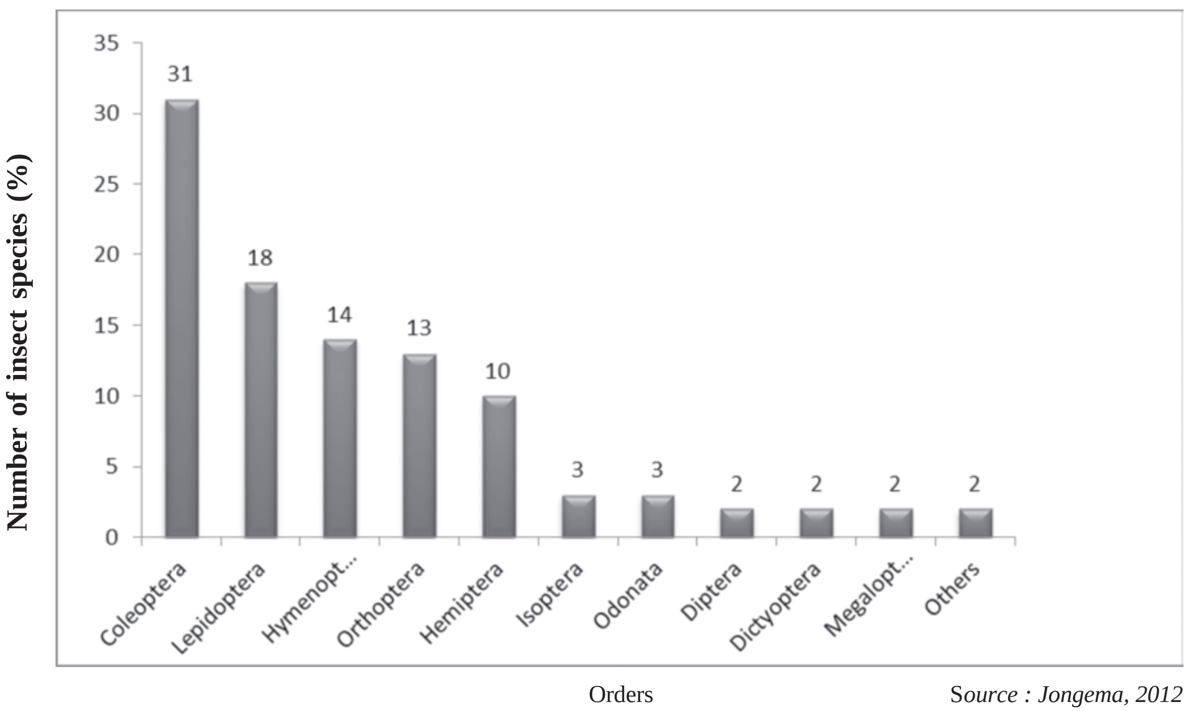
The first reference to entomophagy in Europe was in Greece, where eating cicadas was considered a delicacy. Aristotle (384–322 BCE) wrote in his *Historia Animalium*: “The larva of the cicada on attaining full size in the ground becomes a nymph; then it taste”. He also mentioned that, of the adults, females taste best after copulation because they are full of eggs. In the second century BCE, Diodorus of Sicily called people from Ethiopia *Acridophagi*, or “eaters of locusts and grasshoppers” (*Acrididae*: Orthoptera). In Ancient Rome, natural philosopher and naturalist Pliny the Elder – author of the encyclopedia *Historia Naturalis* – spoke of cossus (larva of the longhorn beetle *Cerambyxcerdo*), a dish highly coveted by Romans. Li Shizhen’s *Compendium of Materia Medica*, one of the largest and most comprehensive books on Chinese medicine during the Ming Dynasty in China (1368–1644), displays an impressive record of all foods, including a large number of insects. The compendium also highlights the medicinal benefits of the insects (FAO, 2013).

Why do we Eat Insects?

The consumption of insects is preferred because of various benefits viz., health, environmental and social/livelihood benefits (FAO, 2013). Being richest source of edible protein the production of insect protein is cost effective also. The details of major three benefits are as follows. The health benefits include i. Insects provide high-quality protein and nutrients comparable with meat and fish; ii. Insects are particularly important as a food supplement for undernourished children because most insect species are high in fatty acids; iii. They are also rich in fibre and micronutrients such as copper, iron, magnesium, manganese, phosphorous, selenium and zinc; iv. Insects pose a low risk of transmitting zoonotic diseases such as like bird flu and mad cow disease. Similarly Environmental benefits include: i. Insects have high feed conversion efficiency because they are cold-blooded. ii. The production of greenhouse gases by most insects is likely to be lower than that of conventional livestock. iii. Insects use significantly less water than conventional livestock; iv. Insect farming is less land-dependent than conventional livestock farming. Livelihood and social benefits include: i. Insect gathering and rearing can offer important livelihood diversification strategies. Insects can be directly and easily collected in the wild. Minimal technical or capital expenditure is required for basic harvesting and rearing equipment; ii. Insects can be gathered in the wild, cultivated, processed and sold by the poorest members of society; iii. Insect harvesting and farming can provide entrepreneurship opportunities in developed, transitional and developing economies; iv. Insects can be processed for food and feed relatively easily. Some species can be consumed whole.

Consumption Status of Insects – Global Trend

It is estimated that edible insects are part of the diet of at least two billion people and more than 1900 insect species are currently used as food. The insects most commonly consumed worldwide are beetles (Coleoptera, 31%), caterpillars (Lepidoptera, 18%) and bees, wasps and ants (Hymenoptera, 14%). Moreover, grasshoppers, crickets and locusts (Orthoptera, 13%) and cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera, 10%) are consumed. Termites (Isoptera), dragonflies (Odonata), flies (Diptera) and other insects each comprise less than 3% of insects consumed (Jongema, 2012) (Fig 1).



Source : Jongema, 2012

Fig. 1. Number of insect species, by order, consumed worldwide

Lepidoptera are consumed almost entirely as caterpillars and Hymenoptera are consumed mostly in their larval or pupal stages. Both adults andlarvae of the Coleoptera order are eaten, while Orthoptera, Homoptera, Isoptera and Hemiptera orders are mostly eaten in the mature stage (Table 1).

Table 1. Consumption of insect in different countries

Country	Consumption of Insect
South America	Butterfly,Grasshoppers, crickets, Cicadas, Ants, Flies, Bees and Wasps
Colombia	Giant queen ants, Palm grubs and Caterpillars
Asia	Grasshoppers, Crickets, Silk worm pupa, Dragonflies, Termites, and Beetles
Thailand	Giant water beetles
Africa	Caterpillars, Mopane worms, Termites and Locusts
Australia	Honey ants, Grubs, Moths, and Cerambycid beetles
China	Silkworm pupae, Fly larvae, Crickets, Blattaria,Termites and Locusts
India	Termites, Dragonflies, Grasshoppers, Ants, Eri and Mulberry silkworms, Honey bees, Crickets

Scope of Entomophagy Under Climate Change Scenario

Climate change is exacerbated by excessive land clearance, and by the greenhouse gas emissions (GHGEs) generated by food pro-duction. Changes in the earth's temperature and in sea levels are in turn expected to have a severe impact on global agri-cultural production, particularly in some of the world's poorest areas (Winsemius *et al*., 2015). The need to change our food system to combat climate change is now unequivocal, particularly since climate change itself is predicted to have devastating effects on global agriculture (Nelson *et al*., 2014). The most significant component of agriculture that contributes to climate change is livestock. Globally, beef cattle and milk cattle have the most significant impact in terms of GHGEs, and are responsible for 41% of the world's CO_2 emissions and 20% of the total global GHGEs (Gerber *et al*., 2013). The atmospheric increases in GHGEs caused by the transport, land clearance, methane emissions, and grain cultivation associated with the livestock industry is the main drivers behind increases in global temperatures.

In contrast to conventional livestock, insects as "minilivestock" are low-GHGE emitters (Oonincx *et al*., 2010), use minimal land, can be fed on food waste rather than cultivated grain, and can be farmed anywhere thus potentially also avoiding GHGEs caused by long distance transportation. If there was a dietary shift toward increased insect consump-tion and decreased meat consumption worldwide, the global warming potential of the food system would be significantly reduced. It is estimated that the global climate change will have profound impacts on virtually all ecosystems. The climate change is set to influence both plants and insects alike. Insects have a unique symbiotic relationship with plant life (Fleshman, 2007). Plants and insects that may not adapt to new changes will have to give way to the survivors and these survivors will have to re-group at different suitable habitats.

In addition to the environmental impacts of livestock in terms of land use, greenhouse gas emissions, and use of nonrenewable energy, the water footprint of mammalian and avian food production is extortionate. Depletion of water resources worldwide calls for a concerted effort to develop future food products that are less water-dependent, and insects are an ideal candidate. To put 1 kg of corn-fed beef steak on the table requires 22,000 L water. Much of this is due to the water footprint of feed crops, which have had devastating effects on natural river systems worldwide. The problems are wicked and food security is the mother of all wicked problems. This calls for extraordinary action and creative solutions. Insects consume much less water than vertebrate livestock by gaining hydration straight from food (Boardman *et al*., 2013). Crickets, for instance, only demand a tiny quantity of food and water to mature. For example, it is necessary to have around 1 gallon of water to grow 1 pound of crickets and 200 gallons of water to grow simply one cow (Ivy *et al*., 1999).

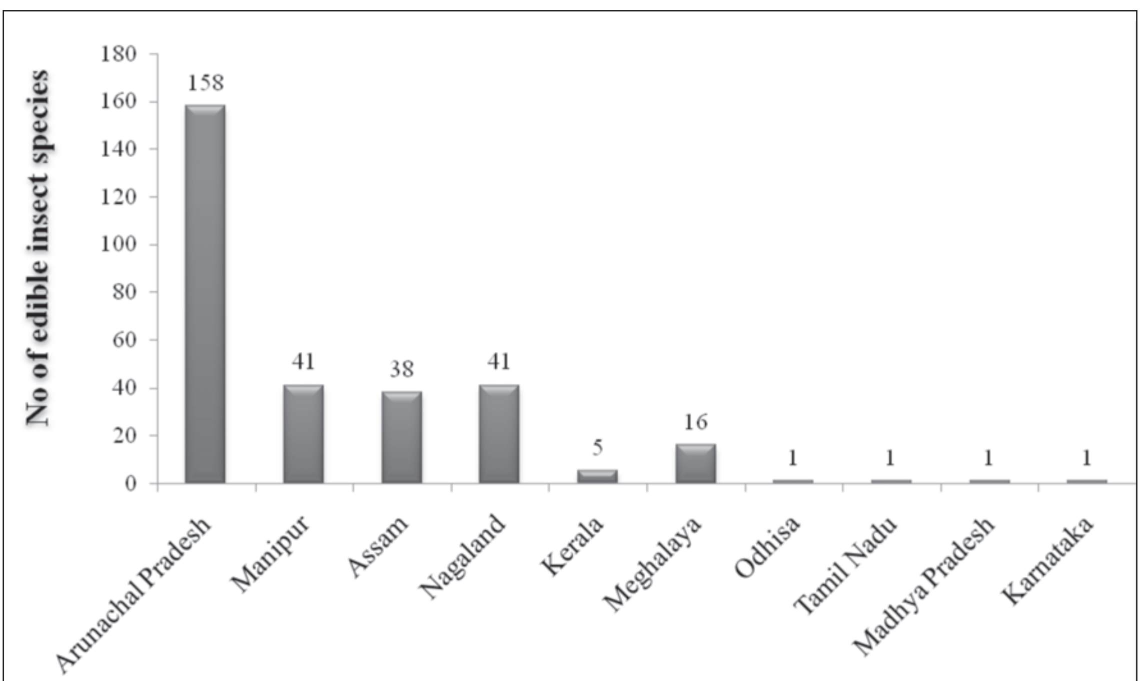
Moisture availability and variability have been shown to be a major determinant of insect habitats. In certain areas, the weather conditions have kept termite mounds moist much longer. This has also encouraged high reproduction in the termites and this has resulted in large populations of alates swarming to form new colonies. Swarming and migration in insects can also be triggered by changes in ambient temperature (Rabb and

Kennedy, 1979). Insects also respond to change in their thermal environment through migration, adaptation or evolution. As such, the insects are able to adopt faster and widely spread to other areas to survive the climate changes, thereby increasing their availability to human population.

Consumption Status in India

Insects, a traditional food in many parts of the world, are highly nutritious and especially rich in proteins. The ethnic people of India also consume insects as food. Food insects are chosen by members of various tribes according to their traditional beliefs, taste, regional and seasonal availability of the edible insects. Preparation of the edible insects for consumption involves mainly roasting or boiling. Sometimes spices are added to enhance the taste. Practice of entomophagy is quite common among the ethnic people of North East India particularly among the tribes of Arunachal Pradesh, Assam, Manipur and Nagaland and to a lesser extent by the tribes of Meghalaya and Mizoram. Comparatively this practice is much lower among the ethnic people of Kerala, Tamil Nadu, Madhya Pradesh, Odisha of South and Central part of India.

A total of about 255 species of edible insects so far recorded from different parts of India. Among the ethnic people of India, the tribes ofArunachal Pradesh outreaches in terms of number of edible insects taken as food, a total of about 158 species, this is followed by in Manipur, Assam and Nagaland (16 to 40 insect species) and to a lesser extent in Meghalaya (Fig.2). However, in Kerala, Madhya Pradesh, Odisha, Tamil Nadu and Karnataka, this number limits only six insect species (Chakravorty, 2014). Thakur and Firake (2012) reported that the cinnamon bug, *Ochrophora montona* (Distant) Heteroptera: Pentatomidae) is fried in oil and consumed in Assam, Mizoram Manipur and Tripura. Paul and Dey (2011) reported termites from Meghalaya served as a source of protein and carbohydrate. The consumption of coleopteran species was highest constituting about 34%; next come Orthoptera (24%); Hemiptera (17%); Hymanoptera (10%); Odonata (8%); Lepidoptera (4%); Isoptera (2%) and the least was Ephemeroptera (1%).



Source : Chakravorty, 2014

Fig. 2. Order wise distribution of edible insects from India

Preference of edible insects though varies from tribe to tribe and region to regionbut in general the ethic tribes of Manipur prefer to consume more of Hemipterans while in Arunachal it is Coleopteran species. The termites are preferred by the tribes throughout India. Preference given to insect species utilized as food by ethnic people of India depends on the insects palatability, availability, and nutritional valueas well as on local traditions and customs (Chakravorty, 2014).

Nutritional Value of Edible Insects

The nutrient content of insects varies considerably between species. Even within the same group of edible insect species, values may differ depending on the metamorphic stage of the insect, habitat and diet.Preparation and processing methods (e.g. drying, boiling or frying) applied before consumption will also influence nutritional composition. Insects have rich protein (20-70 percent), amino acid (30-60 percent), fat (10-50 percent), carbohydrate (2-10 percent), mineral elements, vitamins and other activated elements that promote human health (Chen *et al.*, 2008) (Table 2).

Table 2. Protein, Amino acid, Fat and Carbohydrate content of edible insects (% dry weight)

Order	Protein		Amino acids		Fat		Carbohydrate	
	High	Low	High	Low	High	Low	High	Low
Odonata	65.45	46.37	41.28	14.23	4.78	2.36	51.70	36.10
Orthoptera	65.39	22.80	34.60	2.2	3.90	1.20	57.51	20.23
Homoptera	57.14	44.67	30.60	24.85	2.80	1.54	53.19	32.59
Hemiptera	73.52	42.49	44.30	9.73	4.37	2.04	59.68	38.09
Coleoptera	66.20	23.20	35.86	14.05	2.82	2.79	62.97	13.27
Lepidoptera	68.30	14.05	49.48	5.0	16.27	3.65	61.84	13.27
Hymenoptera	76.69	12.65	55.10	7.99	7.15	1.95	81.27	21.00

Insect Farming

In many places insects are plentiful and widely available, and can be easily cultivated, demanding minimal space, needing far less breeding space than larger animals and producing far less pollution (Dar, 2014). Furthermore, the whole insect can be used or processed into food, contrarily to larger domestic food animals, whose offal, bones and blood are almost never used as food (Melo-Ruiz *et al*., 2013). Since meat production contributes to between 14 to 22% of all greenhouse gases sent into the atmosphere every year (Scholtz *et al.*, 2014), it has been suggested that insects can offer specific benefits over conventional livestock for those who want to reduce their environmental footprint such as diminished greenhouse gas and ammonia emission.

Additionally, research shows that insects are known for their capacity to survive under a diversity of ecological circumstances. They have short life cycles and can be grown very quickly from an egg to a standard selling size. It has also been shown that, unlike mammals, insects have a high reproductive ability (Henry *et al*., 2015). Insects feed on a far broader variety of plants than conventional livestock. It has been suggested that they can also efficiently incorporate waste and side streams into the production systems since numerous insects, such as beetles, grasshoppers, crickets and flies are able to eat agricultural waste or plants that humans and traditional livestock are not able to (Klunder *et al.*, 2012). By converting biomass that humans are not able to consume into edible insect mass, it has been suggested that insects do not compete with the human food supply, as do vertebrate livestock such as chickens and cows, which are mainly fed with corn and grain.

Research shows that insects consume much less water than vertebrate livestock by gaining hydration straight from food. Because insects are so dissimilar to humans, they have less risk of producing pathogens threatening to human health when compared to livestock production. In general, they also cost little to source when compared to other animals. In this sense, aside from their nutritional and environmental benefits, experts also see an extensive prospect for edible insects to offer income and jobs for rural people who capture, rear, process, transport and marketing insects as food.

Popularization of Entomophagy

If future nutritional need of man has to be met, entomophagy seems to be the only alternative and, therefore, it must be popularized among the people. Following are some of the ways in which it can be done:

- *Public education*: Government and media should join to educate people on the benefits of insect-eating. While things done by governments are taken more seriously, the media can carry the idea to masses in a more effective way through their glossy ads.
- *Role of scientist*: Advocacy of entomophagy based on scientific research could go a long way to convince both governments and the people on the nutritive value of insects.
- *Development of mass-harvest methods*: Scientists could also develop methods to mass-produce potential food insects like grasshoppers, alate termites, beetles, moths etc. Light traps, simple lanterns, insect pheromones and other attractants could also be employed to mass-collect useful insects.
- *Development of mass production techniques*: It is imperative that the edible insects, if entomophagy has to become popular, should be cheaply available. This cannot be possible by hand-collection of them. Only mechanized methods of mass-production can achieve this objective.
- *Establishment of research institutes*: Such institutes can engage themselves with finding out safe non-toxic food insects, analyse their nutritive value and publicize them, warm people against harmful and less nutritive insects, find applications for insect-byproducts (chitin, frass) and discover such insects that could be employed to recycle the waste matter.

Limitations for Entomophagy

Generally the insects can sting and bite the human being and they can carry and spread the diseases. These things would make us unacceptable to our connection. The pesticides can accumulate and trickle down the food chain, but entomophagy often drives the most extreme solutions. Food plays a huge role in cultural and social identity. Entomophagy has a biological basis in the form of distaste, which prevents us from consuming foods that are potentially harmful. Eating things that are distasteful challenges an individual's identification with a social group as well as that group's acceptance of the individual.

The consumption of insects is treated as social taboo and identified with poor economic class. Consumers mainly associated "insects" and "insects and diet" with feelings of disgust, repugnancy, horror and fear and strong negative emotions. It has been suggested that implicit negative associations and attitudes toward insects affect our responses and preferences for neutral events, objects and people even when we are unaware of the presence of insect-related stimuli. We are almost never stimulated to view insects as fundamental participants in the ecology that supports all of us or as engaged in relationships that allow other animal species and plant to prosper. In most cases, we are equally indifferent to invertebrate extinctions, despite the fact that their disappearance would be disastrous to our existence.

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17 Toxicity of Heavy Metals - Phytoremediation Techniques

K Uma Maheswari and K Rajeswari

Introduction

Soils contaminated with heavy metals are very difficult to restore. Heavy-metal pollution of soil is mainly accredited to human activities, including, smelting, mining and various industrial activities. With the new era of urbanization and industrialization, soils have become more tainted progressively by heavy metals which cause threats to ecosystems, surface, and ground waters, food safety and human health (Muhammad Bilal Shakoor *et al.,* 2013).

Two of the main sources of heavy metal pollution are geological and anthropogenic activities. Anthropogenic sources of heavy metal contamination come from industrial effluents, mining, fuel production, military operations, smelting processes, and utilization of agricultural chemicals, brick kilns, small-scale industries and coal combustion. One of the dominant sources taking part in increased budget of soil pollution include municipal waste disposal, this may be roadside dumping or end up in landfills, while sewage consumed for irrigation purposes (Muhammad Bilal Shakoor *et al.,* 2013). These contaminants are although a handy source of nutrients, but are proved to be carcinogens and sources of toxic metals. Other types of pollution come from unsafe or excess application of fungicides, fertilizers and pesticides. Water polluted with sewage and industrial emissions, resulting in contaminated vegetables and soils are some other sources of heavy metal pollution.

An increased accumulation of heavy metals can have lethal effects on soil fertility; ecosystem functions and poses a health risk to human beings and animals.

Toxic Effects of Heavy

Metals Plants are capable of accumulating “essential” metals (Ca, Co, K, Mo, Na, Mg, Mn, Ni, Se, Cu, Fe, V and Zn) form soil. Plants require different amounts of these for their growth and development (Chhotu D. Jadia

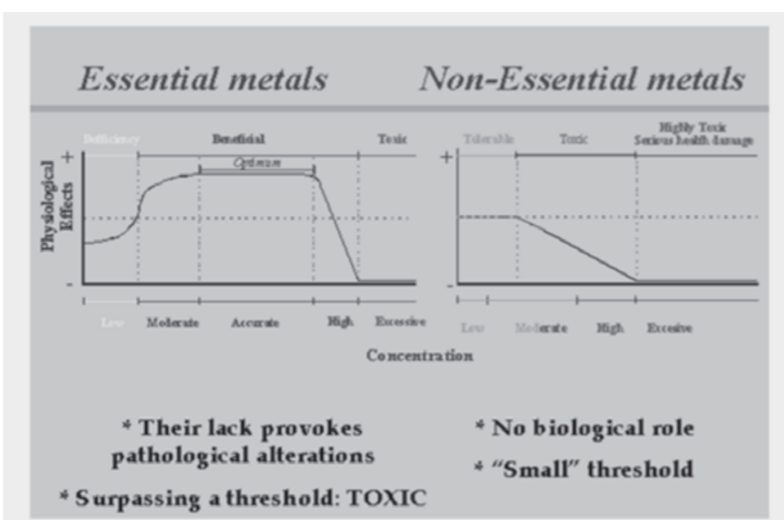

Fig. 1. Conceptual response strategies of metal concentration in plant taps in relation to increasing total metal concentration in the soil

and M. H. Fulekar, 2009). This capability of plants also permits accumulation of other "non- essential" metals (Al, Cd, Cr, As, Hg, Pt, Sb, Te, Pb, Pd, Tl, Au and U) which do not have any contribution in biological function (Fig. 1). Moreover, break down of metals is impossible and when levels inside cells of plant rise above threshold levels, the consequence may be direct toxicity to plant by destroying cell structure and hindering the function of many cytoplasmic enzymes. Moreover, indirect toxic effects may be evident by substitution of nutrients at cation exchange spots in plants (Fig 1).

High levels of metals in soil can be phytotoxic. Poor plant growth and soil cover caused by metal toxicity can lead to metal mobilization in runoff water and subsequent deposition into nearby bodies of water. Furthermore, bare soil is more susceptible to wind erosion and spreading of contamination by airborne dust. In such situations, the immediate goal of remediation is to reclaim the site by establishing a vegetative cover to minimize soil erosion and pollution spread.

It was suggested by Baker (1981), that some plants were able to tolerate presence of high levels of metals in their surrounding by three ways:

- Exclusion, in which there is a restriction of metal transport and metal concentrations are constant and maintained in shoot area over various soil levels
- Inclusion, whereby concentrations of metal in shoots reveal those in the soil solution and having a linear relationship.
- Bioaccumulation, accumulation of metals in the roots and upperparts of plants at both low and high soil levels.

Increased heavy metal levels in the soil can cause elevated crop uptake and it can pose stress on plant growth. At higher quantities, they inhibit growth, obstruct metabolic processes and sometimes plant death may occur. High levels of metals in human nutrition can prove to be toxic and result in acute and chronic disorders.

The remediation of soils contaminated by heavy metals is a cost-intensive and technically complex procedure. Conventional remediation technologies are based on biological, physical, and chemical methods, which may be used in conjunction with one another to reduce the contamination to a safe and acceptable level (Divya Singh *et al.*, 2012). In spite of being efficient, these methods are expensive, time consuming and environmentally destructive. At the same time they are usually harmful to the natural soil environment, and generate large amounts of waste.

Recently, phytoremediation, which is an emerging technology, should be considered for remediation of contaminated sites because of its cost effectiveness, aesthetic advantages and long term applicability.

Phytoremediation

Phytotechnologies an emerging technique during the last two decades and plant based bioremediation technologies that have been collectively termed as phytoremediation. This refers to the use of the green plants to clean up contaminated soil and groundwater. Phytoremediation is a word formed from the Greek prefix "phyto" meaning plant, and the Latin suffix "remedium" meaning to clean or restore. The generic term "Phytoremediation" consists of the Greek prefix phyto (plant), attached to the Latin word remedian (to correct or remove an evil). Phytormediation is an attractive alternative or complementary technology that can be used along with or, in some cases in place of mechanical conventional cleanup treatments that often require high capital inputs, more labor and energy intensive.

Phytoremediation has also been called green remediation, botano-remediation, agro remediation and vegetative remediation. It is a less destructive to the environment, cost effective, aesthetically environmental pollutants removal approach most suitable for developing countries. The plant used in the phytoremediation technique must have a considerable capacity of metal absorption, its accumulation and strength to decrease the treatment time (Anna Ma³achowska Jutsz, Anna Gnida, 2014).

The concept of using hyper accumulator plants to get rid of heavy metals contaminants and other toxins was first initiated in 1983, but in fact the idea has been applied for past three centuries. This method can be implemented to both inorganic and organic contaminants in soil, water and air. The physico-chemical processes for soil treatment make the land worthless for growth of plant as they inhibit all biological functions, including activities of functional microorganisms such as mycorrhiza, fungi, nitrogen fixing bacteria and soil fauna in the course of remediation.

A number of bioremediation procedures are being used to treat soil. Phytoremediation is one of the efficient and potential processes, which recommends the use of plants to extract, seize and detoxify pollutants. There are several ways by which plants cleanup or remediate contaminated sites.

Mechanisms of Metals Uptake Into Roots and Translocation to Shoots

The charge of metal ions allows them not to move freely across the cellular membranes, which are lipophilic structures. Therefore, ion transport into cells must be mediated by membrane proteins with transport functions, generically known as transporters. Transmembrane transporters possess an extracellular binding domain to which the ions attach just before the transport, and a transmembrane structure which connects extracelluar and intracellular media. The binding domain is receptive only to specific ions and is responsible for transporter specificity. The transmembrane structure facilitates the transfer of bound ions from extracellular space through the hydrophobic environment of the membrane into the cell. These transporters are characterized by certain kinetic parameters, such as transport capacity (Vmax) and affinity for ion (Km) (Fig 2).

Vmax measures the maximum rate of ion transport across the cellular membranes. Km measures transporter affinity for a specific ion and represents the ion concentration in the external solution at which the transport rate equals Vmax/2. A low Km value, high affinity, indicates that high levels of ions are transported into the cells even at low external ion concentration. By studying kinetic parameters, Km and Vmax, plant biologists gain insights to specificity and selectivity of the transport system. It is important to note that of the total amount of ions associated with the root, only a part is absorbed into cells. A significant ion fraction is physically adsorbed at the extracellular negatively charged sites (COO-) of the root cell walls. The cell wall-bound fraction cannot be translocated to the shoots and, therefore, cannot be removed by harvesting shoot biomass (phytoextraction). Thus, it is possible that a plant exhibiting significant metal accumulation into the root, to express a limited capacity for phytoextraction. For example, many plants accumulate Pb in roots, but Pb translocation to shoot is very low (Baker and Proctor, 1990).

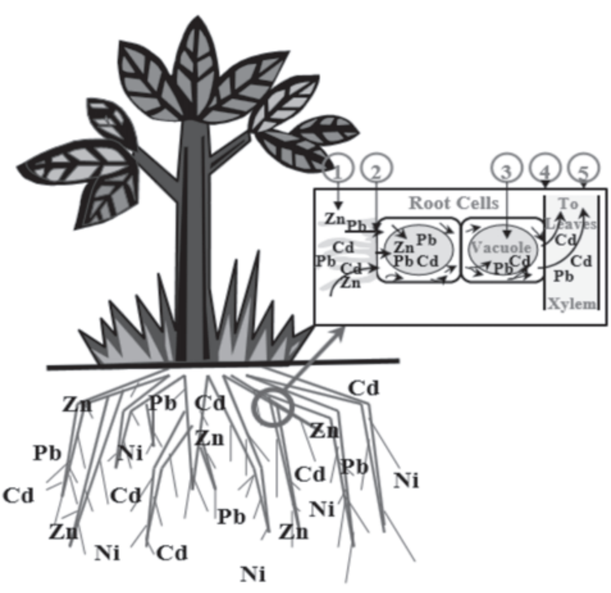

Fig. 2. Mechanism of metal uptake and accumulation in plants

Treatment Methods

Ex-situ method

It requires removal of contaminated soil for treatment on or of site, and returning the treated soil to the resorted site (Rajendra Prasad Bharti *et al*., 2014) For the remediation of polluted soils, conventional methods of ex-situ are applied that depend on excavation, detoxification and devastation of pollutant chemically or physically, which will lead contaminant to become stable, solid and immobile and demolish

In-situ method

Remediation of contaminated site without excavation is in situ. It has been defined as devastation or alteration of the pollutant, immobilization to decrease availability to living organisms and partition of the toxin from the huge mass of soil. In-situ processes have edge on ex-situ processes because they have low cost and have less effect on our ecosystem. On the other hand, the ex-situ process which involves excavation of soil effected with heavy metal pollutants and burial of contaminants in landfill, but the landfil is not an ideal option because it only transfers the pollutants problem to some other areas. It also poses risk to other areas by the transport of polluted soil. Reducing the concentration of heavy metal contaminants to safe level by bringing in the healthy soil and blending with the polluted soil can be a substitute to on-site method. On-site technique of remediation provide a substitute, it includes the cover of inert material on soil. Heavy metal polluted soils can be remediated by making inorganic contaminant immobile. This can be done by making complexes of the contaminants, or by liming for enhancing the pH of soil. Higher pH of soil reduces the solubility of metal elements like Ni, Cu, Cd, and Zn. Many of conventional methods of remediation are costly to execute and form the basis for further interference to previously effected environment.

Different Types Remediation Techniques

Phytoextraction

Phytoextraction is the uptake of contaminants by plant roots (Muhammad *et al*., 2014) and translocation within the plants. Contaminants are generally removed by harvesting the plants. It is the best approach to remove contaminants from soil, sediment and sludge (Fig 3).

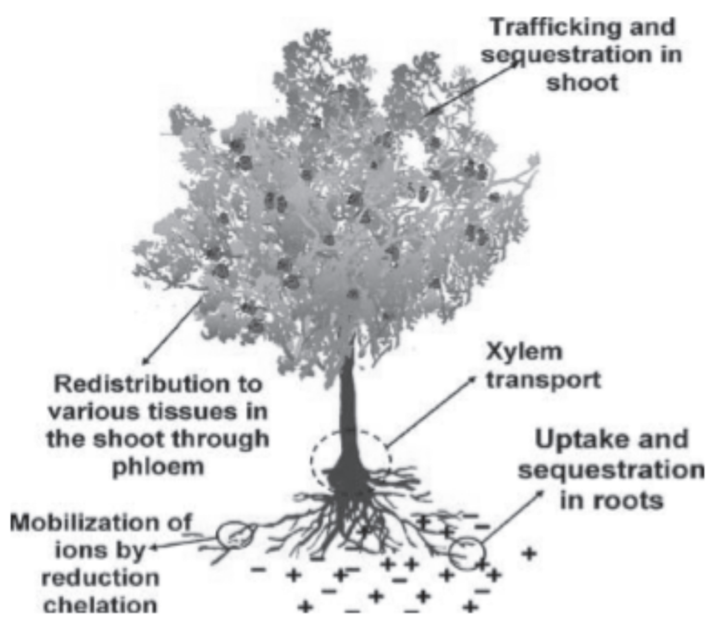

Fig. 3. Schematic representation of mechanism of phytoextraction

a) Continuous or Natural Phytoextraction

Continuous phytoextraction depend on the use of natural hyper accumulator plant with exceptional metal accumulating capacity. Hyper accumulator plant species can accumulate metals up to 100-fold greater than common non-accumulator plant. So, a hyper accumulator plant will concentrate more than 100mg kg”1 Cd, 10mg kg”1 Hg, 1000mg kg”1 Co, Cr, Cu and Pb; 10 000mg kg”1 Ni and Zn.

b) Chelate-assisted (induced) Phytoextraction

Chelant enhanced phytoextraction of metals from contaminated soil have received much attention as cost effective alternative to conventional techniques of improved soil remediation from contaminated soil for more than 10 years. When chelating agent is applied to soil, they form metal chelant complexes which are then taken by plant mostly through a passive apoplastic. Chelators which are strongly involved in the uptake of heavy metals and their detoxification have been isolated from plant (Gaikwad Rupali S. and Khan Shahana J., 2014) TDTA is one of the chelating agents which are the most tested mobilizing amendments for less mobile/ available metals such as Pb.

Rhizofiltration

It is defined as the use of plants, both terrestrial and aquatic, to absorb, concentrate and contaminants from polluted aqueous sources in their roots. Terrestrial plants are more preferred because they (B. Seshadri *et al.* 2015) have a fibrous and much longer root system, increasing amount of root area that effectively removed the potentially toxic metals.

The action of plant rhizosphere is one of the key factors in establishing phytoremediation crops under (typically) harsh conditions. Selection of suitable plants not only enable uptake of specific heavy metals (phytoextraction) but also helps in controlling the bioavailability of the pollutant (phytoimmobilisation) and thereby degradation through ageing (phytodegradation).

Since the processes are initiated at the rhizosphere region, terminologies such as rhizoremediation, rhizodegradation and rhizovolatalisation can also be used, alternatively. There are numerous reviews on the rhizosphere action in phytoremediation over the past two decades

The Role of Rhizosphere Processes in Phytoremediation

Phytoremediation or plant-assisted bioremediation refers (Wenzel (2009) to the use of plants to (Fig 4) :

- Stabilise or immobilise contaminants in soils or sediments which can be termed as phytostabilisation or phytoimmobilisation, respectively
- Volatilise some metals and metalloids by the formation of volatile compounds by the action of rhizosphere microorganisms or after uptake in plant organs – phyto-volatalisation/rhizo-volatalisation
- Extract metals/metalloids via uptake in harvestable plant parts, i.e. typically shoots, which can be termed as phytomining

Remove organic pollutants via microbial degradation in the plant rhizosphere or by metabolising them after uptake in plant organs – phyto-degradation/rhizodegradation

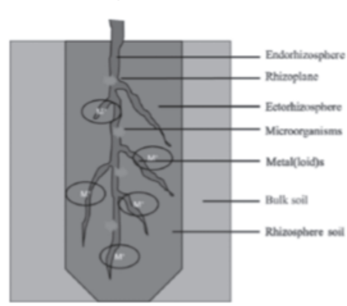

Fig. 4. A section of soil showing bulk soil and rizosphere soil with three regions of rhizospere

Phytostabilization

In this phenomenon use of plants to reduce the mobility bioavailability of pollutants in the environment, thus preventing their migration to groundwater or their entry into food chain (Singh, 2012).

Phytovolatilization

The use of plants to uptake of contaminants from soil and waste water, transforming them into volatilized compound and then transpiring into the atmosphere is known as phytovolatilization (Padmavathiamma and Li, 2007). When using different forms of phytoremediation there are many positive and negative aspects to consider.

Phytodegradation

Phytodegradation is the use of plants and micro-organisms to uptake, metabolize and degrade the organic contaminant. In this approach, plant roots are used in association with microorganisms to detoxify soil contaminated with organic compounds. It is also known as phytotransformation. Some plants are able to decontaminate soil, sludge, sediment, and ground and surface water by producing enzymes. This approach involves organic compounds, including herbicides, insecticides, chlorinated solvents, and inorganic contaminants. Phytodegradation is the breakdown of organic contaminants within plant tissue. Plants produce enzymes, such as dehalogenase and oxygenase that help catalyze degradation. It appears that both the plants and the associated microbial communities play a significant (Doty et al., 2007) role in attenuating contaminants. It is referred to the degradation or breakdown of organic contaminants by internal and external metabolic processes driven by the plant.

Phytoevaporation

Phytoevaporation is associated with the phenomena of contaminants assimilation and transpiration by a plant, and its further release into the atmosphere in the same or modiûed form. This method is applicable for treatment of soils and water contaminated with such inorganic compounds as arsenic, mercury, selenium and their volatile derivatives (The best-known example of phytoevaporation is remediation of soil and groundwater contaminated with selenium. Selenium is taken up by plants in the form of soluble ions SeO42- and SeO32- and secreted in the form of dimethyl selenide. Phytoevaporation of mercury is connected with the breeding of transgenic plants (Arabidopsis thaliana) with the insertion of bacterial genes merA from E. coli (encoding mercury reductase) and merB from Salmonella typhimurium (encoding methylmercury lyase). These enzymes reduce toxic ions Hg2+ to less toxic, volatile metallic mercury Hg0. Despite the attractiveness of the phytoevaporation process (no waste) it poses a major threat to the environment and human life Intake of heavy metals by plants depends mainly on soil pH, redox potential, organic matter content and the presence of other elements. The form of the metal is a very important factor. Free ions are taken the most quickly. Metals enter the interior of the plant cells by diffusion, endocytosis, or with the aid of phytochelatins and metallothioneins characterized by high afûnity for heavy metal. After penetration into the cytoplasm the metal ions are bound by the low molecular weight ligands, and then transported to the vacuole, which protects the plant from serious physiological disorders. Plants have evolved a number of mechanisms protecting them from adverse effects of heavy metals presence.

Rhizodegradation

Rhizodegradation refers to the breakdown of organic pollutants in the soil by microorganisms in the rhizosphere. Rhizosphere extends about 1 mm around the root and is under the inûuence of the plant (The main reason for the enhanced degradation of pollutants in the rhi zosphere is likely the increase in the numbers and metabolic activities of the microbes. Plants can stimulate microbial activity about 10–100 times higher in the rhizosphere by the secretion of exudates containing carbohydrates, amino acids, ûavonoids. The release of nutrients-containing exudates by plant roots provides carbon and nitrogen sources to the soil microbes and creates a nutrient-rich environment in which microbial activity is stimulated. In addition to secreting organic substrates for facilitating the growth and activities of rhizospheric microorganisms, plants also release certain enzymes capable of degrading organic contaminants in soils (Yadav et al., 2010).

Phytodesalination

It is a recently reported and emerging technique. Phytodesalination refers to the use of halophytic plants for removal of salts from salt-affected soils (Rabhi et al., 2010) in order to enable them for supporting normal plant growth. Halophytic plants have been suggested to be naturally better adapted to cope with heavy metals compared to glycophytic plants.

The success of phytoremediation depends upon bioavailability and the capacity of the plant to sequester the metals (Seyyed Gholamreza Moosavi and Mohamd Javad Seghatoleslami, 2013). Plants with high metal extraction capability frequently are slow growing and grow up in small quantities of biomass on metals polluted soil.

The Most Important of Phytoremediation Advantages are:

- Varieties of organic and inorganic compounds are amenable to the phytoremediation process.
- Phytoremediation can be used either as an in situ or ex situ application. In situ applications are frequently considered because minimizes disturbance of the soil and surrounding environment and reduce the spread of contamination via air and waterborne wastes.
- It is a green technology and when properly implemented is both environmentally friendly and aesthetically pleasing to the public. As a green technology, it is applicable for different kinds of organic and inorganic pollutants and provides aesthetic benefits to the environment by using trees and creating green areas, which is socially and psychologically beneficial for all. This green technology is suitable for large areas in which other approaches would be expensive and ineffective.
- Phytoremediation does not require expensive equipment or highly-specialized personnel, and it is relatively easy to implement.
- The greatest advantage of phytoremediation is its low cost compared to conventional clean-up technologies. Disposal sites are not needed.
- It is more likely to be accepted by the public as it is more aesthetically pleasing then traditional methods.
- It avoids excavation and transport of polluted media thus reducing the risk of spreading the contamination.
- It has the potential to treat sites polluted with more than one type of pollutant Furthermore, the expansion of contaminants to air and water is reduced by preventing leaching and soil erosion that may result from wind and water activity.

Disadvantages and Limitations of Phytoremediation

In contrast to its many positive aspects, phytoremediation does have a few disadvantages and limitations that are:

- It is restricted to the rooting depth of remediative plants.
- Remediation with plants is a lengthy process, thus it may take several years or longer to clean up a hazardous waste site, and the contamination may still not be fully remediated. Time is the most serious limitation of phytoremediation, because this approach may require several years for effective remediation.
- The use of invasive, nonnative species can affect biodiversity.
- The consumption of contaminated plants by wildlife is also of concern. Harvested plant biomass produced from the process of phytoextraction may be classified as a RCRA hazardous waste, therefore subject to proper handling and disposal.
- Moreover, preserving the vegetation in extensively contaminated areas is complicated and human health could also be threatened by entering the pollutant into the food chain through animals feeding on the contaminated plants.
- Unfavorable climate is another important consideration because it can limit plant growth and phytomass production, thus decreasing process efficiency.

Phytoextraction of Heavy Metals

Phytoextraction is the main and most useful phytoremediation technique for removal of heavy metals and metalloids from polluted soils, sediments or water. It is the most promising for commercial application (Cluis, 2004). The efûciency of phytoextraction depends on many factors like bioavailability of the heavy metals in soil, soil properties, speciation of the heavy metals and plant species concerned. Plants suitable for phytoextraction should ideally have the following characteristics :

- High growth rate.
- Production of more above-ground biomass.
- Widely distributed and highly branched root system.
- More accumulation of the target heavy metals from soil.
- Translocation of the accumulated heavy metals from roots to shoots.
- Tolerance to the toxic effects of the target heavy metals.
- Good adaptation to prevailing environmental and climatic conditions.
- Resistance to pathogens and pests.
- Easy cultivation and harvest.
- Repulsion to herbivores to avoid food chain contamination

The major dilemma hampering plant remediation effectiveness is that some of the metals are static in soils and their accessibility and phytoextraction rate are restricted by solubility and diffusion to the root surface, chemicals were used to overcome this setback. Numerous studies recognized that chelating agents such as ethylenediamine-tetraacetic acid (EDTA), citric acid (CA) N-(2-hydroxyethyl)-ethylenediaminetriacetic acid (HEDTA) can effectively enhance metal mobility, thereby boosting phytoextraction. Ethylene diamine tetraacetic acid (EDTA) is even though a proficient synthetic chelator however; its persistence for long time in soil and its slow degradation rate amplify its leaching hazard. On the other hand, LMWOA e.g. citric acid is a better substitute to EDTA for the phytoextraction of heavy metals because it is effortlessly biodegradable in the environment.

Approaches of Phytoremediation

1. The application of hyper accumulators producing a relatively low amount of aboveground biomass but accumulating high amounts of one or more elements
2. The application of high biomass producing plants characterized by lower ability to accumulate target elements where total uptake of elements is comparable to that of hyperaccumulators due to high yield of above-ground biomass

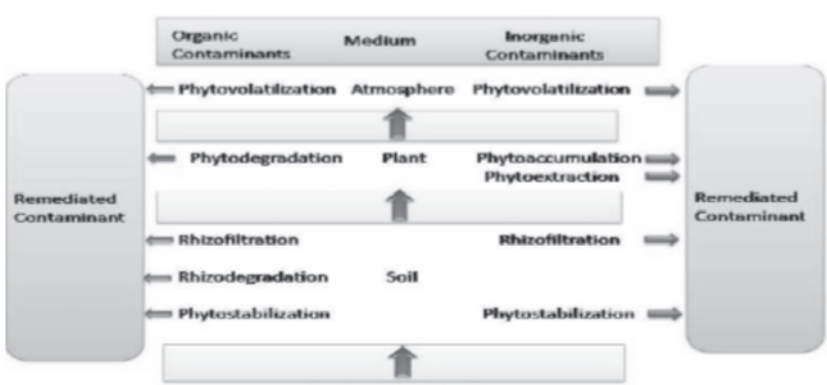

Fig. 5. Phytoremediation Technology (ITRC, 2009)

Hyperaccumulators are defined as “plant species whose shoots contain > 100 mg Cd kg “1 , > 1000 mg Ni, Pb and Cu kg “1 or >10000 mg Zn and Mn kg “1 (dry weight) when grown on metal rich soils”. As of 2010, more than 400 plant species have been identified as metal hyperaccumulators. Grasses have been more preferable in use (Reeves and Baker, 1999)for phytoaccumulation than shrubs or trees because of high growth rate, more adaptability to stress environment and high biomass (Fig 5).

The specific plant and wild species that are used in this technique are effective at accumulating increasing amounts of toxic heavy metals. These plants are known as accumulators. They accumulate heavy metals at higher concentrations (e” 100 times) above ground than do non-hyperaccumulators growing in the same conditions, without showing any observable symptoms in their tissues. The concentration of heavy metals in the shoots should be 50–100 times greater than in ‘normal’ plants. The bioaccumulation coefficient (the ratio of the concentration of a toxic substance in the tissues of an organism to its concentration in the living environment of that organism) must have a value greater than 1. Metal concentrations in the shoots should be higher than in the roots; fast growth and high accumulating biomass; easily grown as an agricultural crop and fully harvestable.

Field Study

Amaranthus dubius was used for remediating contaminated soils of Patancheru, Hyderabad. A pot culture study was under taken to study extraction of heavy metals from contaminated soils by *Amaranthus dubius.* It was found that *Amaranthus dubius* was able to extract Fe, Cd, Co, Pb, Cu & Cr heavy metals from the contaminated soils efficiently. The removal pattern of other nutrients such as Ca, Mg & Mn was also studied and was found quite higher in *Amaranthus dubius* and was found to extract higher content of heavy metals from contaminated soils paving way to lower the heavy metal concentration in these soils for further cultivation of nutrient rich & safe vegetables (Sreedevi *et.al.,* 2011).

Limitations of Phytoremediation

Although phytoremediation is a promising approach for remediation of heavy metal-contaminated soils, it also suffers from some limitations (Hazrat Ali *et al.,* 2013) (Fig 6).

- Long time required for clean-up.
- Phytoremediation efûciency of most metal hyperaccumulators is usually limited by their slow growth rate and low biomass.
- Dificulty in mobilization of more tightly bound fraction of metal ions from soil i.e., limited bio availability of the contaminants in the soil.
- It is applicable to sites with low to moderate levels of metal contamination because plant growth is not sustained in heavily polluted soils.
- There is a risk of food chain contamination

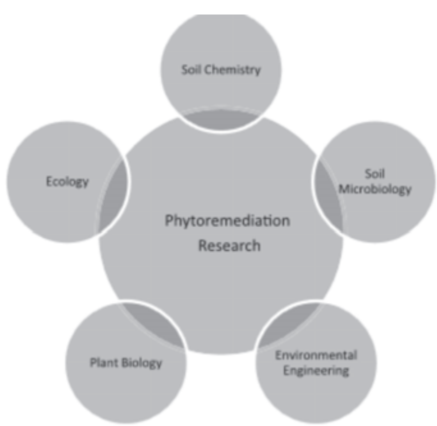

Fig. 6. Schematic showing interdisciplinary nature of phytoremediation research

Use of Phytoremediation and Biochar to Remediate Heavy Metal Polluted Soils

Biochar and phytoremediation techniques have the potential to be combined in the remediation on heavy metal polluted soils (see Fig 1). Biochar can reduce the bioavailability and leachability of heavy metals in the soil. On the other hand phytoextractors can reduce the amount of soil heavy metals in polluted areas.

Biochars have highly heterogeneous properties, which should be understood as maximising the efûcacy of soil remediation. We should comprehend, firstly, how these properties are relevant for heavy metal adsorption and how they contribute to the different mechanism of heavy metal immobilisation, and secondly how to optimise the choice of pyrolysis conditions and feedstocks in order to produce the desired products (Paz-Ferreiro *et al*., 2014) Most experiments utilising biochar or phytoremediators alone and not in combination have been carried out under laboratory conditions. In the case of phytoremediators this can result in an overestimation of heavy metal extraction. For biochar most of the experiments (both in ûeld and under laboratory conditions) have been conducted in the short term, which poses an interrogation on the long-term fate of these heavy metals. In fact it could be expected that, due to aging processes, the ability of biochar to sequester heavy metals decreases with time.

Potential of Different Aquatic Plants in Improving Water Quality

Aquatic plants are known for accumulating and concentrating heavy metals and metal fluxes rough those ecosystems. Several studies have shown that aquatic plants are very effective in removing heavy metals from polluted water. Plant assimilation of nutrients and its subsequent harvesting are another mechanism for pollutant removal. Low cost and easy maintenance make the aquatic plant system attractive to use. Thus, aquatic plants are increasingly applied as a viable treatment for municipal wastewater. The accumulation of metals in various parts of aquatic plants is often accompanied by an induction of a variety of cellular changes, some of which directly contribute to metal tolerance capacity of the plants

However, there are some constraints with using aquatic plants such as the requirement for large area of land, the reliability for the pathogen destruction, and the types and end-uses of aquatic plants. One reason that the aquatic plants are able to remove of the heavy metals from the water than terrestrial plants from soil is the soluble form the metals in water. Metals present in a soluble form in soils before plants can absorb them. In an aqueous solution, metals are ready in soluble form so accumulation by the plants can be achieved much easier. Recently, there has been growing interest in the use of metal-accumulating roots and rhizomes of aquatic and semi-aquatic vascular plants for the removal of heavy metal from contaminated stream.

Phytoremediation of Heavy Metal Contaminated Soil Using Vermicompost

Addition of organic matter may immobilize heavy metals (e.g., Cd, Pb, As, Ni, Co) for soil amelioration, but it may also increase growth rates of plants used in phytoremediation, and as a result, increase pollutant removal efficiency (Korkmaz Belliturk1 *et al.*, 2015). Vermicompost is produced through the degradation of organic wastes through the action of earthworms that results in the bio-oxidation and stabilization of wastes. The manufacturing process of vermicompost differs from traditional composting which requires a thermophilic stage, while vermicompost undergoes a mesophilic transformation. The resulting vermicompost material is a fine-textured, peat-like material which has structural properties that help in retaining water and facilitating aeration. In addition, it increases cation exchange capacity (CEC) in soils, promoting adsorption of positive ions, including heavy metals. While adsorption to CEC sites seems counterproductive, cation exchange can re-release these metals for uptake by metal accumulating plants.

Vermicompost is known to enhance plant growth, and thus help with phytoremediation while at the same time temporarily immobilize metal pollutants. Incidentally, earthworms themselves are bioaccumulators and thus can be used to bioremediate metal contents of compost produced from urban wastes.

Conclusion

Phytoremediation is becoming an important tool in bioremediation of metal contamination in soils, it is essential to continue research in this area to identify hyper accumulators. These plants are highly adapted to accumulate toxic trace metals while growing rapidly in contaminated soils. Their use in all forms of agriculture, from urban to rural, may prevent the loss of important agricultural soil resources through metal contamination. Economic development and an ever rising world population are putting enormous stress on food systems. To feed nearly 9 billion people by 2050, a new vision is needed that ensures food supply, environmental sustainability and economic opportunity through agriculture. Agriculture sustainability is vitally important to support the expanding population, and one that does not compromise soil health. In sustainable agriculture more of the nutrients in food waste and sewage need to be returned to the soil. Field application of sewage and composts derived from urban wastes may actually cause metal contamination. It is thus even more important that efficient phytoremediation techniques are at the ready to keep soils fertile. This may start with the waste processing where phytoremediation, and indeed vermiculture can help produce better, sustainable fertility amendments to avoid nutrient deficiencies, as are seen in some parts of Turkey. Agriculture is a one of the main areas of development in developing countries like Turkey. The increasing interest in the use of vermicomposts as plant growth media, and soil amendment should extend to its use in phytoremediation. Apart from environmental clean-up, other co-benefits that may arise through this practice ranges from raising soil organic matter to reduced soil erosion, and improved biodiversity by encouraging the development of healthy soil ecosystems, all of which will ultimately improve soil quality and productivity within sustainable agriculture.

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18 Microbial Inoculants for Enhanced Nutrient Uptake and Quality of Crops

Suseelendra Desai

Introduction

Agriculture is a major contributor to the Indian economy and nearly 60% of population depends on agriculture and allied sectors for their livelihoods. Many of the industries depend on agriculture sector for their raw materials. The most important objective of agriculture is production of high quality, safe and affordable food for an ever-increasing population. Farming community aims at economic profitability and sustainability. The total cropping area in India is estimated to 142 million ha, out of which rainfed regions contribute about 40% to the national food basket.

The seven billion population today consumes about 25 million tonnes of protein nitrogen each year. By 2050, it is expected to reach 40-45 million tonnes. To meet this demand, the increase in crop production will have to be vertical as there is limited scope for increasing cultivated area. In recent years, Indian agriculture has become highly dependent on inorganic fertilizers to meet the demands of ever increasing population. While the country will require about 45 mt of nutrients (30 mt for food grains and 15 mt for other crops) from various sources, i.e. fertilizers, organic manures and biofertilizers; indiscriminate use of inorganic fertilizers is resulting in degradation of soil health, and environmental pollution. About 70-80% of applied inorganic phosphatic fertilizer and 90-99% of potassium and zinc fertilizers are fixed in soil and thus become unusable. Aberrant rainfall coupled with high price of fertilizers made an uphill task to meet ever-increasing nutrient demands. Though the Government of India provides substantial subsidies on inorganic fertilizers, the scenario may not be the same down the lane in ensuing years due to depletion of core raw materials meant for inorganic fertilizers production.

There has been an ever-increasing interest in the use of native and non-native beneficial microorganisms to improve plant health and productivity while ensuring safety for human consumption and protection of the environment. In the current scenario, many soil-borne microorganisms have proved beneficial over the years and are now integrated into crop husbandry systems as part of integrated pest and productivity management practices. Plant growth promoting rhizo microorganisms (PGPR) comprise bacteria, fungi and actinomycetes that survive in and around the root rhizosphere. The beneficial effects of these microbes on plant growth can be direct or indirect. In general, the rhizosphere is a nutrient rich habitat for complex microbial populations that can positively or negatively influence the plant health and growth. These rhizomicroflora can affect the plant development in a significant way by complex biological interactions.

One of the beneficial activities of these microorganisms is biofertilization and their use as biofertilizers has been in practice since last several decades. The commercial history of biofertilizers began with the launch of 'Nitragin' by Nobbe and Hiltner, a laboratory culture of *Rhizobia* in 1895, followed by the discovery of *Azotobacter* and then the blue green algae and a host of other microorganisms. *Azospirillum* and arbuscular mycorrhizal fungi (AMF) are fairly recent discoveries. In India the first commercial production started as early as 1956. Biofertilizers form an important component of organic food production where inorganic fertilizers are not permissible and hence N2-fixing and phosphate solubilising bacteria, including *Bacillus* sp., *Azotobacter* sp., *Azospirillum* sp., *Beijerinckia* sp., *Pseudomonas* sp. are widely used in organic cropping systems (Lugtenberg and Kamilova, 2009). *Bacillus megaterium, Azospirillum, Azotobacter* and *Rhizobium* were indeed brought under Fertilizer (control) order, 1985 act in India due to their consistent performance in the field. Bureau of Indian standards specified production, quality control parameters, manner of formulation and packing for PSB (IS 14807: 2000), *Azospirillum* (IS 14806: 2000), *Azotobacter* (IS 9138:2002) and *Rhizobium* (IS 8268: 2001).

Recently in 2012, potassium mobilizing biofertilizers and zinc solubilizing biofertilizers were also included in the FCO act. These are not only eco-friendly but also cost-effective. In recent years Government of India has initiated several programs to emphasize the usage of biofertilizers for nutrient management. However, the reception among the end users has been not up to the mark, probably due to under performance in field condition, lower cell population and short shelf-life. The shelf life of common solid carrier based biofertilizers is around six months; however, it could be as high as two years for a liquid formulation. Further, solid carrier based biofertilizers are less thermo-tolerant whereas; liquid formulations can tolerate the temperature as high as 55°C. A novel and effective formulation which can negate the foresaid constrains is the need of the hour. Liquid consortium biofertilizers formulation containing not only the desired microorganism and their nutrients but also special cell protectants or chemicals that promote formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions.

Annually, about 170 million tonnes of nitrogen is contributed through biological nitrogen fixation. Biofertilizers are an important component of the integrated plant nutrient management systems, particularly in rainfed areas, where farmers tend to rely either on ‘no cost’ or ‘low cost’ inputs. In alfisols and vertisols of semi arid regions, Venkateswarlu (1992) reported *Bradyrhizobium* population exceeding 10^3/g soil even during summer months and the population rose sharply following rainfall implying that the size of the native rhizobial populations is not a constraint for optimum nodulation in the areas studied. Species of *Azotobacter* and *Azospirillum* are known to fix nitrogen in a non-symbiotic mode mainly in cereal crops. Similarly, strains of *Bacillus*, *Pseudomonas*, *Aspergillus* and AM fungi have been commercialized for phosphorus mobilization. In the last decade, strains of microbes have been identified for mobilization of important nutrients like zinc, potassium etc.

Biofertilizers have been an alternative to mineral fertilizers to increase the yield and plant growth in sustainable agriculture (Canbolat *et al*., 2006). The production of hormones in PGPR in numerous studies reports the importance of indole acetic acid (IAA) in the roots development (Aloni *et al*., 2006). With the increased availability of nutrients in the soil by the action of *B. subtilis,* higher absorption of nutrients such as phosphorus and nitrogen in plants inoculated with Rhizobacteria on seeds was shown. *B. subtilis* has been assessed as of great potential for use in agriculture and has been used in the formulation of commercial products for agricultural use in several countries (Lazzareti and Bettiol, 1997).

Nitrogen Fixers

The importance of bacteria as key drivers of the nitrogen cycle is exemplified in both bulk soil and the rhizosphere (Rosswall, 1983). Many N_2 fixing bacteria have been found in rhizospheric and endophytic association but the transfer of biologically fixed nitrogen has been demonstrated only in few systems. Bradyrhizobia are well known symbiotic nitrogen fixers in leguminous crops. They are known to form nodules on the roots of the plants and thereby establish symbiotic relationship with the plants. In addition, free nitrogen-fixing bacteria belong to a wide array of taxa; among the most relevant bacterial genera are *Azospirillum*, *Azotobacter*, *Burkholderia*, *Herbaspirillum* and *Bacillus* (Vessey, 2003). Mirza *et al*., (2006) demonstrated nitrogen fixing ability of strains of *Pseudomonas.* The effect of *Azotobacter* and *Azospirillum* is attributed not only to the amounts of fixed nitrogen but also to the production of plant growth regulators such as indole acetic acid, gibberellic acid, cytokinins and vitamins which show additional positive effects on the plants (Rodelas *et al*., 1999). The association of diazotrophic rhizobacteria with grasses is well documented (Baldani *et al*., 1997) and includes several bacterial genera and many important agricultural plants. Most cultivated tropical soils in India are reported to have relatively large populations (>100 cfu. g^{-1} dry soil) of rhizobia capable of nodulating the legumes and fixing nitrogen (Nambiar *et al.,* 1988; Venkateswarlu, 1992; Khurana and Dudeja, 1997).

Phosphorus Mobilizers

Phosphorus is one of the major nutrients limiting plant growth. Most of the soils worldwide are P deficient (Batjes, 1997). The use of rock phosphate as a phosphate fertilizer and its solubilization by microbes (Kang *et al*., 2002), through the production of organic acids (Maliha *et al*., 2004), has become a valid alternative to chemical fertilizers. Several studies have shown that phosphate soulubilizing microorganisms (PSM) solubilized the fixed 'P' in the soil resulting in higher crop yields (Gull *et al*., 2004). The combined application of *Rhizobium* and PSM (Perveen *et al*., 2002) or PSM and arbuscular mycorrhizal (AM) fungi showed enhanced plant growth as compared to their individual inoculation in 'P' deficient soils.

Phosphate solubilizing bacteria are ubiquitous (Gyaneshwar *et al*., 2002) and *Bacillus*, *Enterobacter*, *Erwinia* and *Pseudomonas* spp. are among the most potent strains. PSB are common in rhizospheres of crop plants and few examples of beneficial association of phosphate solubilizing PGPR and plants include *Azotobacter chroococcum* and wheat (Kumar and Narula, 1999), *Bacillus circulans* and wheat (Singh and Kapoor, 1998), *Enterobacter agglomerans* and tomato (Kim *et al*., 1998), *Pseudomonas chlororaphis* or *P. putida* and soybean (Cattelan *et al*., 1999), *Rhizobium* sp. and *Bradyrhizobium japonicum* and radish (Zaidi and Khan, 2006).

Bacilli are prominently known by their ability to solubilize phosphate, which is already a well known component of crop husbandry in many crops. For example, in Soviet Union, a biofertilizer product under the trade name "phosphobacterin" was prepared and commercialized for agricultural applications. Phosphobacterin contained *Bacillus megaterium* var. *phosphaticum* and later on it was also introduced to other countries, like Eastern Europe and India. At CRIDA, *Bacillus megaterium* is being commercially produced in the name of "phosphobacteria" and has gained significant accolades among farmers.

The solubilization of P in the rhizosphere is the most common mode of action implicated in PGPR that increase nutrient availability to host plants (Richardson, 2001). PSMs solubilize the unavailable forms of inorganic-P like tricalcium, iron, aluminium and rock phosphates into soluble forms by release of succinic, citric, maleic, fumaric, glyoxalic and gluconic acids (Gaur, 1990). In culture media, P solubilising ability is generally related to the degree of acidifiction of the media as measured by fall in pH, but the same was not found true in soil (Venkateswarlu *et al.*, 1984). The importance of root growth and architecture for the efficient capture of P, well documented and in many cases, is a specific response of plants to P deficiency (Richardson *et al*., 2009). Under controlled growth conditions, various studies have demonstrated enhanced growth and P nutrition of plants inoculated with PSM (Rodriguez and Fraga, 1999; Gyaneshwar *et al*., 2002).

Potassium Solubilizers

Potassium is another important major nutrients required by the plants for various metabolic processes. Deficiency of potassium not only reduces yields but also predisposes crop to biotic and abiotic stresses. Potassium is also fixed in the soil and is abundantly available in vertisols. However, its availability in the form that is taken up by the plants is very limited. The major potassium solubilizing microbes include *Bacillus mucilaginosus*, and mycorrhiza. Other genera such as *Burkholderia* sp., *Paenibactillus* sp., and *Acidothiobacillus* sp. have also been shown to solubilize potassium. These bacteria re heterotrophic in nature and survive on organic material. These bacteria are able to solubilize insoluble potassium through the production and secretion of organic acids. A few commercial products are available for potassium solubilization.

Zinc Solublizers

PGPR can transform micronutrients which are there in soil that can be used as bio-inoculants to supply micronutrients like zinc, iron, copper etc., zinc being utmost important is found in the earth's crust to the tune of 0.008 per cent but more than 50 per cent of Indian soils exhibit deficiency of zinc with is below the critical level of 1.5 ppm of available zinc (Katyal and Rattan, 1993). The plant constraints in absorbing zinc from the soil are overcome by external application of soluble zinc sulphate ($ZnSO_4$). But the fate of applied zinc in the submerged soil conditions is pathetic and only 1-4% of total available zinc is utilized by the crop and 90% of applied zinc is transformed into different mineral fractions (Zn-fixation) which are not available for plant absorption (crystalline iron oxide bound and residual zinc). There appears to be two main mechanisms of zinc fixation, one operates in acidic soils and is closely related with cat ion exchange and other operates in alkaline conditions where fixation takes by means of chemisorption, (chemisorption of zinc on calcium carbonate formed a solid-solution of $ZnCaCO_3$), and by complexation by organic ligands (Alloway, 2008).

Zinc is a micronutrient required in adequate concentrations by living organisms, but in many instances it exhibits toxic effects at relatively low and high concentrations. Zinc solubilizing potential of few bacterial genera has also been studied. Di Simine *et al*., reported (1998) a zinc solubilizing strain of *Pseudomonas fluorescens* from forest soil. Hutchins *et al*., (1986) reported that *Thiobacillus thioxidans*, *T. ferroxidans* and facultative thermophilic iron oxidizers solubilized zinc from sulphide ore (sphalerite). Saravanan et al., (2007) reported a strain of *Gluconoacteobacter diazotrophicus* with zinc solubilization and its anti nematode activity against *Meloidogyne incognita*. Zn solubilization by microorganisms has been widely studied in fungi and bacteria (Di Simane *et al*., 1998; Fasim *et al*., 2002; Suseelendra Desai *et al*., 2012).

Seed bacterization temporarily changes the balance of the rhizosphere populations and such changes may sometimes enhance the plant growth, yield and uptake of nutrients depending upon the establishment of the introduced cultures. The co-inoculation of *B. subtilis*, *Bradyrhizobium* and AM fungus enhanced the growth, nutrient uptake and yield of green gram. The fact that plant growth and nutrient uptake increased in the presence of AM fungi suggested a strong synergistic relationship between root colonization, P uptake and growth promotion. Vladimir *et al*., (2001) reported that when *B. japonicum* co-inoculated with rhizosphere-competent *Pseudomonas* sp. enhanced nitrogen fixation in soybean. In a two-year field study conducted on pigeonpea using *Pseudomonas fluorescens* showed an increase in grain yield of pigeonpea, maize and wheat by 23.3%, 194% and 16.7%, respectively, over uninoculated control (Tilak and Srinivasa Reddy, 2006).

Bioinoculants and Plant Nutrient Uptake

Inoculating the plants with these microorganisms has shown significant improvement in nutrient uptake and thereby leading to improved nutrient content in the plant parts. Such results have been shown either the inoculants were administered singly or in combinations. Combined inoculation of four beneficial organisms was also found superior over single, dual or triple inoculation of beneficial organisms. Field experiment conducted by Devananda (2000) reported that maximum plant growth, yield and nutrient uptake in pigeonpea was obtained in the combined inoculation of *Rhizobium*, *Azospirillum* and *P. striata*. Veena (1999) have studied the influence of consortia of beneficial rhizosphere microorganism like nitrogen fixers, phosphate solubilizers and major groups of general micrflora isolated from the rhizosphere of sorghum plants in comparison with single, dual, triple and multiple inoculations of most efficient organisms as well as with different levels of NPK fertilizers on growth and nutrient uptake of sorghum. The results had revealed that increasing the complexity of consortia with more number of beneficial organisms enhanced the growth, biomass and nutrient uptake of sorghum plants significantly which was most equivalent to application of 75 to 100 per cent recommended dose of chemical fertilizers.

Mass Production and Formulation Development

After the identification of promising PGPR strain, the first major concern is mass production through commercially viable methods, involves the achievement of adequate growth of the bacteria by cheap raw materials. In many cases biomass production of the bacterial strain is difficult due to the specific requirement of nutritional and environmental conditions for the growth of organism. Mass production is achieved through liquid fermentation techniques. For mass multiplication the selected medium should be inexpensive and readily available with appropriate nutrient balance. Kings' B broth or nutrient broth has been used for the mass production of *Pseudomonas* and *Bacillus* spp., through liquid fermentation technology (Nakkeeran *et al*., 2004). The commercial success of bio-inoculant requires economical and viable market demand, consistent in the stability of PGPR traits of the mother culture, bio-safety and longer shelf life, easy availability of carrier materials (Jeyarajan and Nakkeeran, 2000). Optimization of fermentation technology with suitable medium (synthetic or semi-synthetic) for mass multiplication and identification of suitable carrier material (organic or inorganic) for formulation development with increased shelf life is a barrier in the commercial success of formulation development.

Shelf-Life of the Formulated Product

Shelf life of the formulations decides the commercialization of bio-inoculants. Formulations should support the viable nature of the product for the increased period of storage. Bio-inoculant product should have the minimum shelf life of 8-12 months for industrialization. Carrier material should not affect the viable nature of the bio-inoculant. Commercialization of the bio-products is mainly hampered due to the poor shelf life. Hence research should be concentrated to increase the shelf life of the formulation by developing superior strains that support the increased shelf life, or the organic formulations that support the maximum shelf life with low level of contaminants must be standardized for making bio-inoculant as a commercial venture.

Conclusion

Application of bioinoculant technology as a cost-effective and eco-friendly crop production technology has been well acknowledged. Many small and marginal farmers consider this technology as a boon as it saves the input costs significantly. Experimental results have shown that the produce from bioinoculant-treated crops were superior in terms of nutritive value and thereby addressing not only food security but also nutritional security. However, more research is required to develop quality formulations that assure definitive results to the farmers so that the resource-poor farmers can adopt the technology as a foolproof approach for reduced cost of cultivation and increased productivity and thereby enhanced profitability. Plant-microbe interactions are imminent and most of these interactions are beneficial to the plants. This phenomenon has been exploited for the benefit of the farming community to develop cost-effective and eco-friendly crop health management products to improve crop productivity. Plant growth promoting rhizo microorganisms are known from time immemorial. However, they became popular when inorganic fertilizers and pesticides became cost-prohibitive and their misuse and abuse resulted in environmental pollution hazard. Many genera of microorganisms are known to supplement crops with major, minor and trace element nutrition thus partially meeting the nutrient demands. Identifying efficient strains, mass multiplication and formulation have been mainstay of research agenda to ensure that the desired benefits are harvested by the stakeholders. Nitrogen, phosphorus, zinc and potash solubilizers are already commercial available to the farmers. Easy availability of quality products and at affordable rates and hands on training of stakeholders need to be addressed for successful exploitation of this technology by the farming community.

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19 Food Based Approaches to Combating Micronutrient Deficiencies

Mahtab S Bamji

Introduction

Despite economic growth malnutrition continues to plague India. For nutrition security there has to be Awareness and Access at Affordable Cost to a balanced diet (food security), safe environment and drinking water and health care outreach. Cereal- pulse-based Indian diets are qualitatively deficient in micronutrients- vitamins and minerals; particularly, iron, zinc, vitamin A and some B-complex vitamins like vitamins B_2, folic acid and B_{12}. Despite being a tropical country, vitamin D deficiency is rampant. Though severe clinical forms of micronutrient deficiencies have become rare, milder forms (hidden hunger) are rampant. Sub clinical malnutrition impairs growth, immunity, learning and cognitive ability, pregnancy outcome, productivity and consequently economic growth and development of the nation. Iron deficiency anaemia is a big public health problem despite the anaemia prophylaxis programme in which supplements of iron and folic acid are given to pregnant women, adolescents and children. Food fortification is a powerful tool, but the food to be fortified should reach the poorest of the poor, and the bioavailability of micronutrient from the fortified food known. Universal iodisation of salt has reduced iodine deficiency goitre.

Dietary diversification to ensure food-food complementation is the most empowering and sustainable approach. For that, agriculture has to be nutritionally sensitive and environmentally sustainable. It has to be accompanied with health and nutrition education to bring about behavioural change, and participation of women. For best results, farm scientists and extension workers should be knowledgeable about nutrition, local food habits, and micronutrient rich varieties. Biotechnology including genetic engineering can play an important role in developing biofortified crops and increasing productivity.

Term malnutrition includes both under-nutrition and over nutrition- obesity and associated degenerative diseases. Under nutrition in India is one of the highest in the world. Diet surveys conducted by the National Nutrition Monitoring Bureau (NNMB) (ICMR) and others show that Indian diets are qualitatively deficient in micronutrients- vitamins and minerals (hidden hunger). While in general, households consuming adequate calories, meet their protein requirement (protein quality would be a problem), their cereal-pulse based diets are grossly deficient in micronunutrients, mainly, iron, zinc, vitamins A, B_2, folic acid and vitamin B_{12}. This is primarily because of low intake of, of protective foods such as, vegetables and fruits, (the main source of vitamins and minerals in vegetarian diets), and animal products. Pulses besides being important source of proteins are also good source of some B-vitamins and minerals. While plants do not contain vitamin A, they contain provitamin A carotenoids, the most active form being â carotene. Plant foods do not contain vitamin B_{12}, and hence this vitamin has to be derived from animal foods. Vitamin D_3, (cholecalciferol) is derived from its precursor 7-dehydro cholesterol in the skin on exposure to UV-B radiation of sunlight. Vitamin D_3 is found in animal foods, particularly fish liver oil, but is not present in plant foods. However, it's another form (Vitamin D_2-ergocalciferol) can be synthesised from the plant sterol ergosterol on irradiation with UV-B. This synthetic form is used for food fortification.

Diet surveys conducted by the NNMB between 1975-79 and 2011-12 in rural India show progressive reduction in the intake of all food groups, and consequently nutrients over the years (Figs. 1-5). Remarkably even cereal consumption has also come down and millets are fast disappearing from Indian diets. Faulty infant and young child feeding (IYCF) practices and lack of dietary diversity in complementary foods are the major causes of under-nutrition and micronutrient deficiencies in infants and pre-schoolers.

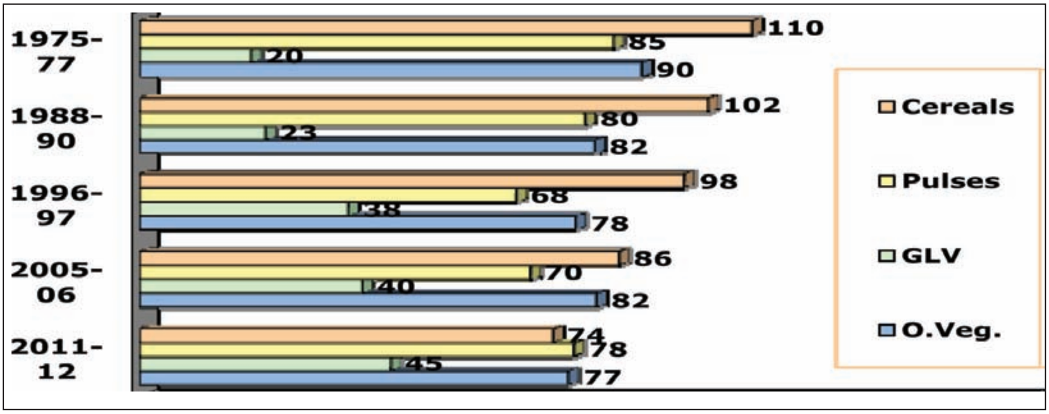

Fig. 1. Average intake of foodstuffs (per CU/day) as % of RDI by period of survey NNMB surveys

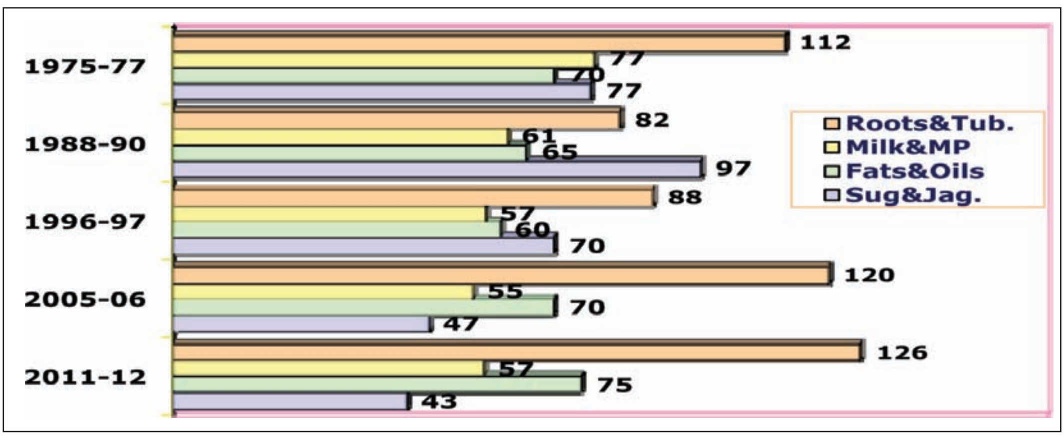

Fig. 2. Average intake of foodstuffs (per CU/day) as % of RDI by period of survey NNMB surveys

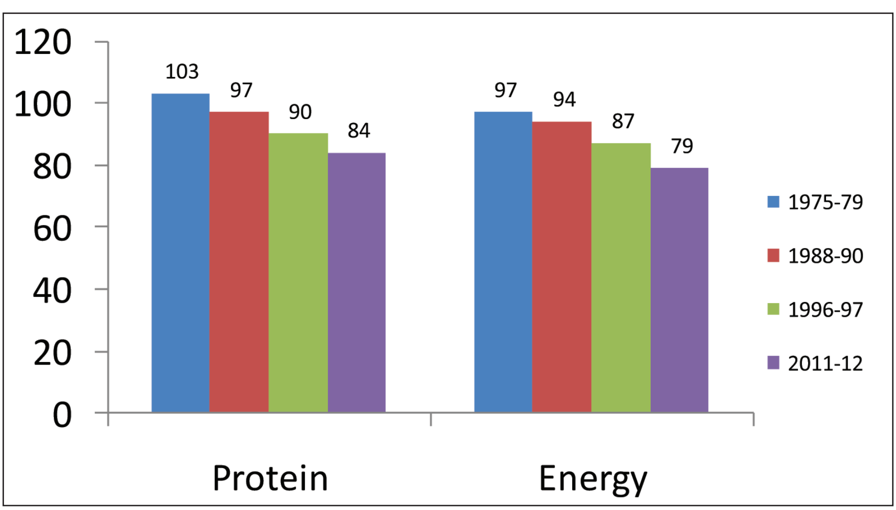

Fig. 3. Average consumption of Nutrients as % of RDA – Time Trends

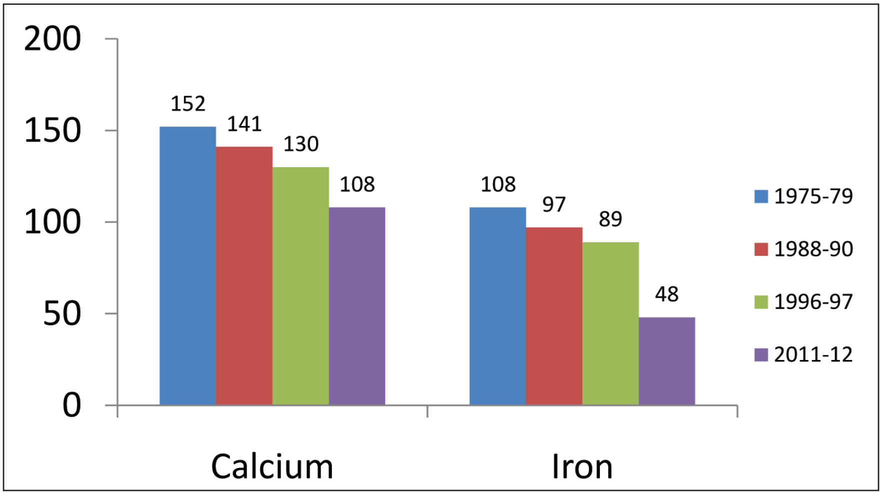

Fig. 4. Average consumption of nutrients as % of RDA – time trends

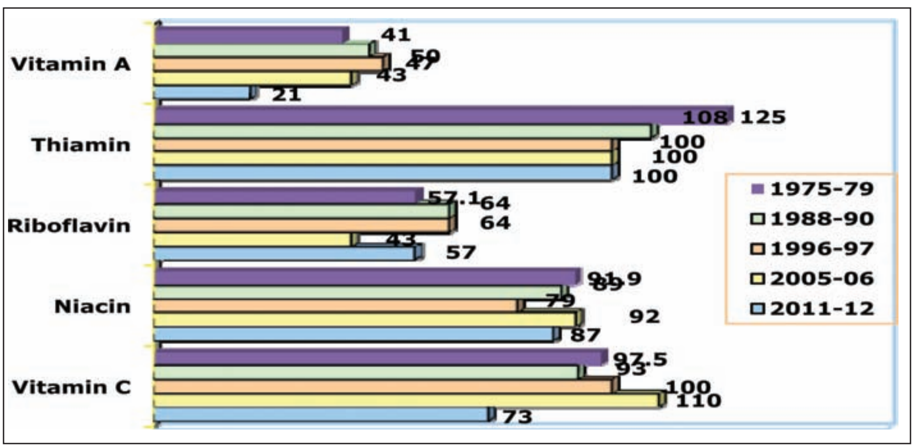

Fig. 5. Average consumption of nutrients as % of RDA – time trends

Consequences of Micronutrient Deficiencies

Today we do not see the severe clinical forms of MN deficiencies like beriberi (vitamin B_1 deficiency), pellagra (niacin deficiency), scurvy (vitamin C deficiency) and rickets (vitamin D deficiency). Even iodine deficiency (goitre) and blindness due to vitamin A deficiency are relatively rare. However, signs and symptoms typical of vitamin A deficiency, like, night blindness and Bitot spots in the eye are seen among children and pregnant women. Sub-clinical deficiencies of micronutrients, recognised by biomarkers and dietary intake, have serious effects, such as impaired growth, immunity, learning and cognitive ability, work performance, and pregnancy outcomes. Apart from human suffering and medical costs, micronutrient deficiencies adversely affect productivity and economic growth. According to one estimate, micronutrient deficiencies together are responsible for about 35% of child deaths, and 11% of total disease burden (Roy *et al.*, 2009). According to the reports of various agencies, micronutrient deficiencies are estimated to cost India, $ 2.5 billion each year (Micronutrient Initiatives and UNICEF 2004, quoted in India Health Report - Nutrition 2015). Among the micronutrient deficiencies, iron deficiency anaemia is of particular concern. Iron deficiency anaemia has been reported in 55.3% of women aged 15-49 years and 69.5% of children aged 6-59 months (India Health Report on Nutrition, 2015). Vegetarian Indian diets are high in phytates which affect iron absorption. They are also low in iron absorption promoter like vitamin C. Bioavailability of micronutrients, is higher from animal foods than plant foods. Deficiencies of B-complex vitamins like vitamin B_2 (riboflavin), folic acid and B_{12} are also common.

Since folic acid and B_{12} are needed for maturation of erythrocytes, their deficiencies lead to megaloblastic anaemia. These vitamins are needed for DNA synthesis. Raised level of homocysteine in blood is implicated in cardiovascular diseases. B-Vitamins like folic acid, B_{12} and B_6 are needed for its metabolism and their deficiency has been implicated in raised levels of serum homocysteine. Recent studies show rampant vitamin B_{12} deficiency in India. Despite being a tropical country vitamin D deficiency is rampant, perhaps due to inadequate exposure to mid day sun. Pollution contributes to blocking the UV radiation. Vitamin D is needed for calcium absorption, maintenance of blood levels of calcium and bone calcification. When blood leels of calcium fall, calcium is desorbed from the bone to maintain the blood levels leading to osteoporosis a common problem in the elderly, particularly women. In children vitamin D deficiency impairs bone formation and rickets.

Strategies for Combating Micronutrient Deficiencies

Both dietary and non-dietary factors contribute to the high prevalence of MN deficiencies in India. The latter include, poor sanitary conditions including, open defecation and access to safe drinking water (which result in infections), and health care outreach. Though important, the non-dietary factors are beyond the scope of present discussion. There are basically four approaches for combating micronutrient deficiencies:

- Pharmaceutical supplementation,
- Food fortification.
- Addition of micronutrients to cooked foods and
- Dietary diversification.

Programme of iron folic acid supplementation to pregnant women has been in operation in India since many years. Recently its scope was enlarged by including children and adolescent girls. Despite this programme, anaemia persists, perhaps due to poor implementation and compliance because of communication gap. Implementation of the massive dose of vitamin A programme is very patchy and cannot take the credit for the decline in blindness due to vitamin A deficiency. Food fortification while processing and addition of micronutrients to cooked foods have shown positive results but they have limitations. The choice of food to be fortified should be accessible to the poorest of the poor. In India such a food is salt. Iodised salt has helped to reduce the incidence of iodine deficiency disease (goitre). Salt double fortified with iodine and iron has been developed by the National Institute of Nutrition, Hyderabad, but has yet to be popularised. Fortification of wheat flour and rice with B-vitamins and minerals and milk and oil with vitamins A and D is done in some countries with good results. Bioavailability of the fortified nutrient has to be examined.

Dietary Diversification for Food and Nutrient Security

According to the FAO; for food security, “all people, at all times, should have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life” (FAO, 2006). There should be awareness and access at affordable cost to all food groups: cereals and millets, pulses (grain legumes), vegetable and fruits, foods of animal origin, fats and sugars. Foods of plant origin are also rich in fibre and health promoting phytochemicals or nutraceuticals. A balanced diet should supply the required quantity of energy, protein, fat, carbohydrates, vitamins and minerals at household and individual level, based on age, gender and physiological status. Having adequate stocks of cereals at the national level does not ensure food security for the people. In 1992, FAO (Rome) at an international conference on Nutrition recommended food based strategies for combating micronutrient deficiencies, through dietary diversification, using locally available foods to satisfy local food habits). Farm extension workers should be sensitive and knowledgeable about the local dietary preferences, the nutrient content of locally grown foods, and their bioavailability. They should strive to increase the productivity and nutrient content of such foods using conventional breeding methods and biotechnology. In rural areas where food is produced this can be achieved by leveraging nutrition into cropping pattern. In urban areas, nutritionally promotive marketing strategies are needed. In some countries urban agriculture has gained importance for food production. City grown foods should be monitored for chemical pollution (Mehrag, 2016). Supplying micronutrients through diet protects against nutrient toxicities and imbalance because of biological regulatory mechanisms at the level of absorption.

Foods Rich in Micronutrients

In Indian diets, cereals are the major source of B vitamins (other than vitamin B_{12}) and minerals because of the quantity consumed. Apart from proteins, pulses also contribute to micronutrients. Millets are rich in B-vitamins and minerals, besides fibre. Being climate resilient they are the grains of the future (Table 1). Finger millet (ragi) is exceptionally rich in calcium. Minor millets like foxtail millet and Barnyard millet are also rich in micronutrients. Fruits like citrus fruits, guava, papaya and 'amla' (Indian gooseberry (Emblica officinalis)) are rich sources of vitamin C (Table 2). Green leafy vegetables are also rich in vitamin C besides other micronutrients. Being very heat labile, vitamin C is lost in cooking. Consuming raw vegetables and fruits or mild cooking of vegetables will help. Since plants do not contain vitamin B_{12} even to get the small quantity of 1 µg, foods of animal origin like milk, eggs, meat and fish should be consumed. Though plants lack pre-formed vitamin A, they contain pro vitamin A - carotenoids, mainly â-carotene which are converted to vitamin A in the intestine and stored in the liver. Dark green leafy vegetables (GLV) and orange-yellow vegetables and fruits are rich source of â-carotene. (Table 3). GLV are also rich in other vitamins and minerals (Tables 4 and 5). GLV are easy to grow and available throughout the year. Yet their consumption is very low (NNMB Surveys). This is an area where nutrition education can play an important role.

Table 1. Nutrient Content of cereals and millets per 100 G

Grain/nutrient	Bajra	Jowar	Ragi	Rice-milled	Maize	Wheat-flour
Protein (g)	11.6	10.4	7.3	6.8	11.1	12.1
Calcium (mg)	42	25	344	10	10	48
Iron (mg)	8	4.1	3.9	3.2	2.3	4.9
Zinc (mg)	3.1	1.6	2.3	1.4	2.8	2.2
Vitamin B1 (mg)	0.33	0.37	0.42	0.06	0.42	0.49
Vitamin B2 (mg)	0.25	0.13	0.19	0.06	0.10	0.17
Folic acid (mg)	45.5	20	18.3	8.0	20	36.6
Fibre (g)	1.2	1.6	3.6	0.2	2.7	1.2

Table 2. Vitamin C rich fruits

Name	Vitamin C content, mg/100g
Citrus fruits	40-64
Guava	200
Papaya	57
Amla	600
Daily requirement for an adult woman(mg)	40

Table 3. Commonly Consumed Vegetables and Fruits other than GLV rich in β Carotene

Name of the Foodstuff	β Carotene mg/100 g
Carrot *(Daucus carota)*	6.460
Mango, ripe (*Magnifera indica)*	1.990
Sweet Potato (Yellow) *(Ipomoes batatas)*	1.810
Yellow Pumpkin (*Cucurbita maxima)*	1.160
Chillies, green (*Capsicum annuum)*	1.007
Papaya, ripe (*Carica papaya)*	0.880
Tomato, ripe (*Lycopersicon esculentum)*	0.590

Source Gopalan *et al.*, 1989, reprinted, 2011, Table reproduced from Bamji and Bhaskarachari (2015), with permission of the editors and co-author

Table 4. Vitamins in Commonly Consumed Green Leafy Vegetables (GLV) in India

Name of the Foodstuff (Local / Botanical Name)	β carotene	Thiamine	Riboflavin	Niacin	Folates	Vitamin C
	mg /100g				µg /100 g	mg/ 100g
Agathi *(Sesbania grandiflora)*	15,440	0.21	0.09	1.2	-	169
Amaranth *(Amaranthus Caudatus)*	8.340	0.03	0.3	1.2	149	99
Ambat chukka *(Rumex vesicarius)*	2.800	0.03	0.06	0.2	125	12
Beet Greens *(Beta vulgaris)*	5.862	0.26	0.56	3.3	15	70
Cabbage *(Brassica oleracea var.capitata)*	0.120	0.06	0.09	0.4	23	124
Celery leaves *(Apium graveolens var.dulce)*	3.990	0.02	0.11	1.2	36	62
Colocasia leaves *(Colocasia anti-quorum)*	5.920	0.06	0.45	1.9	126	63
Coriander leaves *(Coriandrum sativum)*	4.800	0.05	0.06	0.8	62	135
Drum Stick leaves *(Moringa oleifera)*	19.69	0.06	0.05	0.8	40	220
Fenugreek leaves *(Trigonella foenum graecum)*	9100	0.04	0.31	0.8	-	52
Gogu *(Hibiscus cannabinus)*	6.97	0.07	0.39	1.1	-	20
Knol-Knol Greens *(brassica oleracea var. caulorapa)*	4.146	0.25	0.10	3	194	157
Lettuce *(Lactuca sativa)*	1.100	0.09	0.13	0.5	38	10
Basella *(Basella rubra)*	2.840	0.03	0.16	0.5	-	87
Mint *(Mentha spicata)*	5.480	0.05	0.26	1	114	27
Mustard leaves *(Brassica campestris var. sarason)*	2.622	0.03	0.11	0.80	187	33
Ponnanganni *(Alternathera sessilis)*	1.926	0	0.14	1.2	-	17
Spinach *(Spinacia oleracea)*	2.740	0.03	0.26	0.5	123	28

Source Gopalan *et al.*, 1989, reprinted, 2011. Table reproduced from Bamji and Bhaskarachari (2015), with permission of editors and co-author

Table 5. Minerals in Commonly Consumed Green Leafy Vegetables

Name of the Foodstuff (Local / Botanical Name)	Ca	P	Fe	Mg	Na	K	Cu	Mn	Mo	Zn	Cr
	(mg/100g)						(µg/100g)				
Agathi (Sesbania grandiflora)	1130	80	3.9	-	-	-	-	-	-	-	-
Amaranth (Amaranthus Caudatus)	200	40	2.32	122.1	230	341	78	365	130	178	6.9
Ambat chukka (Rumex vesicarius)	63	17	0.75	123.7	-	-	42	403		271	6.1
Beet Greens (Beta vulgaris)	380	30	16.2	70	226	762	75	321	-	380	-
Cabbage (Brassica oleracea var. capitata)	39	44	0.8	31.7	18	170	22	183	78	298	4.7
Celery leaves (Apium graveolens var.dulce)	230	140	6.3	52	35.5	210	10	100	-	130	-

Coriander leaves (Coriandrum sativum)	184	71	1.42	31.4	58.3	256	141	497	1120	323	13.5
Drum Stick leaves (Moringa oleifera)	440	70	0.85	41.7	9	259	69	375	-	163	9.5
Fenu Greek leaves (Trigonella foenum) graecum	395	51	1.93	33.8	76.1	31	96	229	400	358	5.8
Gogu Knol-Knol Greens	172	40	2.28	66.1	-	-	84	298	-	272	5.2
Greens (brassica oleracea var. caulorapa)	740	50	13.3	31	40	296	10	100	ND	190	-
Lettuce (Lactuca sativa)	50	28	2.4	30	58	33	80	300	1.3	180	6.7
Mayalu (Basella rubra)	200	35	10	-	-	-	-	-	-	-	-
Mint (Mentha spicata)	200	62	15.6	60.3	-	-	179	572	-	438	8.2
Mustard leaves (Brassica campestris var. sarason)	155	26	16.3	32	25	354	147	480	-	200	-
Ponnanganni (Alternathera sessilis)	510	60	1.63	46.2	-	-	185	464	-	-	948
Spinach (Spinacia oleracea)	73	21	1.14	63.5	58.5	206	95	559	10	295	4.8

Source: Gopalan *et al.*, 1989, reprinted, 2011, Table reproduced from Bamji and Bhaskarachari (2015), with written permission of the editors, and co-author.

Farm-Based Approach to Combating Micronutrient Deficiencies

India produces enough cereals (including millets) to meet its present and projected demand. (Table 6). If hunger still persists in some population groups, it is due to lack of purchasing power and inequity in distribution. Pulses are a rich source of proteins and micronutrients. Their demand cannot be met through production within the country. (Praduman kumar *et.al.*, in press). Active agriculture intervention is needed to increase the productivity and supply of pulses. Food security act of India is the step in the right direction. However it stops at providing only cereals and millets. The food basket needs to be enlarged to include pulses and oil at least. Public should be educated to utilise the money saved in purchasing the subsidised foods to buy other protective foods.

India is among the top three countries for the production of vegetables, fruits, milks and fish. Table 7 shows that while the current and projected production of vegetables and fruits exceeds the demand, there is availability gap due to post harvest losses. No country can feed over 1.5 billion people with this kind of wastage (Praduman Kumar, *et al.,* in press). Apart from availability at the national level, there is also the problem of purchasing power particularly for the high value foods, and consequently distributive injustice. Farmer who produces food prefers to sell it rather than use it for her or his home. Nutrition education can play an important role. Nutrition literacy is low even among the agriculture scientists and planners, who think of agriculture only in terms of income and export at best to quench hunger and meet protein requirement. Importance of micronutrients is often lost. Human nutrition should be an important subject in agriculture syllabus. While human nutrition was included as a subject in agriculture degree programme in the past, in recent years it has been deleted. A well- informed agriculture extension worker will try to leverage nutrition into cropping patterns. Farmers with small land holdings are generally reluctant to diversify to nutrition gardening, for meeting household nutrition security. With proper advice on cultivation of micronutrients dense foods, the problem of micronutrient hunger can be addressed. A detailed review of past and recent experiences on this aspect has been done by Arimond et al (FAO, 2011).

Table 6. Demand-supply projections and gaps for major food grains, edible oils and sugar, India. (Unit: Million tons)

Commodities	Year	Supply Projection	Demand Projection	Demand supply gap
Total cereals	2010	219.5	218.1	1.4
	2020	262.6	253.6	10.0
	2030	315.1	284.2	30.9
Pulses	2010	16.2	18.0	-1.8
	2020	20.7	21.9	-1.3
	2030	26.4	26.6	-0.2
Edible oils	2010	8.2	13.6	-5.5
	2020	12.5	17.0	-4.5
	2030	19.1	21.3	-2.1

Praduman Kumar *et al*., Proc.INSA in press

Table 7. Demand-supply projections and gaps for high-value food commodities in India

Commodities	Supply, demand & gap	Projections (Million tons)			Post hervest losses (%)
		2010	2020	2030	
Vegetables	Supply (S)	140.6	186.4	210.5	23.99
	Demand (D)	124.7	154.8	192.0	
	Availability (A)	106.9	141.7	160.0	
	Gap (A-D)	-17.8	-13.1	-32.0	
Fruits	Supply (S)	73.5	97.7	116.4	20.00
	Demand (D)	64.8	80.9	103.0	
	Availability (A)	58.8	78.2	93.1	
	Gap (A-D)	-6.0	-2.7	-9.9	
Milk	Supply (S)	116.5	156.6	188.7	5.03
	Demand (D)	111.9	138.3	170.4	
	Availability (A)	110.6	148.7	179.2	
	Gap (A-D)	-1.3	10.4	8.8	

Praduman Kumar *et al*., Proc.INSA in press

Importance of Biofortified Crops

Biofortification involves enriching the germplasm with a nutrient through conventional breeding, molecular marker driven breeding or genetic engineering. The first two strategies are feasible when the desired traits like high iron or zinc or high vitmains are present in a wild variety within the species. Where such an option is not there like â-carotene in rice, genetic engineering involving gene transfer from another food or even non-food source would be needed. Once a biofortified variety is developed and seeds released to the farmers, it is self sustainable with wider outreach. The importance of this strategy to combat MN deficiencies is seen from the fact that the 2016 World Food Prize has been awarded to scientists who have contributed to this field. Maria

Andrade, Robert Mwanga, Jan Low, of the International Potato Research Centre, Peru have developed the Orange flesh sweet potato (OFSP) rich in â-carotene through conventional breeding. While Dr. Andrade and Dr. Mwanga, are plant scientists who bred the â-carotene (provitamin A) enriched OFSP, Dr. Low organised nutrition studies and programs which encouraged almost two million households in 10 African countries to plant, purchase and consume this nutritionally fortified food. Dr. Howarth Bouis, the founder of Harvest Plus at the International Food Policy Research Institute (IFPRI), has pioneered multi-institutional approach to biofortification as a plant breeding strategy. As a result of his leadership, crops such as iron and zinc fortified beans, rice, wheat and pearl millet, and Vitamin A-enriched cassava, maize and OFSP are being tested or released in over 40 countries. Genetic engineering is a powerful tool which can help immensely. Strategies to ensure its health and environmental safety have to be put in place. Lot of misguided resistance from some powerful NGOs and others is obstructing progress of science and harming the cause of nutrition security.

Homestead Gardens for Improving Household Micronutrient Security- Indian Studies

In late 90s studies were done in Andhra Pradesh by the National Institute of Nutrition-NIN (Vijayraghavan *et al*., 1997), and West Bengal, by the All India Institute of Hygiene and Public Health,-AIIHPH (Chakravarty *et al*., 2000) to examine the feasibility of combating vitamin A deficiency through homestead production of pro-vitamin A rich vegetables and fruits. The term homestead includes area around the house and family farms. In these studies planting material (good quality seeds and saplings) of green leafy vegetables and yellow orange vegetables and fruits were distributed with knowhow and do-how on growing them, to ensure seasonal availability. Health and nutrition education to bring about behavioural change (behavioural change communication-BCC) was an important part of the intervention. The Andhra Pradesh study included 20 villages from two agro-climatic regions. In West Bengal, after a pilot study in 5 villages, the experiment was extended to three diverse blocks. Local government functionaries were also involved. Both the studies showed good acceptance of homestead nutrition gardens leading to increase in the frequency of consumption of provitamin A- rich vegetables and fruits by children. Knowledge of mothers with preschool children on issues related to health and nutrition as judged by Knowledge Attitude Practice (KAP) surveys showed significant increase. While in West Bengal there was statistically significant reduction in the ocular signs of vitamin A deficiency (Bitot spots) in preschool children, in AP the impact was less remarkable, and statistically not significant. In more recent years, the author has been trying to promote the concept of Nutritionally promotive and environmentally sustainable agriculture in the villages of Medak district of AP (now Telangana) through the NGO, Dangoria Charitable Trust. (Bamji *et al*., 2011, Murty *et al*., 2016). While in the first study, all the interested households in the selected 15 villages, (population 24,000) were included for raising nutrition gardens, the second study was targeted to pregnant women and mothers with preschool children aged 6-24 months who had registered in the 11 ICDS centres from 8 villages. The first 1000 days after conception are most crucial from nutrition point of view. Organic methods of farming like vermin composting and botanical pesticides made from neem seeds or chilli garlic decoction were also introduced. Farmers were explained that such diversification would not only improve household micronutrient security, but also save water and raise the water table. Beans would enrich the soil with nitrogen.

Like in the earlier studies the acceptance of homestead gardens was good. There was marked improvement in the knowledge of mothers on issues, such as; components of a balanced diet, importance of protective foods, healthy cooking practices, correct breast feeding and complementary feeding practices etc. However, some wrong practices such as avoiding papaya during pregnancy and discarding excess water after cooking rice persisted but to a lesser extent. Household diet surveys done initially and after 3 years showed significant increase in the consumption of GLV, with not much change in the consumption of other vegetables. 25-50% of the latter were sold, and home-grown ones, replaced what was purchased. However, in households which did not raise nutrition gardens, there was significant decrease in the consumption of vegetables over the three year experimental period, due to sharp rise in market price of vegetables. (Bamji *et al.*,2011). This would suggest that homestead production at least shields against price rise. Like in the earlier studies BCC formed an important part of the study. In the second targeted study (Murty *et al*., 2016), impact on growth of children aged 6-24 months was monitored through ICDS records. Progressive decline in undernutrition (under weight) was observed.

The impact on undernutrition may be due to the strong component of education. In each of the three years, malnutrition tended to increase during rainy season and was lowest during winter when the supply of vegetables is known to be good. Morbidity tends to be high during monsoon and this can have an impact on child nutrition.

MS Swaminathan Foundation

Currently MS Swaminathan Foundation, Chennai, India is developing a "A farming system model to leverage agriculture for nutritional outcomes" (farming systems for nutrition-FSN) in Wardha District of Vidarbha region of Maharashtra, and Koraput district of Odisha (Das *et al.,* 2014). The objective is to demonstrate the feasibility of nutrition-sensitive agriculture. The main components of the model are:

- Survey to identify the major nutritional problems,
- Design context specific suitable agricultural interventions to address the local nutritional problems,
- Built-in specific nutritional criteria,
- Improve small farm productivity and profitability,
- Undertake nutrition awareness programmes, and
- Introduce monitoring systems for assessing impact on nutrition outcomes".

Homestead Production of Livestock

The white revolution in India has been brought about by family dairy farming. There are only few large commercial dairies in India. Goat rearing is also largely a home activity. However, systematic studies on the impact of these, on household nutrition security have not been done. Most of the produce is sold for income. This would help if backed with BCC so that the income earned is used for the purchase of MN rich foods for the family, particularly for women and children. In recent years there is a decline in the consumption of cereals, but increase in the consumption of animal products. Egg is nutritionally one of the most wholesome foods with good quality protein and almost all micro nutrients. However the benefit of increase in commercial poultry farming has gone largely to urban areas. Backyard poultry (BYP) on the other hand can benefit rural households. High egg-yielding BYP breeds have been developed. These birds can lay over 160 eggs per year compared to the conventional breeds which lay just 30-40 eggs per year. BYP needs little space, water or foods since they are free- roaming birds and forage. However, better quality supplementary feed can certainly help. In studies conducted by the author in villages of Medak district, BYP with high egg- yielding breeds resulted in almost 2 fold increase in the frequency as well as quantity of eggs consumed by the families. (Murty *et al.*, 2013, Murty *et al.*, 2016). Thus this is a promising intervention for improving household nutrition security. However, care is needed to prevent the female birds from mating with free-roaming male birds of non-descript local breeds. Either adult female birds should be made available and breeding disallowed, or local male birds should be removed.

International Studies on Homestead Production of Foods

A large programme on improved homestead gardens and poultry was conducted by the Hellen Keller International in Bangladesh, Cambodia, Nepal and Philippines to increase the access to micronutrient rich foods to poor households. Nutrition education was an important component. State governments were involved. (Bushamuka *et al.*, 2005, Iannoti *et al.*, 2009, Rahman *et al.*, 2008 and Talukdar *et al.*, 2010). Here again there was significant improvement in mothers' knowledge of nutrition, and consumption of these foods by mothers and preschool children. Significant reduction in the prevalence of anaemia was seen in Bangaladesh and Philippines.

Conclusion

Though homestead production of vegetables, fruits and livestock is a promising approach towards household micronutrient security, it is not a stand-alone strategy since land holdings are small and the farmers' first priority is income. It should be complemented with other strategies like micronutrient supplementation where needed as in the case of anaemia, and food fortification. To leverage agriculture for nutrition security

(LANS), there has to be nutrition literacy at all levels. Farm scientists and extension workers should be knowledgeable about nutritional needs, micronutrient dense local varieties of vegetables and fruits, local food habits etc. and complement technological interventions with BHC. Local KVKs and ICDS centres (anganwadi workers) and ASHA workers should work in tandem for better outreach.

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20 Breeding for Quality in Cereals

Basudeb Sarkar and Salini K

Introduction

Ensuring food security by producing sufficient quantity of food grains through intensive production system is not enough for ensuring a healthy live of present and future generations. In fact, there is an increasing concern about the quality food which is affected by excessive use of pesticide chemicals and fertilizers resulting contamination of the food chain and drinking water. Nutritional insecurity contributes to the deaths of millions of people each year and affects people's health. Food insecurity and malnutrition are currently among the most serious concerns for human health, causing the loss of countless lives in developing countries. It is projected that the number of malnourished and undernourished people approaching one billion worldwide, with no sign of going down for the coming decade (FAO, http://www.fao.org). Worldwide, emphasis is increasingly being put on the relationship between food, nutrition and health (WHO, 2004; WCRF, 2007).

Nutritional health and well-being of human beings are mostly dependent on plant foods. We require at least 49 nutrients including minerals, amino acids and vitamins to meet the metabolic needs which can be supplied by an appropriate diet. To remain healthy, our daily diet must include sufficient quantity of quality foods with all the essential nutrients, in addition to foods that provide health benefits beyond basic nutrition. Although India has become self-sufficient in food production, providing the require amount of quality food to the ever increasing population will be a daunting task in the future due to the continuing loss of arable lands, the prevalence of unfavourable environmental conditions including drought, salinity, floods and diseases. In order to ensure food and nutritional security for future generations, the world must produce 50% to 100% more food than at present in spite of the predicted adverse environmental conditions (Baulcombe, 2010)

Nutritional Quality

Nutritional quality traits determine the value of produce in human/animal nutrition. These characters include protein content and quality, oil content and quality, vitamins, minerals etc., and also the presence of anti-nutritional factors. These traits are not easily appreciated by consumers and farmers, but they are of paramount value in determining human and animal health. Various factors affects the nutritional quality of food products are soil factors, climatic factors, crop and variety, management practices and post-harvest handling and storage.

Protein Content

Plant proteins are cheaper, easier to store and transport but they do not have a well-balanced amino acid composition. Therefore, considerable breeding effort has been directed at improving the protein content and quality of food crops. Protein content in cereals generally shows strong negative correlation with yield. As a consequence, progress in breeding for improved protein content without reducing yield has been generally been slow.

The protein contains in wheat grain generally varies between 8 to 15%. Durum wheat has higher concentration as compared to bread wheat. Wheat protein also has imbalance in amino acids composition like the concentration of lysine is usually half of what should be needed for balance with other amino acids. Although protein content is a genetic character, it is also influenced by environmental condition under which the crop is grown. Breeding for improvement of protein content and quality needed presence of genetic variation among germplasm or in related species. Genetic component of this variation must also be separable from environmental component in order to introgression this trait in developing new varieties. In wheat, ATLAS 66 was used as the source of higher protein content to improve the protein content of variety 'Lancota' by 1-2% without a reduction in grain yield. Thus 'Atlas 66' genes may be termed as '*protein content genes*' which affect protein content without affecting yield. Coarse cereal oats contain proteins that have excellent amino acid balance, and protein content does not seem to decline with yield. Groat (naked seed) protein content in commercial oat varieties ranges from 9-20%. *Avena sterilis,* a weedy oat type, has 30.3% groat protein. Some progeny extracted from the cross *A.* sativa *x* A. sterile showed 20-30% yield increase without any reduction in protein content. Protein content should always be considered in combination with 1000-grain weight and other yield components as there is undesirable linkage between high protein content and shriveled grains.

The above two examples illustrate that different approaches are needed for increasing protein content. In the case of wheat, grain protein content was improved, while yield was unaffected. In contrast, yield was enhanced in oats, while protein content was maintained at the previous level. Successful examples of either kind come from conventional breeding programmes by exploiting on natural genetic variability present in the germplasm.

Protein Quality

The protein quality is determined by the type and bioavailability of different amino acids available in the grains. Of the 20 amino acids present in our body's proteins, nine are treated as essential to our diet as human body cannot manufacture them viz., histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Therefore, these nine amino acids are called essential amino acids (EAA). Cereals are generally deficient in lysine, tryptophan and/or threonine while, pulses are deficient in sulphur containing amino acids like tryptophan. To meet the balanced requirement of amino acids, consumption of pulses and cereals in the ratio of 1:3 may provide excellent balance of our amino acid requirement. This also improves bio-availability and utilization of proteins which is assayed in terms of protein efficiency ratio (PER), biological value (BV) and digestibility.

Cereal proteins are classified into four groups based on their solubility viz., albumins, globulins, prolamines and glutelins. While based on prolamine concentration cereals can be further divided into three groups. The first group includes rice and oats which has lowest prolamine concentrations of 5-15% with an excellent amino acid balance in their proteins. Barley and wheat form the second group with 30-40% prolamines, while maize and sorghum have the highest prolamine content (50-60%). However, prolamines are poor in lysine and have very poor nutritional value. High lysine content is generally associated with higher PER values.

The presence of genetic diversity for high protein content and its quality in major cereals made it possible in identifying donors for using in crop improvement programme. Number of mutants with improved protein quality have been identified in maize, sorghum and barley although combining grain quality with plum grain has remain a major cin genetic improvement in these crops. A rigorous breeding efforts in combining quality traits and better grain filling through hybridization programme was successful in combining plump grains and high protein and/or lysine in wheat, maize and barley. For example in barley all high Lys mutants, except Hiproly mutant, prolamin content has been reduced, while in high Lys maize and sorghum mutants, prolamin is reduced to a level comparable to that of normal barley.

Vitamin Content

Vitamins form an essential component of nutritional quality and foods are the chief source of vitamins especially vitamins C, A and $B_{6.}$ Vitamin A is a fat-soluble that is naturally present in many foods. The most common type of provitamin A in foods and dietary supplements is beta-carotene. The rice plant can naturally produce beta-carotene, which is a carotenoid pigment that occurs in the leaves and is involved in photosynthesis. However, the plant does not normally produce the pigment in the endosperm since photosynthesis does not occur in the endosperm.

Mineral Content

Humans require 22 mineral elements, which can all be supplied by an appropriate food. Some are required in large amounts, but others, such as Fe, Zn, Cu, I and Se, are required in trace amounts. These mineral elements mostly enter the food chain through plants product. Among these mineral elements most frequently lacking in human foods are Fe, Zn and I, although other elements, such as Ca, Mg, Cu and Se, can also be deficient among some populations. It is estimated that, millions of people living in developing countries are suffering due to Fe and Zn deficiency. These deficiencies are due to high intakes of carbohydrate rich staple foods with low intakes of vegetables, fruits, and animal and fish products, which are rich sources of minerals. Key reasons for mineral malnutrition is due to low content of minerals in these staple foods in combination with of anti-nutrient compounds that reduces their bioavailability. Several crops contain anti-nutritional factors. For example pearl millet contains phytic acid and phenols which reduce the bioavailability of minerals.

Quality of Major Staple Foods

Rice

Among cereals, rice is the main staple food for more than 60% world's population. It is called as the queen of cereals occupying >11% of world crop area. Genetic improvements in rice for higher production and productivity through the development of high yielding varieties, along with improved cultivation practices, has resulted in green revolution during 1960s. During green revolution era, the major emphasis was given for improving the grain yield to meet the increasing demand of food for increasing global population. Post green revolution era, as the purchasing power of people have improved over the years and with increasing concern about health issues, the demand for quality food is increasing for all food crops including rice.

Rice quality is a combination of many characteristics that affect its market value and utilization as food. Based on market demand quality in rice may be divided into different classes such as market quality, milling quality, cooking/processing quality and nutritional quality. Market quality refers to the general appearance and physical properties of rice grain such as size, shape, uniformity of grain, colour of grains etc. The preference of market quality traits varies depending on the geographical locations. Rice is classified in the market as long, medium or short grain type having specific milling, cooking and eating qualities. The milling quality is determined by the yield to total rice after dehusking. The short and medium grain cultivars normally give larger mill yields than long grain cultivars. Cooking quality of rice is determined by physico-chemical properties of starch. Among them, amylose content determines the relative stickiness or dryness of cooked rice. Varieties with high amylose (> 25%) content cook dry and flaky, while those with low amylose content cook sticky. Gelatinization temperature (GT), determines resistance to cooking. In India, moderate GT as well as intermediate amylose content is preferred. Water uptake, amylose content and alkali reaction measures gelatinization temperature as predictors of cooking and processing qualities. High amylose content, medium GT and low water absorption characterize long grain cultivars whereas low amylose, low GT and high water absorption characterize medium and short grain cultivars. Breeding for improved nutritional quality would be beneficial if it could be accomplished without any yield loss. The average protein content is about 8% in brown and 7% in milled rice. Although rice protein relatively low as compared to other cereals, the nutritional value rice protein is high due to favourable balance of amino acids. Milled rice is relatively poor in fat, protein, vitamins and micronutrients, particularly deficient in lysine, vitamin A, iron and zinc. Therefore, biofortification for enrichment of vitamin A and other micronutrients into elite genetic background is an important objective of breeding for quality. Donors for high iron (Nilagrosa, Jalmagna, Tong Lan, Mo Mi, Azucina) and zinc (Conjay Roozay, Zuchem, Xua Bue Nuo) are available for the improvement of quality in rice.

Among different types of rice available, the aromatic basmati rice is considered as the best quality rice for its unique quality. The basmati rice are characterized by long slender superfine grains with pleasant aroma, extra elongation of kernel and soft texture, palatability and easy digestibility of cooked rice. The traditional basmati cultivars are tall, prone to lodging, photoperiod and temperature sensitive and very low yielding. To combine the quality attributes of basmati rice in the high yielding background, a systematic programme on genetic improvement of Basmati rice was initiated which resulted in the development of popular varieties like Basmati-217, Type-3, Basmati-370, Taraori Basmati, Basmati-386 and Ranbir Basmati, Sabarmati, Impoved Sabarmati, Pusa 33, Pusa 1121, Yamini (CSR30), and Pant Sugandh Dhan-15. etc. Pusa Basmati-1, the first semidwarf photoperiod insensitive and high yielding basmati rice variety has revolutionized the basmati rice production in India.

Wheat

Although, wheat is mainly cultivated for its grain, which are usually processed in to flour and utilized for numerous end products, the quality of end product is of utmost consideration for the wheat consumers. Broadly the wheat grain quality criteria include features like physical appearance, processing qualities, nutritional values and biological properties. The physical characteristics includes colour, texture / hardness, appearance, grain weight, test weight. As wheat grain is one of the important source of human nutrition and rich source of protein, starch and minerals, the chemical composition of wheat grain is very important in defining the wheat quality for consumers. The chemical composition of starch, amylose and amylopectin content is important as per desirable end product such as noodles, pasta, thickness, bread etc. High protein is preferred for bread and low protein for biscuit purposes. The ratio of gluten / gliadin fractions of the protein also dictates the quality of end produce. The improved amino acid balance is essential for better nutritional quality as wheat grains deficient in lysine and there is a negative correlation between protein and lysine content. Efforts to improve lysine as well as high protein content are needed to improve nutritional quality of wheat.

Genetic Control of Nutritional Traits

The quality traits may be governed by oligogenes or polygenes, while some traits may have maternal effects. The mode of inheritance depends mainly on the trait in question and the material used for the study of inheritance. The genetic control of many quality traits are oligogenic in nature. For example, traits like amylose content in rice, lysine content in maize, barley and sorghum are controlled by oligogenes. Introgression of these traits in improved cultivars are relatively easy as compared to polygenic traits *e.g.*, Hiproly barely, *opaque-2* maize, etc. However, most of the quality traits are controlled by polygenes with variable heritability. The nature of gene action for these traits are both additive and dominance types. Most of these polygenic trait affected by the environmental factors. Improvement of polygenic quality traits is usually more difficult than that of oligogenic traits. Maternal effects are also known to influence in case of some quality traits like seed size, protein content etc.

Genetic Resources for Quality Traits

The availability of genetic diversity among cultivated crops is essential prerequisite for making genetic gain in any crop be it for yield or quality. The donors for quality traits can be found among cultivated variety, germplasm collection, spontaneous or induced mutants or wild relatives. Cultivated varieties, genetic stocks or advanced breeding lines are the most preferred donors for quality improvement since, these traits are already under improved background of the crop and can easily be utilized in breeding programmes. If a trait of interest is not available in the cultivated varieties, the breeders look for alternate source for the trait. Genes affecting protein content of wheat grain is widespread in wheat germplasm. These genes produce small effects and are difficult to introgress and study their inheritance pattern. Large effects of genes governing wheat protein were first reported by Middleton et al.(1954). The soft wheat cultivars ‘Atlas 66’ and Atlas 50, developed in North Carolina, USA produced significantly higher protein than other varieties. Similarly, genes for protein with large effect were also reported in common wheat cultivar Nap Hal (Watson etal 1966). Atlas 66 and Nap Hal was used extensively for improving the protein content in wheat. An extensive search in germplasm collection of primary gene pool of cultivated crops may lead to identification of several donors in germplasm collection. The donors from primary genepool of cultivated species are easily crossable to introgress in improved back ground. For example, high lysine lines of sorghum, IS11167 and IS11758 were identified from Ethiopian collections. These lines also have high (15%) protein content, but their seeds are shriveled and red in colour. They have been extensively used in sorghum breeding programmes. Sometimes quality traits are not abundant in cultivated species. In such cases, mutation breeding approach are followed to create new genetic variability. Through mutation breeding approach many quality traits, particularly protein and oil quality mutants were developed. For example, P721 opaque mutant of sorghum has opaque endosperm, used to identify vitreous endosperm mutant which was high in lysine content.

Wild relatives of cultivated species are being utilized for introgression of various quality attributes. These traits are introduced in the cultivated background through wide hybridization and subsequent recovery of desirable segregants in the segregating generations. Apart from convention breeding approaches, modern tools of genetic engineering are also being used for transfer of novel traits. When the genes from unrelated or distantly related organism is introduced into the genome of an organism using the techniques of genetic engineering is called *transgene*. The cultivars developed through this genetic transformation methods are called transgenic. Genetic engineering provide a powerful means for the development of new cultivars. For developing transgenic cultivars, the biosynthetic pathway, or the key enzymes involved in the pathway, leading to the production of the concerned trait should be known. The modification of biosynthetic pathway through genetic transformation may help in achieving the goal of altered product quality. Golden rice is an example of transgenes used for improving the quality character.

Breeding Methods

The various breeding methods are used for the improvement of quality traits through conventional as well as new breeding tools of genetic engineering. The prerequisite of applying any breeding strategy is identification of diverse genepools for the trait of interest. Once the suitable donors are identified these traits can be introduced into improved background to develop new cultivars by various methods such as hybridization followed by selection. Other approaches like mutation breeding and genetic engineering are also employed to develop cultivars specific quality traits.

Hybridization

This is the most widely used breeding approach to develop high yielding varieties with desirable traits. The breeding methods followed to carry forward the segregating generations for identifying transgressive segregants derived from crosses depend mainly on the type of parents involved in the cross. The breeding methodology will also depend on the mode of pollination of the crop that is whether it is self or cross pollinated species. In cases, both the parents of a cross are high yielding varieties, pedigree method of selection will be the most suitable breeding methodology. If one parent involved in crossing has inferior agronomic features, backcross breeding scheme will be the most appropriate. When quality trait is governed by oligogenes and has undesirable linkages with the quality trait, the early segregating generations of a cross may be subjected to sib-mating followed by selection for desirable plant types in an effort to break linkages. In case traits are controlled by polygenes recurrent selection methods are used in segregating generations for genetic improvement**.**

Wide Hybridization

Wild relatives often contribute useful quality genes. Mostly wild relatives are not easily crossable. In such cases hybridization programme may possess several problems and embryo rescue techniques are used to recover such crosses and then carried forward for identifying desirable plant types. The product so developed may not be directly utilized as a variety but are useful in developing pre-breeding materials for using in the breeding programme. The lines derived from such crosses will usually serve as parents in hybridization programmes.

Mutagenesis

A desired quality trait may sometimes be present in a spontaneous/induced mutant, e.g high lysine mutants of maize, barley and sorghum. Mutation breeding is very useful in situations where only one or two simple changes are needed in well adapted local cultivars. Mutation breeding approached are being followed in creating variability in crops having narrow genetic diversity, flowers are very small and very difficult for hybridization for creating variability. A wide array of physical and chemical mutagens is being used for mutation breeding program. Some of these mutants so developed are either released directly as varieties or used as donor sources for improving specific characters. Often a quality mutant may have some undesirable features associated with the desirable quality trait. These mutant lines may be further subjected to mutagenesis and mutants lacking the undesirable features, but having the desired quality trait, may be isolated. The high lysine sorghum mutant, P721 opaque, has opaque endosperm; this trait was eliminated by above approaches and high lysine lines/ mutants having vitreous endosperm were isolated.

Genetic engineering

The cutting age science of genetic engineering involves introduction of a gene from within or outside the available genepool using different genetic transformation techniques. Among various crops maize, soybean, cotton, canola is most widely used for genetic transformation mainly for insect pest and herbicides resistance and also for quality traits. Genetic engineering research has been used to improve some of the essential amino acids in crop plants. Among the essential amino acids, Lys, Trp, and Met have received the most attention because they are most limiting factor in cereals (mainly Lys and Trp) and legumes crops (particularly Met), which represent the major sources of human food (Shai Ufaz and Gad Galili, 2008).

Through conventional breeding methods quality in maize was improved by developing quality protein maize (QPM) cultivars, which are rich in Lys and to some extent Trp. However, conventional breeding approaches have resulted in relatively limited success in other crops. This is mostly due to limited availability of genetic diversity in these crops and in most cases these traits are associated with abnormal plant growth. For such situation, the genetic engineering for quality traits seems more promising, as this approach allows seed-specific expression of specific traits of interest, using seed-specific promoters. In fact, a high lysine maize cultivar, LY038, developed more than 10 years back by genetic engineering, represents the first genetically modified (GM) crop with high nutritional value to be approved for commercial use in number of countries including USA, Japan, Canada and Australia.

In case of rice, seed storage protein was improved through genetic engineering where, the 7S legume seed storage protein, a â-phaseolin, gene was transferred. Transgenic plants expressed the 7S gene in their endosperm. DuPont (USA) have synthesized and patented' a gene encoding a protein, called CP3-5, containing 35% lysine and 22% methiomine. The *CP3-5* gene was linked with seed-specific promoters and transferred into and expressed in maize tissue culture cells. Rice gene *gt 1* encodes the major seed storage protein. It has been modified to encode higher levels of lysine, tryptophan and methionine. The modified *gt 1* gene, driven by its own promoter, was transferred into rice protoplasts; the resulting transgenic rice plants expressed the modified gene in their developing endosperm. Similarly, a modified zein protein gene encodes a protein having improved methionine content was introduced in maize, rice and wheat. Transgenic plants containing the modified zein gene showed up to 3.8% methionine in their seed proteins.

Breeding Efforts for Quality in Major Food Crops

Rice

Rice is the predominant staple food in many developing countries, providing 27 percent of dietary energy supply, 20 percent of dietary protein and 3 percent of dietary fat. Rice can contribute nutritionally significant amounts of thiamine, riboflavin, niacin and zinc to the diet, but smaller amounts of other micronutrients. Many factors influence the nutrient content of rice, including the cultivar, agricultural practices, postharvest conditions and handling. The major traits of nutritional quality in rice are protein content and protein quality. Although, protein content of rice varieties varies from 6 to 18%, most rice varieties have around 7% protein. Efforts to develop a high yielding rice variety having 8-9% protein have not been successful due to the low heritability of this trait and controlled by polygenes. On the other hand, protein quality, i.e., amino acid balance in rice is better as compared to other cereals and lysine content ranges between 3-8%. Although relatively low in protein compared to other cereals, the nutritional value of rice protein is high due to its favourable balance of amino acids. Milled rice is relatively poor in fat, protein and a number of vitamins and micronutrients, particularly deficient in lysine, vitamin A, iron and zinc. Biofortification for enrichment of vitamin A as well as micronutrients into elite genetic background is also an important objective of breeding for quality. Gene sources for high iron (Nilagrosa, Jalmagna, Tong Lan, Mo Mi, Azucina) and zinc (Conjay Roozay, Zuchem, Xua Bue Nuo) are some important resources for the improvement of quality in rice.

Golden rice

The transgenic golden rice was developed by transforming rice using two beta-carotene biosynthesis genes: psy (phytoene synthase) from daffodil (*Narcissus pseudonarcissus*) and crt1 from the soil bacterium

Erwinia uredovora. The psy and crt1 genes were transformed into the rice nuclear genome and placed under the control of an endosperm specific promoter, so that they only express in the endosperm. The first Golden rice was called SGR1, and under greenhouse conditions it produced 1.6 µg/g of carotenoids.

In the subsequent development, "Golden Rice 2" was developed, which combined the phytoene synthase gene from maize with crt1 from the original golden rice. Golden rice 2 produces 23 times more carotenoids than first golden rice (up to 37 µg/g), and preferentially accumulates beta-carotene (up to 31 µg/g of the 37 µg/g of carotenoids). To improve the nutritional quality, major focus is given on developing rice varieties with Pro-vitamin A, high iron and zinc content in the polished grain as most of the rice consumed are of polished types. Golden Rice, has been used to develop elite breeding lines, through marker assisted selection (MAS). The breeding lines are similar in agronomic performance to IR64, PSBRc82 and BR29. Iron content is being increased using both conventional and transgenic approaches. Through conventional breeding, enhanced levels of zinc have been produced and QTLs are being mapped. Pyramiding genes for Pro-vitamin A, high iron and zinc content is done to develop micronutrient enriched rice (Brar *et al.,* 2012*).* With the recent advances in analytical tools, molecular markers, applied genomics, proteomics and metabolomics, the scope for improving nutritional quality in rice, and combining that with high yield, seems more promising than before.

Wheat

Among cereals, wheat is the most important crop in terms of production and consumption. World nutrition mostly depends on wheat and wheat products viz. chapati, bread, biscuit, pasta and fermented products, as the people all over the world consume wheat product(s) in one of these forms (Agrawal and Gupta 2006). The wheat breeding for nutritional quality is mainly focused to improve the amino acid balance for better nutritional quality. Wheat grains deficient in lysine and there is a negative correlation between protein and lysine content. Efforts to improve lysine as well as high protein content are needed to improve nutritional quality of wheat.

Grain protein content and quality are also most targeted traits in quality breeding and the highly influenced by the environmental conditions. Protein content is variable depending upon variety and the environment. The various components of wheat grain protein are albumins, globulins, gliadins and glutenins. Gliadins and glutenins together are known as gluten. Glutenins confer elasticity, while gliadins confer mainly viscous flow and extensibility to the gluten complex. Several studies revealed that HMW (high molecular weight) glutenin subunits are important for various quality parameters for different end uses. The best breads are produced from dough that has a mix of strength, elasticity and plasticity properties largely determined by the balance between the gliadin and glutenin subunits. The presence of translocations 1B/1R resulted in the poor quality due to the production of secalins from rye chromosome. The complex and genetically additive nature of inheritance of most quality traits has led to the development of breeding methods for selection of genotypes in early generations. Selection and testing for quality begins in early generations led to identifying better segregant with improve quality. While attempting new crosses, at least one parent with desired quality must be selected in designing crossing strategies as end use requirements determine the potential new cultivars. In general, pedigree or modified pedigree method has been widely used. Exploration of genetic variation for quality traits present in wild relatives and alien species may require pre-breeding before they are used in the breeding programme. Novel biotechnology tools have opened the possibilities of investigating the basic and biochemical aspects of individual protein subunits and of other molecules contributing to the end use quality of wheat.

Biofortification is the process of breeding food crops that are rich in bioavailable micronutrients. CIMMYT (International Maize and Wheat Improvement Center) Mexico, is leading the Harvest Plus research effort in collaboration with national agricultural research and extension systems for biofortification of wheat for high iron and zinc content using conventional and molecular breeding approaches. Therefore, along with optimal level of starch and protein, adequate level of essential elements like calcium, phosphorus, iron, zinc and carotenoids and antioxidant are needed to fight against world malnutrition. High protein and starch are important for growth and energy whereas gluten, a complex protein made of glutenin (Gln) and gliadin (Gld), is essential for water and gas retention ability for making loaf and chapati. Water soluble albumin and globulin improve biological value of protein and are considered as factors for nutritional superiority (Stehno *et al*., 2008). On the other hand the micronutrient iron, calcium and zinc, which are involved in haemoglobin biosynthesis, ossification, and brain development respectively, become deficient with the increase of phytic acid level as they act as chelating action by phytic acid (Ekhlom *et al*., 2003), whereas trypsin inhibitor inhibits protein digestion.

Maize

Maize is a basic staple food for large population groups in developing countries in Asia and Africa. However, its low nutritional value, mainly with respect to protein, many efforts have been made to improve the biological utilization of the nutrients it contains**.** The maize kernel is composed of approximately 7% starch, 10% protein, 5% oil, 2% sugar and 1% ash. The maize protein known as zein is low in biological value due to low concentration of the essential amino acids lysine and tryptophan. Usually, the increase in grain yield increases the starch concentration of the grain while reducing the grain protein concentration. This negative correlation between yield and protein need to be broken to develop varieties with high yield and protein concentration. It was also found that the greater nitrogen supply increased grain protein concentration but yield response to added nitrogen is low after a certain level. Therefore, the major objective of quality breeding in maize include the development of cultivars with high protein and balanced amino acid profile. Efforts are also needed for developing cultivars with high oil, waxy amylase and low phytate which are associated with different end use quality. Significant progress was made in altering the composition of various quality traits. Several mutants have been discovered and developed to alter the starch fractions of the maize endosperm. Genes that modify either the structure or quality of the kernel endosperm have been effectively used to develop specialty corn. A break through was made with the discovery of opaque-2 gene which doubled the lysine and tryptophan content in the endosperm and breeding efforts led to the development of opaque-2 based hybrids, synthetics and composites although they have poor agronomic characters which are being improved. Subsequently, DNA based markers along with conventional breeding procedures are being utilized to develop QPM (quality protein maize) genotypes with improved nutritional quality. The improved nutritional quality in Opaque 2 maize is due to the decreased amount of prolamine (Zein) and the increased concentration of albumins, globulins, and glutelins, resulting in a larger amount of lysine in the whole kernel. An opaque-2 hybrid of maize gave 86 to 92 per cent grain yield of its normal counterpart. But at CIMMYT, Mexico, some hard endosperm opaque-2 populations were found to yield nearly as much as their normal counterparts. Hard endosperm opaque-2 varieties developed at CIMMYT were evaluated in several countries; the best opaque-2 entry yielded equal to or better than the normal check in seven countries. It may be pointed out that the original opaque-2 version had soft and chalky endosperm. Subsequent breeding efforts have accumulated modifying genes that produce vitreous type endosperms in opaque-2 genotypes. A high protein quality single cross hybrid Vivek, QPM9, containing opaque-2 gene has been released in India; it has normal dent grains, and yields at par with the parental version Vivek Hybrid Maize 9.

Sorghum

Sorghum is one of the main staples of the world's poorest food-insecure people, supporting more than 300 million lives in Africa and Asia. Grain sorghum is becoming even more of an important staple food in Africa in the face of growing food scarcity and several prolonged droughts. However, in the past, the results of global sorghum research have not substantially benefited African farmers mainly because of the inferior quality and poor commercial value of the released lines. Although sorghum is widely used and consumed, this crop is known to have low nutritional quality, because of its characteristic low lysine content.

As in other cereals, lysine is the first limiting amino acid in sorghum. After screening more than 9,000 accessions in the world germplasm collection (Singh and Axtell,1973) two sorghum lines of Ethiopian origin, IS11167 and IS11758, had exceptionally high lysine at relatively high levels of protein. Both lines were also high in oil percentage. The protein efficiency ratio (PER) values obtained with IS11167 and IS11758 were 1.78 and 2.06, respectively, as compared with the PER of 0.86 obtained for normal sorhgum. Inheritance studies suggested that the increased amount of lysine in each line was controlled by a single recessive gene that could be easily transferred by standard plant breeding procedures.

On the other hand anti-nutritional polyphenolic compounds, also known as tannins, present in the grain of sorghum cultivars substantially reduce the bio-availability of protein and other nutrients, thus have negative effect on the nutritional quality of grain sorghum. Often the grains are brown in colour, and as the intensity of this pigment increases, so does the polyphenol content.

In sorghum grain, the increased protein resulting from better nutrition of the plant is largely prolamine, of low nutritive value. Protein levels are low under conditions in which nitrogen is limiting at grain filling. Riley (1980) has made a thorough study of the protein situation is sorghum: the progress made in trying to use two high-lysine genes from Ethiopia, and the mutant in P-721 from Purdue. Plump seeds were unobtainable with the Ethiopian source in crosses, while lysine content transferred better from P721, but yields were poor. In case of sorghum, P721 opaque mutant has 60% higher lysine than its parent, and the trait is governed by a single partially dominant gene. P721 mutant was crossed with elite sorghum lines to transfer the mutant gene into several diverse genetic backgrounds. Some of the opaque lines isolated from these crosses were as high yielding as the normal vitreous controls, suggesting that this high lysine trait can be combined with high yields provided the mutant gene is placed in the proper genetic background. The opaque endosperm is not liked by growers and consumers. Therefore, several lines having high lysine and vitreous endosperm were identified from the germplasm. In addition, P721 opaque mutant was subjected to mutagenesis, and vitreous mutants with high lysine were isolated. All these high lysine vitreous endosperm types had higher grain weight, but lower protein and lysine contents than P721 opaque. Breeding for improved nutritional quality has got lot of significance in the present condition. Sorghum Research Unit, Dr. PDKV, Akola (MS) has recently developed one high yielding kharif sorghum hybrid CSH-35 (SPH 1705) with excellent quality parameters. Crude protein content (%) of CSH-35 was more (9.68%) as compared to CSH 16 (9.04%) and CSH 23 (8.66%). Total sugar % of CSH-35 was higher (1.66%) as compared to check CSH 16 (1.54%) indicating good amylolyptic activity while preparation of roti and also good taste of roti.

Pearlmillet

Pearl millet is a highly cross-pollinated crop that is extensively grown in semi-arid tropical regions of the Indian sub-continent and Africa. The protein content of pearl millet varies from 8 to 23 per cent, lysine from 0.9 to 3.8 per cent, oil 2.8 to 8.0 per cent, and carbohydrates 59.7 to 74.5 per cent. The presence high variability for micronutrient Fe and Zn in pearl millet collect has made this crop as an important source of Fe and Zn (Parthasarathy et al. 2006). A large variability has been found for these micronutrients in improved populations and breeding lines (Velu et al. 2006). Efforts are going on the improvement of grain quality and micronutrient density in pearl millet. During initial screening of germplasm accessions by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) found ranges of 30–76 ppm iron and 25–65 ppm zinc in pearl millet. Hybridization programme was initiated and simultaneous simultaneous selection for both micronutrients were made. The study revealed that both micronutrients are largely under additive genetic control. This concerted effort at ICRISAT lead to the development and identification of breeding lines and germplasm with >90 ppm iron and >60 ppm zinc. Subsequently, a full breeding pipeline initially included open-pollinated variety (OPV) development and later on hybrids and hybrid-parent development. The major focus of the breeding program was to develop higher yielding, high-iron hybrids with stable yield and iron performance for the different agroecological zones in India. An iron OPV, ICTP 8203-Fe, was first released for Maharashtra state in 2013. Due to its high iron content and wide adaptation, ICTP 8203-Fe was notified as “Dhanshakti” in February 2014 for cultivation in all pearl millet-growing states of India.

Barley

Barley (Hordeum vulgare L.) is the fourth most important cereal crop after wheat, rice and maize in the world. Barley has been traditionally considered as poor man’s crop because of its low input requirement and better adaptability to harsh environments like drought, salinity, alkalinity and marginal lands. Barley is best known around the world as a feed grain and grains for malting and brewing. When most people think of composition of beer, they only think of barley over other cereals. Although utilization of barley for food is relatively low as compared to other cereals today, barley has remained an important food source poor people living in Western & Eastern Asia, Northern & Eastern Himalayan region nation like Tibet, Nepal and in Northern and Eastern Africa. Moreover, there has been resurgence of interest and use of barley as food primarily in the developed world due to increasing use as an ingredient in baby foods and its high medicinal value for health benefits.

For considering barley grain for malting a number of grain and malt traits are considered important to the industry for different end products. Majority of these traits are not independent and also influenced by the environmental conditions. Therefore, it requires a comprehensive breeding strategy to bring all these important traits into a single genetic back ground.

Effort were made to develop high lysine barley cultivars. One spontaneous mutant was identified in barley which was an Ethiopian land race (Hiplroly) through the screening of world barley collection. Subsequently, using physical and chemical mutagen high lysine mutant were identified at the Riso National Laboratory, Rosklide, Denmark. This high lysine trait in barley mutants is governed by single recessive genes, and the genes found in Hiproly, Notch-2 and Riso 1508 are non-allelic. The endosperms of these mutants were shrunken. High lysine lines derived from a backcross programme with barley variety Mona using Hiproly as the non-recurrent parent had small but well-filled grains.

Conclusion

The importance of optimal nutrition for human health and development is well recognized. Adverse environmental conditions, such as drought, flooding, extreme heat and so on, affect crop yields more than pests and diseases. Thus, a major goal of plant scientists is to find ways to maintain high productivity under stress as well as developing crops with enhanced nutritional value. Genetically-modified (GM) crops can prove to be powerful complements to those produced by conventional methods for meeting the worldwide demand for quality foods. Crops developed by genetic engineering can not only be used to enhance yields and nutritional quality but also for increased tolerance to various biotic and abiotic stresses. Integration of conventional breeding with modern biotechnology in a sustainable manner, can fulfil the goal of attaining food security for present as well as future generations.

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21 Role of Natural Anti-Oxidants to Manage Oxidative Stress

Sushil K Yadav

Introduction

Food provides not only essential nutrients needed for life but also other bioactive compounds with anti-oxidant properties for health promotion and disease prevention. Prevention is a more effective strategy than treatment of chronic diseases. Plant-based foods, such as fruit, vegetables and whole grains, which contain significant amounts of bioactive phytochemicals, may provide desirable health benefits beyond basic nutrition to reduce the risk of chronic diseases. Cells in humans and other organisms are constantly exposed to a variety of oxidizing agents, some of which are necessary for life. These agents may be present in air, food and water or they may be produced by metabolic activities within cells. The key factor is to maintain a balance between oxidants and antioxidants to sustain optimal physiological conditions in the body. Overproduction of oxidants can cause an imbalance, leading to oxidative stress, especially in chronic bacterial, viral and parasitic infections. Oxidative stress can cause oxidative damage to large biomolecules such as proteins, DNA and lipids, resulting in an increased risk for cancer and cardiovascular disease. To prevent or slow down the oxidative stress induced by free radicals, sufficient amounts of antioxidants need to be consumed. Fruit and vegetables contain a wide variety of antioxidant compounds (phytochemicals) such as phenolics and carotenoids that may help protect cellular systems from oxidative damage and lower the risk of chronic diseases. There are more than 8000 phytochemicals present in whole foods. These compounds differ in molecular size, polarity and solubility, and these differences may affect the bioavailability and distribution of each phytochemical in different macromolecules, sub-cellular organelles, cells, organs and tissues. Pills or tablets simply cannot mimic this balanced natural combination of phytochemicals present in fruit and vegetables. This study suggests that vitamin C at a high dose (500 mg) may act as a pro-oxidant in the body. We do not have an RDA for phytochemicals. Therefore, it is not wise to take mega-doses of purified phytochemicals as supplements before strong scientific evidence supports doing so.

Nutrition plays a vital role in healthy growth and development of an individual. The quantity and quality of food we need to consume is governed by our build, sex, activity and metabolic rate. No single food will provide all the essential nutrients that the body needs to be healthy. A diet that includes a variety of different food items is most likely to provide all the essential nutrients. If we do not get an adequate supply of essential nutrients, it can result in failure to flourish, poor growth and development, poor physical and mental health, various infections, diseases and in worst cases, even death. It is ironic that oxygen, an element indispensable for life, under certain situations has deleterious effects on the human body. Our body constantly reacts with oxygen during breathing and our cells produce energy by oxidation of food we consume. Oxidation happens under a number of circumstances including: when cells use sugars/glucose to make energy, when the immune system is fighting off bacteria and creating inflammation, when our bodies detoxify pollutants, pesticides and cigarette smoke. In fact, there are millions of processes taking place in our body at any one moment which can result in oxidation. As a consequence of this activity, highly reactive molecules are produced known as free radicals. In a biological context, ROS are formed as a natural byproduct of the normal metabolism of oxygen and have important roles in cell signaling and homeostasis. However, during times of stress (any biotic or abiotic), ROS levels can increase dramatically. This may result in significant damage to cell structures. Cumulatively, this is known as oxidative stress. In addition to causing some damage to cells, proteins and DNA (genes), they also stimulate repair. It is only when so many free radicals are produced and they devastate the repair processes and it becomes an issue. Oxidative stress is known to cause aging, grey hair, wrinkles, arthritis, decreased eye sight and even cancer. To know, if oxidative stress is causing an irreparable damage in your body we look out for the following signs: Fatigue, Memory loss and/or Brain fog, Muscle and/or Joint pain, Wrinkles and Grey hair, Decreased eye sight, Headaches and Sensitivity to noise and Susceptibility to infections.

Production of Free Radicals in the Human Body

Free radicals and other ROS are derived either from normal essential metabolic processes in the human body or from external sources such as exposure to X-rays, ozone, cigarette smoking, air pollutants and industrial chemicals. Free radical formation occurs continuously in the cells as a consequence of both enzymatic and non-enzymatic reactions. Enzymatic reactions, which serve as source of free radicals, include those involved in the respiratory chain, in phagocytosis, in prostaglandin synthesis, and in the cytochrome P-450 system. Free radicals can also be formed in non-enzymatic reactions of oxygen with organic compounds as well as those initiated by ionizing reactions. Some internally generated sources of free radicals are: Mitochondria, Xanthine oxidase, Peroxisomes, Inflammation, Phagocytosis, Arachidonate pathways, Exercise, Ischemia/Reperfusion injury. Some externally generated sources of free radicals are: Cigarette smoke, Environmental pollutants, Radiation, Certain drugs, pesticides, Industrial solvents and Ozone. There are two ways to reduce oxidative stress. Avoiding exposure to unnecessary oxidation and increasing anti-oxidants. Anti-oxidants are of two kinds: enzymatic and non-enzymatic. Now we will discuss what is their role and how enzymatic and non-enzymatic anti-oxidants keep a check on the level of reactive oxygen species.

Role of Antioxidants

In human body, cells use oxygen for catabolism of carbohydrates, proteins and fats which supply them energy. The human body obtains its energy by consuming nutrients and oxygen as fuel. It also makes use of oxygen to help the immune system, destroys foreign substances and fight diseases. A deeper study at cellular level reveals the role of mitochondria in reducing oxygen concentration by the transfer of electrons to create energy in the form of ATP and generation of water molecule. This process happens almost every time but sometimes instead of generating water, a “free radical” is produced. The part of the body that undergoes the most free radical damage wears out first and potentially develops degenerative diseases.

This is the darker side of oxygen often referred to as oxidative stress, which seems to be the underlying cause of all degenerative diseases. Free radicals are mainly oxygen molecules or atoms that have at least one unpaired electron in their outermost orbit. In the process of utilization of oxygen during normal metabolism within the cell to create energy, active free oxygen radical is created. These essentially have an electrical charge and want an electron from any molecule or substance in the vicinity to produce reactive oxygen species (ROS). These have such violent movement that they have been shown chemically to create bursts of light within the body. Antioxidants stop these free radical chain reactions by slowing down other oxidation reactions and removing ROS. If the free radicals are not rapidly neutralized by antioxidants, these may create even more volatile free radicals and cause damage to the cell membrane, vessel wall, proteins, fats, or even the DNA of the cell. Also, ROS are believed to cause and aggravate several human pathologies such as neurodegenerative diseases, cancer, stroke and many other ailments. There are hundreds of antioxidants of natural and synthetic origin. The interest of such compounds is due to their effective role against the destructive actions of free radicals.

Mechanism of Action of Antioxidants

Two principle mechanisms of action have been proposed for antioxidants. The first is a chain-breaking mechanism by which the primary antioxidant donates an electron to the free radical present in the systems. The second mechanism involves removal of ROS initiators (secondary antioxidants) by quenching chain-initiating catalyst. Antioxidants may exert their effect on biological systems by different mechanisms including electron donation, metal ion chelation, co-antioxidants, or by gene expression regulation.

Levels of Antioxidant Action

The antioxidants acting in the defense systems act at different levels such as preventive, radical scavenging, repair and *de novo*, and the fourth line of defense, i.e., the adaptation.

The first line of defense is the preventive antioxidants, which suppress the formation of free radicals. Although the precise mechanism and site of radical formation in vivo are not well elucidated yet, the metal-induced decompositions of hydroperoxides and hydrogen peroxide must be one of the important sources. To suppress such reactions, some antioxidants reduce hydroperoxides and hydrogen peroxide before hand to alcohols and water, respectively, without generation of free radicals and some proteins sequester metal ions.

Glutathione peroxidase, glutathione-s-transferase, phospholipid hydroperoxide glutathione peroxidase (PHGPX) and peroxidase are known to decompose lipid hydroperoxides to corresponding alcohols. PHGPX is unique in that it can reduce hydroperoxides of phospholipids integrated into biomembranes. Glutathione peroxidase and catalase reduce hydrogen peroxide to water.

The second line of defense is the antioxidants that scavenge the active radicals to suppress chain initiation and/or break the chain propagation reactions. Various endogenous radical-scavenging antioxidants are known: some are hydrophilic and others are lipophilic. Vitamin C, uric acid, bilirubin, albumin and thiols are hydrophilic, radical-scavenging antioxidants, while vitamin E and ubiquinol are lipophilic radical-scavenging antioxidants. Vitamin E is accepted as the most potent radical-scavenging lipophilic antioxidant.

The third line of defense is the repair and de novo antioxidants. The proteolytic enzymes, proteinases, proteases and peptidases present in the cytosol and in the mitochondria of mammalian cells, recognize, degrade and remove oxidatively modified proteins and prevent the accumulation of oxidized proteins. The DNA repair systems also play an important role in the total defense system against oxidative damage. Various kinds of enzymes such as glycosylases and nucleases, which repair the damaged DNA, are known.

There is another important function called adaptation where the signal for the production and reactions of free radicals induces formation and transport of the appropriate antioxidant to the right site.

Enzymatic Anti-oxidation

Cells are protected against oxidative stress by an interacting network of antioxidant enzymes. Here, the superoxide released by processes such as oxidative phosphorylation is first converted to hydrogen peroxide and then further reduced to give water. This detoxification pathway is the result of multiple enzymes, with superoxide dismutases catalyzing the first step and then catalases and various peroxidases removing hydrogen peroxide.

Superoxide Dismutase

Superoxide dismutases (SODs) are a class of closely related enzymes that catalyze the breakdown of the superoxide anion into oxygen and hydrogen peroxide. SOD is present in almost all aerobic cells and in extracellular fluids. There are three major families of superoxide dismutase, depending on the metal cofactor: Cu/Zn (which binds both copper and zinc), Fe and Mn types (which bind either iron or manganese), and finally the Ni type which binds nickel. In higher plants, SOD isozymes have been localized in different cell compartments. Mn-SOD is present in mitochondria and peroxisomes. Fe-SOD has been found mainly in chloroplasts but has also been detected in peroxisomes and CuZn-SOD has been localized in cytosol, chloroplasts, peroxisomes and apoplast.

In humans (as in all other mammals and most chordates), three forms of superoxide dismutase are present. SOD1 is located in the cytoplasm, SOD2 in the mitochondria, and SOD3 is extracellular. The first is a dimer (consists of two units), while the others are tetramers (four subunits). SOD1 and SOD3 contain copper and zinc, while SOD2 has manganese in its reactive center.

Catalase

Catalase is a common enzyme found in nearly all living organisms, which are exposed to oxygen, where it functions to catalyze the decomposition of hydrogen peroxide to water and oxygen. Hydrogen peroxide is a harmful by-product of many normal metabolic processes: to prevent damage, it must be quickly converted into other, less dangerous substances. To this end, catalase is frequently used by cells to rapidly catalyze the decomposition of hydrogen peroxide into less reactive gaseous oxygen and water molecules. All known animals use catalase in every organ, with particularly high concentrations occurring in the liver. Catalase has heme as a cofactor.

Glutathione Systems

The glutathione system includes glutathione, glutathione reductase, glutathione peroxidases and glutathione S-transferases. This system is found in animals, plants and microorganisms. Glutathione peroxidase is an enzyme containing four selenium-cofactors that catalyze the breakdown of hydrogen peroxide and organic hydroperoxides. There are at least four different glutathione peroxidase isozymes in animals. Glutathione peroxidase 1 is the most abundant and is a very efficient scavenger of hydrogen peroxide, while glutathione peroxidase 4 is most active with lipid hydroperoxides. The glutathione S-transferases show high activity with lipid peroxides. These enzymes are at particularly high levels in the liver and also serve in detoxification metabolism.

Non-enzymatic Anti-oxidation

Nutraceutical is a term coined in 1979 by Stephen De Felice. It is defined “as a food or parts of food that provide medical or health benefits, including the prevention and treatment of disease.” Nutraceuticals may range from isolated nutrients, dietary supplements and diets to genetically engineered “designer” food, herbal products and processed products such as cereals, soups and beverages. A nutraceutical is any nontoxic food extract supplement that has scientifically proven health benefits for both the treatment and prevention of disease. The increasing interest in nutraceuticals reflects the fact that consumers hear about epidemiological studies indicating that a specific diet or component of the diet is associated with a lower risk for a certain disease. The major active nutraceutical ingredients in plants are flavonoids. As is typical for phenolic compounds, they can act as potent antioxidants and metal chelators. They also have long been recognized to possess anti-inflammatory, anti-allergic, hepato-protective, antithrombotic, antiviral and anti-carcinogenic activities.

Role of Nutrition and Diet

We know that consuming the right quantity and the right types of food makes a balanced diet. The quantity of food intake is decided by our build, sex, activity and metabolic rate. The right types of food are important because the body needs a wide range of nutrients in varying amounts in order to function healthily. Our diet should contain protein, fats, carbohydrates and fiber in the form of fresh vegetables and fresh fruit, all in the right amounts, providing you with a good supply of essential amino acids, essential fatty acids, vitamins, minerals and of course fresh drinking water. Avoiding foods which are rich in some or all of the nutrients the body needs and filling up on those which lack nutritive value is hazardous to health. No single food will provide all the essential nutrients that the body needs to be healthy. A diet that includes a variety of different foods is most likely to provide all the essential nutrients. Knowing what foods contain which nutrients, why they are needed and just how much is needed, will help us to build a healthy body and a healthy life. In summary, if we do not get an adequate supply of essential nutrients, it can result in failure to flourish, poor growth and development, poor physical and mental health, various infections, diseases and in worst cases, even death.

Nowadays, vitamins and minerals supplements are found in almost every store and many of them are available in specific products such as vitamin A can be found in apricots, carrots, butter. Minerals are usually elements of certain kinds of foods, the most common example being the addition of iodine to the diet, through the popular “iodized salt”. Also, most health experts assess that our body needs at least two liters of water daily because it is the main component (we are about 70% water) and around 20 % to be taken from food or different beverages including water, juice, and coffee. All these nutrients prevent the normal body mechanism from oxidative stress that is free radical degenerative mechanism.

Although certain levels of antioxidant vitamins in the diet are required for good health, there is considerable doubt as to whether antioxidant-rich foods or supplements have anti-disease activity and if they are actually beneficial, it is unknown which antioxidant(s) are needed from the diet and in what amounts beyond typical dietary intake. Some researchers dispute the hypothesis that antioxidant vitamins could prevent chronic diseases, while others maintain such a possibility is unproved and misguided from the beginning.

Polyphenols, which often have antioxidant properties *in vitro*, are not necessarily antioxidants *in vivo* due to extensive metabolism. In many polyphenols, the catechol group acts as electron acceptor and is therefore responsible for the antioxidant activity. However, this catechol group undergoes extensive metabolism upon uptake in the human body, for example by Catechol "https://en.wikipedia.org/wiki/Catechol-O-methyl_transferase"-O-methyl "https://en.wikipedia.org/wiki/Catechol-O-methyl_transferase"transferase, and is therefore no longer able to act as electron acceptor. Many polyphenols may have non-antioxidant roles in minute concentrations that affect cell-to-cell signaling, receptor sensitivity, inflammatory enzyme activity or gene regulation. Although dietary antioxidants have been investigated for potential effects on neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis, these studies have been inconclusive.

Ascorbic Acid

Ascorbic acid or vitamin C is a monosaccharide antioxidant found in both animals and plants. As it cannot be synthesized in humans and must be obtained from the diet, it is a vitamin. In cells, it is maintained in its reduced form by reaction with glutathione, which can be catalyzed by protein disulfide isomerase and glutaredoxins. Ascorbic acid is a reducing agent and can reduce and thereby neutralize ROS such as hydrogen peroxide. In addition to its direct antioxidant effects, ascorbic acid is also a substrate for the antioxidant enzyme ascorbate peroxidase, a function that is particularly important in stress resistance in plants. Recent studies have shown that this vitamin is the best antioxidant within the plasma or fluid of the blood primarily because it is water soluble. It protects the LDL cholesterol from becoming oxidized within both the plasma and the sub-endothelial space. The major benefits of vitamin C include protection against immune system deficiencies, cardiovascular disease, prenatal health problems, eye disease and even skin wrinkling. It is also necessary for the maintenance of healthy connective tissue, which gives support and structure for other tissues and organs and helps in healing wounds. Vitamin C is highly concentrated in the fluid within the eye and is a very important antioxidant for the retina. Recent studies have indicated that the supplementation with vitamin C can slow down the progression of age-related macular degeneration.

Glutathione

Glutathione is a cysteine-containing peptide found in most forms of aerobic life. It is not required in the diet and is instead synthesized in cells from its constituent amino acids. Glutathione has antioxidant properties since the thiol group in its cysteine moiety is a reducing agent and can be reversibly oxidized and reduced. In cells, glutathione is maintained in the reduced form by the enzyme glutathione reductase and in turn reduces other metabolites and enzyme systems as well as reacting directly with oxidants. Due to its high concentration and central role in maintaining the cell's redox state, glutathione is one of the most important cellular antioxidants. In some organisms, glutathione is replaced by other thiols, such as by mycothiol in the actinomycetes, or by trypanothione in the kinetoplastids.

Glutathione is the most potent intracellular antioxidant present in every cell. Among the various antioxidants and detoxifying enzymes existing in mitochondria, mitochondrial glutathione (mGSH) has come out as the main category of protection for the maintenance of the appropriate mitochondrial redox environment to avoid or repair oxidative modifications leading to mitochondrial dysfunction and cell death. mGSH is found in plentiful quantity in mitochondria and is extremely versatile in its ability to oppose hydrogen peroxide, lipid hydroperoxides, or xenobiotics, mainly as a cofactor of enzymes such as glutathione peroxidase or glutathione-S-transferase (GST). Owing to the involvement of mGSH in different pathologic conditions such as hypoxia, ischemia/reperfusion injury, aging, liver diseases and neurologic disorders, it is becoming evident that it has an important role in the pathophysiology and biomedical strategies aimed to boost mGSH levels. Supplementation with the precursors of glutathione have shown significant enhancement of the overall immune system. Even patients of HIV infections have experienced this positive effect.

Tocopherols and Tocotrienols (Vitamin E)

Vitamin E is the collective name for a set of eight related tocopherols and tocotrienols, which are fat-soluble vitamins with antioxidant properties. Of these, á-tocopherol has been most studied as it has the highest bioavailability, with the body preferentially absorbing and metabolizing this form. It has been claimed that the á-tocopherol form is the most important lipid-soluble antioxidant and that it protects membranes from oxidation by reacting with lipid radicals produced in the lipid peroxidation chain reaction. This removes the free radical intermediates and prevents the propagation reaction from continuing. This reaction produces oxidized á-tocopheroxyl radicals that can be recycled back to the active reduced form through reduction by other antioxidants, such as ascorbate, retinol or ubiquinol.

Carotenoids

Carotenoids are the colorful plant pigments some of which the body can turn into vitamin A, are powerful antioxidants that can help prevent some forms of cancer and heart disease, and act to enhance our immune response to infections. These are precursors of vitamin A and are sometimes called as provitamin A. The most important beta-carotene is bright-orange one because it yields more vitamin A than the other types. Some other carotenoids, such as lycopenes are orange-red pigments found in tomatoes and watermelon. These do not convert to vitamin A, but still are of value because they have potent antioxidant properties. There is also abundant evidence that lycopene helps reduce the risk for prostate cancer. Most other carotenoids, such as alpha-and gamma-carotenes, cryptoxanthin, beta-zeacarotene, zeaxanthin, lutein, capsanthin and canthaxanthin have less vitamin A activity than beta-carotene, but possess anticancer activity.

Carotenes are valuable preventive medicines that are used to a larger extent among other antioxidants. Also, research has shown that people who eat a lot of foods rich in beta-carotene-the carotenoid with the greatest vitamin A value, are less likely to develop lung cancer. Even among smokers, lung cancer is less likely to occur in those people who eat a diet that includes lots of vegetables and fruits containing beta-carotene. A well known property of the carotenoids is the fact that they are capable of protecting the surrounding normal tissue from potential damage created by the inflammatory response of the immune system. Supplementation of the carotenoids can increase the number and effectiveness of the T-helper cells and natural killer cells which constitutes an important part of our defense system against cancer cells. This greatly improves tumor surveillance of immune system.

Coenzyme Q10 (CoQ10)

It is also known as ubiquinone, ubidecarenone, coenzyme Q and chemically is a 1,4-benzoquinone, where Q refers to the quinone functional group, and 10 refers to the number of isoprenyl chemical subunits in its tail. It is an oil-soluble, vitamin-like substance present in most eukaryotic cells, primarily in the mitochondria. It actively participates in generating energy in the form of ATP and ninety five percent of the human body's energy is produced in this way. Hence, the organs with the higher energy requirements such as the heart, liver and kidney have the very high CoQ10 concentrations.

Ageing process results in the decrease in CoQ10 levels and makes the mitochondria vulnerable to oxidative damage. CoQ10 is critical for the optimal function of the immune system because of its major role in the production of energy in the immune system. Supplementation of CoQ10 has been shown to reverse these problems and significantly enhance the immune system.

Silicon

Silicon supports collagen found in skin thereby giving a more youthful and supple appearance while helping prevent the development of wrinkles. This mineral is also important because of its ability to strengthen the connective tissue matrix which strengthens bone. Silicon can even reduce swelling of joints that are due to injury which in turn will allow them to heal more quickly. Silicon also aids with digestive function because it maintains the tissues that are found along the body's digestive tract. Using a silica supplement can decrease intestinal and stomach inflammation as well as help eliminate problems such as constipation, diarrhoea and ulcers. Silicon is an essential mineral for helping keep blood vessel walls supple and strong. It may even help clear up plaques as well as prevent heart disease. Hence, it improves cardiovascular health of a person. Silica does wonders at helping develop a lustrous and beautiful head of hair because it repairs the majority of the collagen and connective tissues found in the body and this will in turn improve strength of hair. Patients with osteoporosis in whom the generation of new bone is desirable, need increased amount of silicon.

Boron

Boron is an interesting nutrient when it comes to bone metabolism. It has been a known fact that arthritis is associated with a dietary deficiency of the mineral boron. Boron is a membrane catalyst which allows various ions to pass through the cell membrane, particularly phosphates to support synthesis of ATP. This will give energy for efficient repair. It is obvious that in osteoarthritis, the cartilage is worn out, if it is because it lacks the necessary energy for cell division which explains the action of boron. Also, studies have shown that people who had been taking boron supplement have harder bones than the others who do not. This also supports the fact that boron does influence calcium metabolism. Recent research has shown that lack of boron is one of the main causes of osteoporosis. The studies took boron in supplementation and concluded that the urinary excretion of calcium is decreased by approximately 40 percent. Boron also increases magnesium concentration and decreases phosphorus levels.

Zinc

Zinc is an essential trace element for humans, animals and plants. It is vital for many biological functions. Zinc is found in all parts of the body, but muscles and bones contain most of the body’s zinc (90%). Zinc is especially important for the growing fetus whose cells are rapidly dividing. It also helps to avoid congenital abnormalities and pre-term delivery. Among all the vitamins and minerals, zinc shows the strongest effect on the immune system. It plays a unique role in the T-cells. Low zinc levels lead to reduced and weakened T-cells which are not able to recognize and fight off certain infections. An increase of the zinc level has proven effective in fighting pneumonia and diarrhea and other infections. Zinc can also reduce the duration and severity of a common cold. Zinc is also used as an anti-inflammatory agent and can help to sooth the skin tissue, particularly in cases of poison ivy, sunburn, blisters and certain gum diseases. This mineral is important for the normal functioning of vitamin D. Studies have shown lower zinc levels in serum and bones of patients with osteoporosis.

Melatonin

Melatonin, also known chemically as N-acetyl-5-methoxytryptamine, is a naturally occurring hormone found in animals and in some other living organisms, including algae. Melatonin is a powerful antioxidant that can easily cross cell membranes and the blood–brain barrier. Unlike other antioxidants, melatonin does not undergo redox cycling, which is the ability of a molecule to undergo repeated reduction and oxidation. Melatonin, once oxidized, cannot be reduced to its former state because it forms several stable end-products upon reacting with free radicals. Therefore, it has been referred to as a terminal (or suicidal) antioxidant.

Uric Acid

Uric acid accounts for roughly half the antioxidant ability of plasma. In fact, uric acid may have substituted for ascorbate in human evolution. However, like ascorbate, uric acid can also mediate the production of active oxygen species.

Physical Exercise

During exercise, oxygen consumption can increase by a factor of more than 10. However, no benefits for physical performance to athletes are seen with vitamin E supplementation and 6 weeks of vitamin E supplementation had no effect on muscle damage in ultra-marathon runners.

Increased Antioxidative Stress

Inappropriate antioxidative intake may cause increased antioxidative stress. Antioxidants can neutralize ROS and decrease oxidative stress; however, this is not always beneficial with respect to the development of a disease and its progression (e.g., cancer) or for delaying aging since antioxidants cannot distinguish among the radicals with a beneficial physiological role and those that cause oxidative damage to biomolecules. Indirect methods are used in order to overcome these problems. Indirect methods usually measure the changes in endogenous antioxidant defense systems or measure the ROS-induced damage of cellular components. Measuring the damage caused by ROS instead of direct measuring of ROS seems logical, since it is the damage caused by ROS that is important rather than the total amount of generated ROS. Methods have been developed to detect and quantify oxidative damage to proteins, lipids, and DNA. The principle behind fingerprinting methods is to measure products of damage by ROS, that is, to measure not the species themselves but the damage that they cause. Of course, the end-products must be specific markers of oxidative damage. A good marker of oxidative damage must increase by oxidative stress (i.e., upon the treatment with, e.g., paraquat, diquat, ionizing radiation, hyperoxia) and it must remain unchanged in the absence of the oxidative event.

The key to the future success of dietary antioxidant supplementation may be in the fine tuning of the suppression of oxidative damage without disruption of the well-integrated antioxidant defense networks. The selective enhancement of the defense system could be a major strategy for a successful intervention by antioxidant administration.

Plants as Source of Antioxidants

Synthetic and natural food antioxidants are used routinely in foods and medicine synthetic antioxidants, and consumer preferences have shifted the attention of manufacturers from synthetic to natural antioxidants. In view of increasing risk factors of human to various deadly diseases, there has been a global trend toward the use of natural substance present in medicinal plants and dietary plats as therapeutic antioxidants. It has been reported that there is an inverse relationship between the dietary intake of antioxidant-rich food and medicinal plants and incidence of human diseases. The use of natural antioxidants in food, cosmetic, and therapeutic industry would be promising alternative for synthetic antioxidants in respect of low cost, highly compatible with dietary intake and no harmful effects inside the human body. Many antioxidant compounds, naturally occurring in plant sources have been identified as free radical or active oxygen scavengers. Attempts have been made to study the antioxidant potential of a wide variety of vegetables like potato, spinach, tomatoes and legumes. Strong antioxidants activities have been found in berries, cherries, citrus, prunes and olives. Green and black teas have been extensively studied in the recent past for antioxidant properties since they contain up to 30% of the dry weight as phenolic compounds.

Apart from the dietary sources, Indian medicinal plants also provide antioxidants and these include (with common/ayurvedic names in brackets) *Acacia catechu* (kair), *Aegle marmelos* (Bengal quince, Bel), *Allium cepa* (Onion), *A. sativum* (Garlic, Lahasuna), *Aleo vera* (Indian aloe, Ghritkumari), *Amomum subulatum* (Greater cardamom, Bari elachi), *Andrographis paniculata* (Kiryat), *Asparagus recemosus* (Shatavari), *Azadirachta indica* (Neem, Nimba), *Bacopa monniera* (Brahmi), *Butea monosperma* (Palas, Dhak), *Camellia sinensis* (Green tea), *Cinnamomum verum* (Cinnamon), *Cinnamomum tamala* (Tejpata), *Curcma longa* (Turmeric, Haridra), *Emblica officinalis* (Indian gooseberry, Amla), *Glycyrrhiza glapra* (Yashtimudhu), *Hemidesmus indicus* (Indian Sarasparilla, Anantamul), *Indigofera tinctoria, Mangifera indica* (Mango, Amra), *Momordica charantia* (Bitter gourd), *Murraya koenigii* (Curry leaf), *Nigella sativa* (Black cumin), *Ocimum sanctum* (Holy basil, Tusil), *Onosma echioides* (Ratanjyot), *Picrorrhiza kurroa* (Katuka), Piper beetle, *Plumbago zeylancia* (Chitrak), *Sesamum indicum, Sida cordifolia,Spirulina fusiformis* (Alga), Swertia decursata, Syzigium cumini (Jamun), *Terminalia ariuna* (Arjun), *Terminalia bellarica* (Beheda), *Tinospora cordifolia* (Heart leaved moonseed, Guduchi), *Trigonella foenum-graecium* (Fenugreek), *Withania somifera* (Winter cherry, Ashwangandha) and *Zingiber officinalis* (Ginger).

Antioxidants in Food

Spices, herbs, essential oils and cocoa are rich in antioxidant properties in the plant itself and *in vitro*, but the serving size is too small to supply antioxidants via the diet. Typical spices high in antioxidants that are confirmed *in vitro* are clove, cinnamon, oregano, turmeric, cumin, parsley, basil, curry powder, mustard seed, ginger, pepper, chili powder, paprika, garlic, coriander, onion, cardamom and a few more. Some herbs with high antioxidant potential are sage, thyme, marjoram, tarragon, peppermint, oregano, savory, basil and dill weed. Dried fruits are a good source of antioxidants by weight or serving size because water has been removed making the ratio of antioxidants higher. A few examples of this category are pears, apples, plums, peaches, raisins, figs and dates. Deeply pigmented fruits like cranberries, blueberries, plums, blackberries, raspberries, strawberries, blackcurrants, figs, cherries, guava, oranges, mango, pomegranate and grape juice also have significant antioxidant properties. Also, there are a few cooked vegetables which are rich in antioxidants such as artichokes, cabbage, broccoli, asparagus, avocados, beetroot and spinach. Typical nuts are pecans, walnuts, hazelnuts, pistachio, almonds, cashew nuts, macadamia nuts and peanut butter are also moderate antioxidants. Sorghum bran, cocoa powder and cinnamon are rich sources of procyanidin antioxidants found in many fruits and some vegetables.

Conclusion

Antioxidants are emerging as prophylactic and therapeutic agents. Many are being used as nutritional supplements for prophylaxis of certain diseases along with mainstream therapy. However, there are several factors related to dietary antioxidants such as poor solubility, inefficient permeability instability, extensive first pass metabolism and rapid gastrointestinal degradation, which have limited their extensive use. Hence, there is need to develop new drug delivery systems to improve the performance of antioxidants. Also, we know that antioxidants counteract the detrimental effects of free radicals. Hence, a therapeutic strategy may be formulated where antioxidant capacity of the cells may be used for long term effective treatment. However, the exact role of antioxidant supplementation in disease prevention still remains a debatable issue. Furthermore, extensive research is needed before this supplementation can be recommended as an adjuvant therapy. Nowadays, we find an overabundance of antioxidant supplements available over the counter and their usage is unorganized. To ensure safe and beneficial use, availability of antioxidants must be regulated by prescription from certified health professionals. The public may however be advised about the advantages of antioxidants and they should be encouraged to take the food containing fresh fruits, green leafy vegetables, seeds, nuts and vegetable oils which are rich sources of antioxidants. Use of dietary supplements, functional foods, and nutraceuticals is increasing as industry is responding to consumers' demands. However, there is a need for more information about the health benefits and possible risks to ensure the efficacy and safety of dietary supplements. It is recommended that consumers follow the US Department of Agriculture dietary guidelines to meet their nutrient requirements for health improvement and disease prevention. We believe that the evidence suggests that antioxidants are best acquired through whole-food consumption, not as a pill or an extract.

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22 Importance of Horticultural Crops in Foods and Nutrition Constraints in Production of Quality Foods

N N Reddy

Introduction

People have food security when they are able to grow enough or buy enough food to meet their daily needs for a healthy life. Access to nutritious food is a key dimension of food security. In Africa and Asia, urban households spend up to 50 percent of their food budgets on cheap "convenience" foods often deficient in the vitamins and minerals essential for health. Fruit and vegetables are the richest natural sources of micronutrients. 90 per cent of the developing world's chronically under-nourished children live in Asia and Africa. In India, 18 per cent of children under five years of age suffer from acute under-nutrition. But in developing countries, daily fruit and vegetable consumption is just 20-50 percent of WHO recommendations.

Enlisting Production Constraints for Reshaping Horticulture

Soil physical and chemical properties are major factors that limit water and nutrient use efficiency. These factors include texture and the cation exchange capacity (CEC). Most soil-related constraints are associated with sandy soils. Soils with low water and nutrient-holding capacity provide little room for inefficiencies of irrigation or fertilizer application.

Inadequate availability of quality planting material, poor health of old and neglected orchards, Inadequate production, protection and On-Farm handling, weak database and poor market intelligence pose a serious threat to the development. One of the recent threats facing the horticultural industry in India is the large volume of imports which are of high quality and available at exorbitant prices are preferred by most supermarkets. This can be done away by removing the bottlenecks faced by the local farmers. In addition we have to fight with crop specific Pests and Disorders of national importance are :

Mangoes	-	Malformation; alternate bearing / irregular bearing, spongy tissues
Guava	-	Wilt
Citrus	-	Decline
Coconut	-	Root wilt; Ganoderma wilt; Tatipaka disease; Eriophid mite
Black pepper	-	*Phytophthora* foot rot, and nematodes
Ginger	-	Rhizome rot and Bacterial wilt
Cardamom	-	'Katte' disease
Oil palm	-	Ganoderma
Vegetables	-	Virus disease
Coffee	-	White stem borer, Berry borer, leaf rust
Rubber	-	Phytophthora leaf fall disease, corynespora, leaf disease and pink disease

Common Problems

(i) Inadequate availability of disease free, high quality planting material.

(ii) Micro-propagation techniques are under exploited.

(iii) Slow dissemination and adaptability of improve high yielding cultivars/hybrids.

(iv) Inadequate facility for identification of nutrient deficiency and disorders.

(v) Lack of diseases and pests' outbreak forecast service.

(vi) Unavailability of refined intensive integrated production systems.

(vii) Lack of quality standards.

(viii) Lack of technologies in value addition.

(ix) Lack of post harvest management technology and infrastructure.

(x) Weak database and poor market intelligence.

(xi) Poor marketing practices and infrastructure.

(xii) Instability of prices, with no support price mechanism.

(xiii) Inadequate technical manpower/human resource in farming system.

(xiv) Poor credit supply, high rate of interest coupled with inadequate crop insurance scheme.

(xv) Ineffective transfer of technology

(xvi) Poor linkage between R&D sectors, industries and farming communities.

(xvii) Late implementation of government policies and schemes.

(xviii) Absence of horticultural crop suitability maps of India based on agroclimatic conditions.

Crop Specific Problems

Fruit crops

Long gestation period, Predominance of senile orchards (e.g. apple and mango), Lack of technology to manage problems like spongy tissue, alternate bearing and malformation in mango, wilt in guava, decline in citrus, etc., Location specific technologies are not available. Lack of proper crop management and soil health techniques.

Vegetable crops

High cost of production due to labour intensive technologies, Exorbitant charges of hybrid seeds, Risk intensive production system, Lack of low cost environmental controlled green houses for high quality production, Supply and demand profile frequently changing with season, year and kind of vegetable, Non availability of technology for extending production to semi arid areas under low moisture regime and mild problematic soil conditions.

Potato : Lack of varieties for diverse cultivation, processing problems, Low seed multiplication rate (5-10 times) from breeders' seed to certified seed, Rapid deterioration of varieties due to viral complexes.

Lack of awareness of TPS technology, Lack of required cold storage space and non availability of low cost short term storage structure.

Mushroom **:** Available technology not cost effective, Lack of design of low cost mushroom houses. Inadequate availability of quality spawn of different strains.

Tuber crops **:** Slow multiplication rate, Poor management practices for pests like sweet potato weevil and diseases like cassava mosaic and colocasia blight.

Floriculture

Lack of indigenous production techniques, F_1 hybrids not fully exploited, Narrow product range.

Medicinal and Aromatic Plants

Trade of medicinal and aromatic plants is very secretive due to absence regulatory mechanism.

Less number of spp under cultivation (out of 4000 identified only 20-30 are cultivated).

Spices

(i) Lack of variability for host resistance to biotic and abiotic stresses.

(ii) Severe crop losses caused due to disease and pests.

(iii) Vagaries of monsoon affect crop growth, productivity and sustainability.

Coconut

(i) Large area of old and senile plantations under rainfed condition.

(ii) Rainfed cropping nature.

(iii) Prevalence of diseases and pests like root-wilt, ganoderma wilt, Thanjavur wilt, tatipaka diseases and eriophide and red palm weevil pests pose severe threats to industry.

(iv) Farm level processing is inadequate.

Arecanut

(i) Incidence of diseases like yellow leaf diseases.

(ii) Lack of irrigation facilities.

Oilplam

(i) Poor water management in the palm orchards.

Cocoa

(i) Large areas of old and senile plantations.

(ii) Lack of high yielding clones.

(iii) Black pod rot in cocoa continues to be problems in production front.

(iv) Farm level processing is inadequate.

Cashew

(i) Increasing level of senility of the existing plantation.

(ii) Poor management of pests like tea mosquito bug and stem borer.

(iii) Farm level processing is inadequate.

Tea

(i) Old age of tea bushes.

(ii) Slower pace of replantation- the rate of replanting < 0.4% as against the desired 2.0%

(iii) Poor drainage and lack of irrigation when needed greatly reduces the yield.

(iv) Stagnation in productivity level compounded by high land labour ratio.

(v) Higher rate of taxation in the income from tea.

(vi) Stiff competition from the soft drinks.

Coffee

(i) Presence of large number of tiny growers with less than two hectare.

(ii) Existence of old moribund plant material - reluctance of replant with new varieties.

Rubber

(i) Unattractive financial assistance to growers to undertake scientific planting.

(ii) Low price of rubber.

(iii) Inadequate infrastructure for primary processing.

(iv) Stiff competition from natural and synthetic rubber

Infrastructure

Inadequate Post Harvest Infrastructure, Poor Marketing Infrastructure, Inadequate Processing Facilities, Inadequate Research and Extension Support.

Nutritional security: Malnutrition-under-nutrition and imbalanced nutrition-is a major health problem in developing and developed countries. Even among wealthy only about 7 percent children between 6 and 24 months receive adequate feeding, health care and environmental health in India.

There is a horticultural remedy for every nutritional malady. Fruits, vegetables, spices and aromatic plants are the reservoirs of much needed fibre, vitamins, minerals, anti-oxidants, lipids, flavourants, odourants and essential phyto-chemicals. Fruits, vegetables (including leafy vegetables) and nuts are important in daily diet as they contain micronutrients, vitamins and minerals, fiber, vegetable protein and bioactive compounds (Quebedeaux and Eisa, 1990; Wargovich, 2000). Leafy vegetables like red and green amaranth, Indian spinach, water spinach, drumstick leaves and *jute leaves*, are excellent sources of iron, beta carotene (pro vitamin A), and folic acid. Ripe mango and papaya, carrot, orange fleshed sweet potato and pumpkin contain high quantities of pro vitamin A whereas local citrus fruits as well as star fruit, jujube and guava provide vitamin C, good for enhancing absorption of iron from the diet. Moreover, vegetable and fruit gardens are largely managed by women and set close to the households. Horticulture products, therefore, not only make a vital contribution to household food and nutrition security, but they can also generate employment for women and foster economic security.

Impact of Urban Food Security : Intensive horticulture production on urban peripheries makes sense. But as cities grow, valuable agricultural land is lost to housing, industry and infrastructure resulting production of fresh food being pushed further into rural areas. The cost of transport, packing and refrigeration, the poor state of rural roads, and heavy losses in transit add to the scarcity and cost of fruit and vegetables in urban markets. Our competitor China has integrated food production into urban development since the 1960s. Today, more than half of Beijing's vegetable supply comes from the city's own market gardens, and it costs less than produce trucked from more distant areas. Horticulture in and around Hanoi produces more than 1,50,000 tonnes of fruit and vegetables a year. In Cuba, which has promoted intensive UPH since the early 1990s, the sector accounts for 60 percent of horticultural production - and Cubans' per capita intake of fruit and vegetables exceeds the FAO/WHO recommended minimum. As urbanization accelerates in sub-Saharan Africa, many countries are seeking to develop their commercial horticulture sectors to ensure urban food security. The first step is to legalize, promote and protect long established small-scale market gardens.

Poor man's crop and rich man's food, the leafy *Moringa* or drumstick, is one such important culinary item to ward off nutrient deficiency in the wake of climate change because it is a naturally-occurring bio-fortified crop suited to Indian climate. Bio-fortification differs from conventional fortification in that it aims to increase nutrient levels in crops during plant growth rather than through manual means during their processing.

Impact of Household Food Security

Programmes of UPH also promotes home, school and community gardens, where the urban poor grow their own fruit and vegetables and earn income from the sale of surpluses. School gardens are a proven means of promoting child nutrition. They familiarize children with horticulture, provide fresh fruit and vegetables for healthy school meals, help teachers develop nutrition courses and, when replicated at home, improve family nutrition as well.

Opportunities to Increase Consumption of Micronutrient Rich Horticulture Crops

Horticultural interventions combined with extensive nutrition education offer a long-term, food-based strategy to control and eliminate micronutrient malnutrition. As an example a standard recipe is mentioned from locally available ingredients:

Sabji Misrito Soup, 6 Servings

- Green papaya : 100 g
- Pointed gourd : 100 g
- Snake gourd : 100 g
- Sweet pumpkin : 100 g

- Yard long beans: 100 g
- Leafy vegetables (*pui/lal shak*) : 100 g
- Potato: 100 g
- Onions (finely chopped) : 1 tsp
- Flour (rice or wheat) : 2 tsp
- Egg : 2 pcs
- Oil : 3 tsp
- Spices : cumin, green chilies, black pepper powder, ginger and garlic paste – to taste
- Lemon : 1 pc

Boil 10 cups of water in a large vessel, add oil, salt, ginger/garlic paste and chopped onions. Add all chopped vegetables except the leafy vegetables. Add paste of flour, stir and bring to boil. Add beaten egg and cumin, stir slowly. After 1 minute add leafy vegetables and remaining spices. Serve with lemon. Nutritive value/ serving: Energy 142 kcal; CHO 11 g; Protein 7 g; Fat 7 g; Vitamin A [RAE] 139 ìg; Iron 2 mg; Calcium: 60 mg; Vitamin C 28 mg.

Role of Horticultural Crops in Human Nutrition

Vitamins: The deficiency of any vitamin from the diet for considerable period may lead to diseased state or disorder conditions. Fruits and vegetables supply several vitamins.

Calcium: It is essential for development of bones regulation of heartbeat, controlling blood clots. Sources: Acid lime, Orange, Fig, Dried apricots, wood apple, cabbage, greens, beans, carrot, onions, peas, tomatoes, agati, spinach drumstick leaves etc.

Iron: It is required for production of haemoglobin and it is constituent of red blood corpuscles. Its deficiency causes anaemia, smooth tongue, pale lips, eyes and skin and frequent exhaustion. Sources: Custard apple, Guava, Pineapple, Straw berry, Grape, Black currents, dried dates, carrot, drumstick leaves, beans and agati etc.

Phosphorous: It is essential for maintaining the moisture content of tissues and for development of bones. Sources: Guava, Grape, Jackfruit, Passion fruit, Orange and vegetables like Carrot, Chilli, Drumstick leaves, Beans, cucumber and onion.

Proteins: These are bodybuilding foods essential for growth. Protein deficiency causes retarded growth and increased susceptibility to diseases and causes lethargy. Sources: Most of the fruits are low in proteins except guava and Banana. Vegetables like peas and beans are rich in proteins.

Enzymes: These are required for controlling several metabolic activities in the body. Sources: Papaya-Papain and Pineapple-Bromelin.

Fibre and roughages (*Cellulose and pectin*): Fruits and vegetables supply roughages. Help in digestion and prevent constipation. Sources: Fruits contain low content of fibre. Guava and anola are better sources compared to other fruits. Leafy vegetables are rich in fibre content/

The Simple Solution

- Fruits and vegetables improve absorption of phytates whole grains, seeds, pulses
- Green leafy vegetables–Fe, Vitamin A; More available Fe than legumes
- Tree nuts, Portulaca–Essential fatty acids (Omega 3)
- Mango, Pumpkin, Carrot, Orange-fleshed sweet potato – Vitamin A, Vitamin C 1/2 cup pumpkin, 2/3 a carrot, 1 mango supplies RDA of Vitamin A and Vitamin C
- Citrus, guava, broccoli, peppers, potato—Vitamin C
- Foods are better accepted and more sustainable than vitamin supplements or pharmaceuticals for some populations

Horticultural Food Crops

Fruits: Fruits of woody perennial plants have long been prized for sources of refreshment, for their delightful flavors and aromas, and as nourishing foods.

Nuts: The important tree nuts that enter into international trade include almonds, Brazil nuts, cashews, chestnuts, hazelnuts, macadamias, pistachios, pecans and hickories, and walnuts.

Beverage crops: Beverage crops include the subtropical crops—coffee, tea, and maté—and the tropical cacao used for cocoa and the confection chocolate.

Vegetables: Vegetables are typically herbaceous (softstemmed) plants in which various parts are used as food, including roots, tubers, leaves, fruit, or seed. There are various groupings based on the part consumed and taxonomic affinity.

Culinary herbs and spices: Allspice, anise, basil, capsicums, caraway, cardamom, cinnamon, chervil, clove, coriander, cumin, dill, fennel, funugreek, garlic, ginger, laurel, marjoram, mint, mustard, nutmeg and mace, onion, organum, parsley, pepper, poppy seed, rosemary, saffron, sage, savory, sesame, star anise, tarragon, thyme, and turmeric.

Functions of Foods

Food satisfies hunger, social needs, cultural and religious needs, builds body tissues and regulates body processes, protective in function and supplies energy.

Fruits and Vegetables

Eating plenty of fruits and vegetables can help you ward off heart disease and stroke, control blood pressure and cholesterol, prevent some types of cancer, avoid a painful intestinal ailment called diverticulitis, and guard against cataract and macular degeneration, two common causes of vision loss. Free radicals damage cellular membranes, proteins and DNA and cells and produce a range of diseases in body. Phenols, flavonoids, anthocyanins and carotenoids are some of the important antioxidant found in fruits and vegetables. In this section we will study the nutrient and non-nutrient components of fruits and vegetables.

Enzymes and Pigments

Fruits and vegetables are rich in colour imparting pigments and enzymes. The chief pigments of fruits and vegetables are carotenoids, chlorophyll and anthocyanin.

Table 1. Vitamin content in fruits and vegetables

Product	Calorific value (cal/100g)	Vitamin A (IU/100g)	Vitamin B (mg/100g)	Vitamin C (mg/100g)	Nicotinic acid (mg/100g)
Fruits					
Apple	56	-	0.03	2	0.2 0.03
Aonla	59	-	0.03	700	0.2 0.03
Banana	153	-	0.04	19	0.3 0.03
Guava	66	-	0.03	300	0.2 0.03
Lime	59	26	0.02	63	0.1 0.02
Mango	50	4800	0.04	24	0.3 0.05
Orange	49	350	0.05	68	0.3 0.06
Papaya	40	2020	0.04	46	0.2 0.05
Pear	47	14	0.02	-	0.2 0.03
Pineapple	50	60	0.03	63	0.2 0.04
Tomato	21	320	0.04	32	0.4 0.05

Leafy Vegetables					
Cabbage	33	2000	0.06	124	0.4 0.12
Drum stick	96	11300	0.06	220	0.8 0.12
Radish leaf	33	6700	0.05	65	0.5 0.12
Spinach	32	5500	0.05	48	0.5 0.11
Roots and Tubers					
Carrot	47	2000-4300	0.04	3	0.4 0.02
Onion	51	-	0.08	11	0.4 0.01
Potato	99	40	0.10	17	1.2 0.01
Radish	21	-	0.06	15	0.4 0.02
Sweet Potato	159	-	0.05	-	0.3 0.01
Yam	79	434	0.06	-	0.7 0.08
Other Vegetables					
Brinjal	34	5	0.05	23	0.8 0.06
Ash gourd	15	-	0.06	5	0.4 0.01
Cauliflower	39	38	0.10	66	0.9 0.08
French been	26	221	0.08	14	0.3 0.06
Cucumber	14	-	0.03	7	0.2 0.02
Lady Finger	41	58	0.06	16	0.6 0.06
Pea	109	139	0.25	9	0.8 0.01
Pumpkin	28	84	0.06	2	0.5 0.04
Snake gourd	22	160	0.04	-	0.3 0.04

Carotenoids are natural compounds that give the deep yellow, orange and red colours to fruits and vegetables such as apricots, carrots and tomatoes, orange, capsicum, mango and papaya. Carotenoids also are plentifully found in in dark green vegetables, such as spinach, but the dense chlorophyll marks the carotenoid colours. The major carotenoids found in fruits and vegetables include alpha-carotene, â-carotene, lutein, lycopene and zeaxanthin (Table 1). The body can convert á-carotene, â-carotene and cryptoxanthin to retinol so they are called pro-vitamin A carotenoids. Lycopene, lutein and zeaxanthin donot have pro-vitamin A activity. Lycopene is the orange- red pigment of tomatoes. Enzyme like Ficin in figs and papain in papaya are the major proteolytic enzymes. These enzymes can react with proteins of the human skin and cause dermatitis. Phenoloxidases in potatoes, apples, pears, grapes, strawberries, and figs are responsible for the discoloration of cut surfaces when exposed to air. Other enzymes responsible for color changes in fruits and vegetables are chlorophyllases, anthocyanases and peroxidase. Lipoxygenase and lipase are the enzymes linked with off-flavour in frozen peas and beans. Citrus fruits and tomatoes are rich in pectin esterase, and pears and tomatoes in polygalacturonase, both being pectolytic enzymes responsible for softening of fruit texture during ripening (Table 2 and 3).

Factors Affecting Nutritional Qualities

Temperature and light intensity have strong effect on the nutritional quality. Soil type, rootstock, mulching, irrigation, fertilization, cultural practices influence water and nutrient supply to the plant can affect the composition and quality attributes (appearance, texture, taste and aroma) of the harvested plant parts (Goldman *et al*., 1999).

Delays between harvest and consumption or processing can result in losses of flavor and nutritional quality. Temperatures, RH, O_2, Co_2, and ethylene outside the ranges are optimum for each commodity during the entire post harvest handling system (Lee and Kader, 2000). Low temperature favour synthesis of sugar and vitamin C while short duration decreases the rate of ascorbic acid oxidation. Maximum beta-carotene of tomatoes occurs at 15 to 21^{o}C but it is reduced if temperatures are higher or lower than this range. The B vitamins are crop specific to temperature sensitivity. Warm season crops (beans, tomatoes, peppers, melons) produce more B vitamins at high (27-30^{o}C versus low (10-15^{o}C) temperatures. Cool season crops such as broccoli,cabbage, spinach, peas produce more B vitamins at low temperature. Light intensity has little effect on the B vitamins but as light intensity increases, vitamin C increases and total carotenoids and chlorophyll decrease (Gross, 1991).

Table 2. Fruits and vegetables rich in dietary fiber.

Soluble fiber	Insoluble fiber
Apples, Cranneberries, Grapefruit, Mango, Oranges, Bananas, Berries, Cherries, Pears	Apples, Bananas, Cherries, Pear
Asparagus, Brussels Sprouts, Carrots	Broccoli, Red cabbage, Spinanch, Sprouts
Peanuts, Pecanuts, Walnuts,	Almonds, Sunflower seeds
Oat bran, Oatmeal, Psyllium	Brown rice, whole-wheat breads

Table 3. Fiber content in some fruits and vegetables

Fruits & Vegetables	Serving size (g)	Total fiber (g)
Fruits		
Apple	138	2.76
Banana	114	1.94
Cantaloupe	133	0.93
Grapes	100	1.0
Orange	131	2.49
Pineapple	0.88	0.13
Strawberry	149	2.68
Vegetables		
Green beans	67	1.27
Broccoli	78	2.57
Cabbage	70	2.54
Carrots	72	1.19
Corn	83	1.74
Potato	156	5.05
Turnip	82	2.05
Peas	80	2.80

Phytochemicals in Fruits and Vegetables

Phytochemicals are essentially chemical compounds that can be found in plant foods like fruits, vegetables, beans and whole grains. These compounds give distinctive color, smell and taste. Antioxidants are actually part of a group of compounds called phytochemicals. Different phytochemicals are linked to different colored fruits and vegetables, eating a variety of colored fruits and vegetables will mean ingesting a variety of phytochemicals. Each phytochemical potentially benefits body in a different way, so it's good to try and mix it up whenever you can. These compounds are linked to possible prevention of chronic diseases like cancer, heart disease, diabetes, and high blood pressure. Another group of phytochemicals are polyphenols and flavonoids. These tiny compounds are known for their antioxidant ability and prevent chronic diseases. There are thousands of phytochemicals in plants. Flavonoids can boost the antioxidant capacity of cells when ingested with a source of Vitamin C or E (a food synergy). It is recommended to eat a variety of fruits, vegetables and other minimally processed foods to benefit from these potentially powerful compounds. Some examples of foods (and beverages) containing polyphenols include apples (with the skin), grapes, berries, citrus, pomegranate, onion, garlic, cabbage, cauliflower, broccoli, tea, red wine, beer and chocolate.The following are phytochemicals:

Carotenoids: The orange, red and yellow pigments of fruits and vegetables (dark green chlorophylls of vegetables and kiwi masks the colors of carotenoids).

Thiocyanates : Sulfur compounds keep your nose away at the aroma of boiling cabbage.

Daidzein and genistein: hormone-like compounds in many fruits and vegetables.

Dietary fiber: Other phytochemicals like vitamins perform beneficial housekeeping chores in our body. They keep cells healthy, prevent the formation of carcinogens (cancer-producing substances), reduce cholesterol levels and help move food through intestinal tract.

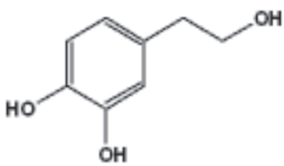
Response to drugs: Some of these phytochemicals influence our response to drugs. Naringenin, in addition to serving as an antioxidant, free radical scavenger, anti-inflammatory chemical, carbohydrate metabolism promoter and immune system modulator also inhibits the cytochrome P450 enzyme system in the liver. Individuals taking statin medications for high cholesterol are instructed to avoid grapefruit because naringenin will inhibit the breakdown of statins and cause a dangerous level to accumulate in the body. Yams (containing carotenoids) can help prevent some of the oxidative damage associated with free radicals, improving cancer and heart disease prognosis.

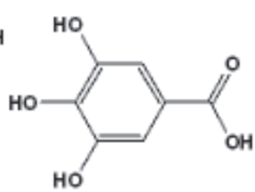
Hormonal Function

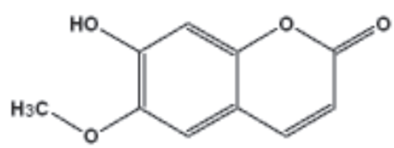
Isoflavones in soy and the lignans in flax block estrogen receptor sites, diminishing estrogen effect on certain tissues. There are enzymes in the liver that make estrogen less effective. These enzymes can be up-regulated by indoles, found in cruciferous vegetables. Protect DNA: Phytochemicals such as capsaicin, which makes peppers spicy, may help protect DNA from carcinogens. Garlic is anti-bacterial due to allicin.

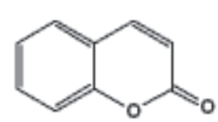
What are Phytochemicals?

Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties. They are non-essential nutrients to the human body for sustaining life. Plant produce these chemicals to protect themselves but they can also protect humans against diseases. There are more than thousand known phytochemicals. Some of the well-known phytochemicals are lycopene in tomatoes, isoflavones in soy and flavanoids in fruits.









How do Phytochemicals Work?

There are many phytochemicals and each works differently. Some possible actions:

Antioxidant : Most phytochemicals have antioxidant activity and protect our cells against oxidative damage and cancers. Phytochemicals with antioxidant activity: allyl sulfides (onions, leeks, garlic), carotenoids (fruits, carrots), flavonoids (fruits, vegetables), polyphenols (tea, grapes).

Hormonal action : Isoflavones, found in soy, imitate human estrogens and help to reduce menopausal symptoms and osteoporosis.

Stimulation of enzymes : Indoles found in cabbages, stimulate enzymes that make the estrogen less effective and could reduce the risk of breast cancer. Other phytochemicals, which interfere with enzymes, are protease inhibitors (soy and beans), terpenes (citrus fruits and cherries).

Interference with DNA replication :Saponins in beans interfere with the replication of cell DNA, prevent multiplication of cancer cells. Capsaicin, found in hot peppers, protects DNA from carcinogens.

Anti-bacterial effect : Phytochemical allicin from garlic has anti-bacterial properties.

Physical action : Some phytochemicals bind physically to cell walls preventing adhesion of pathogens to human cell walls. Proanthocyanidins have anti-adhesion properties in cranberry. Cranberries reduce urinary tract infections and improve dental health.

Common Phytochemicals

Resveratrol in grapes/grape skins, Isoflavones in soy, Lycopene in tomatoes, Lutein in spinach and Naringenin in grape fruit (Table 4).

Whole Foods

Indeed, a varied diet rich in whole foods offers the best combination of dietary micronutrients and phytochemicals. Unfortunately, in today's nutritional world, we're replacing these whole foods with processed foods low in vitamins, minerals and phytochemicals. Nutrient deficiencies unseen for hundreds of years are beginning to reappear. With these deficiencies come poor health, increased disease risk, obesity and more.

Functional Foods

The term 'functional' is used to describe foods and drinks that are enriched with particular nutrients or substances that have the potential to positively influence health over and above their basic nutritional value. Functional foods are usually similar to foods that are consumed as part of our usual diet e.g. yogurt, drinks, bread.

Key Points

- Functional foods deliver additional benefits over and above their basic nutritional value.
- The term 'functional foods' can be viewed as encompassing a broad range of products.
- Some functional foods are generated around a particular functional ingredient, for example foods containing probiotics, prebiotics, or plant stanols and sterols.
- Other functional foods or drinks can be foods fortified with a nutrient that would not usually be present to any great extent (e.g. folic acid fortified bread or breakfast cereals).
- Functional foods and drinks provide health benefits but not alternative to a balanced diet**.**

Important Functional Foods

- Probiotics are live microorganisms mostly bacteria impart health benefits.
- Prebiotics promote growth of particular beneficial bacteria which tone up large intestine and also inhibit the growth of potentially harmful bacteria to intestinal health.
- Stanols and sterols, occur naturally in small amounts in plants and fruits, have a cholesterol lowering effect and are added to products such as reduced/low fat spreads.

Functional Foods from Plant Sources

- *Oats* **:** This plant food can reduce total and low density lipoprotein (LDL) cholesterol.
- *Soy* **:** Soy has been in the spotlight during the 1990s. Not only is soy a high quality protein, as assessed by the FDA's "Protein Digestibility Corrected Amino Acid Score" method, it is now thought to play preventive and therapeutic roles in cardiovascular disease (CVD), cancer, osteoporosis, and the alleviation of menopausal symptoms.
- *Flaxseed* **:** Flaxseed oil contains the most (57%) of omega-3 fatty acid, a-linolenic acid. Consumption of flaxseed reduce total and LDL cholesterol (Cunnane *et al.*, 1993).

Table 4. Phytochemicals their food sources and effects

Class	Food Source(s)	Action(s)
Phytoestro gens (Isoflavones)	Soy, flaxseed, seeds, nuts, yams, alfalfa, red clover sprouts, licorice root	Block some cancers, aid in menopaus, improve memory.
Phytosterols Saponins	Plant oils, corn, soy, sesame, safflower, wheat, pumpkin Yams, beets, beans, cabbage, nuts, soybeans	Block hormonal role in cancers. Inhibit uptake of cholesterol from the diet. Prevent cancer cells from multiplying.
Terpenes	Carrots, yams, winter squash, sweet potatoes, apples, cantaloupe	Antioxidants, protect DNA from free radicalinduced damage.
	Tomatoes, tomato-based products	Block UVA,UVB. protect against cancers (prostate).
	Citrus fruits (flavonoids), apples (quercetin)	Promote protective enzymes in liver. Antiseptic
	Spinach, kale, beet, turnip greens, cabbage	Protect eyes from macular degeneration
	Red chili peppers	Prevent carcinogens from binding to DNA.
Phenols	Fennel, parsley, carrots, alfalfa, cabbage, apples	Prevent blood clotting, anti-cancer properties.
	Citrus fruits, broccoli, cabbage, cucumbers, green peppers, tomato	Antioxidant function. Flavonoids block membrane receptor sites for certain hormones.
	Grape seeds, apples	Strong antioxidants. Fight germs and bacteria. Strengthen immune system, veins, capillaries.
	Grapes (skins)	Antioxidant, antimutagens, promote detoxification, carcinogen inhibitors.
	Yellow and green squash	Antihepatotoxic and antitumor properties.
S compounds	Onions, garlic	Promote liver enzymes, inhibit cholesterol synthesis, reduce triglycerides, lower BP, improve immunity.

- *Tomatoes* **:** Lycopene is primary carotenoid found in this fruit (Gerster, 1997), and it has a role in cancer risk reduction (Weisburger, 1998).
- *Garlic* :Flavor and pungency are due to oil and water-soluble, sulfur-containing elements, responsible for medicinal effects ascribed to this plant (Nagourney, 1998).
- *Broccoli and other Cruciferous Vegetables* **:** cruciferous vegetables decrease cancer risk due to high content of glucosinolates (Verhoeven *et al*., 1997).
- *Citrus Fruits* : Citrus fruits are protective against a variety of human cancers. Citrus fruits are particularly high in a class of phytochemicals known as the limonoids. (Hasegawa and Miyake, 1996).

- *Cranberry* **:** Cranberry juice cures urinary tract infections and also inhibits the adherence of *Escherichia coli* to uroepitheial cells.
- *Tea* : Tea is second only to water as the most widely consumed beverage in the world. Polyphenols comprise up to 30% of the total dry weight with Catechins.
- *Probiotics* : Probiotics are defined as live microorganisms mostly bacteria which when taken in adequate amounts confer a health benefit. Traditionally, bacteria have been used for the production of fermented foods such as yogurt and sauerkraut. Probiotics stimulate the immune system. Probiotics may help prevent the development of some allergic diseases, such as atopic dermatitis (an allergic skin reaction) in childhood.
- *Prebiotics* **:** First used in 1995 and can be defined as a non-digestible food ingredient that can deliver beneficial effects on health by selectively stimulating the growth and/or activity of specific health-promoting bacteria in the colon. Prebiotics promote the growth of particular bacteria in the gut that are beneficial to intestinal health (for example Lactobacillus sp., Bifidobacteria sp. and Lactococcus sp.). They also inhibit the growth of potentially harmful toxin producing Clostridia and Escherichia coli. Foods naturally containing prebiotic properties include leeks, chicory, asparagus, bananas, artichokes, garlic, onion, wheat, soybean, oats and some honeys.
- *Plant stanols and sterols* : Although plants usually only contain a small amount of fat, their seeds are relatively concentrated sources. Interest in one particular group of plant derived lipids, plant stanols and sterols.
- *Sterols* : Components of cell membranes controlling membrane fluidity and permeability. Present naturally in small quantities in fruits, vegetables, nuts, seeds and legumes.
- *Stanols* : are chemically similar to sterols. They occur in similar sources such as nuts, seeds and legumes but in smaller quantities than sterols.

The structure of plant stanols and plant sterols is very similar to that of cholesterol and so they are able to compete with cholesterol in the human gut. It is thought that including plant stanols and sterols in the diet reduces the absorption of cholesterol. These days, products fortified with plant stanol or sterol esters are widely available.

Fortification

- Nutrients may be added to foods irrespective of whether or not the nutrients are originally present in the food. The fortification of flours (except whole-meal and some self-raising varieties) with calcium began in World War 2, in anticipation of reduced supply of dairy products and its addition by law continues today.

Adding Nutrients to Foods

Different fibre fractions and nutrients have been added to foods over time, including:

- Vitamins (e.g. vitamins A, C, D and a range of B vitamins)
- Minerals (e.g. iron, iodine, calcium and zinc)
- Proteins and/or amino acids

Adding nutrients to foods, particularly staple foods, can increase intakes among most of the population. One example is the addition of iodine to salt to decrease iodine deficiency disorders.

Ethnic Foods

Ethnic foods are defined as foods originating from a heritage and culture of an ethnic group who use their knowledge of local ingredients of plants and/or animal sources. To illustrate, Hindu food from India, Maori food from New Zealand, and Masai food from Kenya are ethnic foods. Ethnic food can be defined as an ethnic group’s or a country’s cuisine that is culturally and socially accepted by consumers outside of the respective ethnic group. For example, Greek food, Indian food, Italian food, Thai food, and Korean food are all considered ethnic food outside of their own countries. Furthermore, foods eaten by people of different religions are also considered ethnic food. For example, traditional Buddhist cuisine, Christian cuisine, and Muslim cuisine are also included in the category of ethnic food.

Table 5. Protein-rich crops

Grains	Protein per 100 g	% of RDA
Lentil	25.1	44.8 %
Green Gram	24.5	43.8 %
Cow Peas	24.1	43 %
Moth Beans	23.6	42.1 %
French Beans (Dry)	22.9	40.9 %
Peas (Dry)	19.7	35.2 %
Bengal Gram	17.1	30.5 %
Peas(Tender)	7.2	12.9 %
Soyabean (White) Seeds	43.2	77.1 %
RDA For Protein is 56 grams		

Mushrooms as a functional foods : Basidiomycetes and some species of ascomycetes produce edible mushrooms have higher protein and minerals and less fat but are rich in vitamins B, D, K and sometimes A and C. Mushrooms are therapeutic foods, useful in preventing diseases such as hypertension, diabetes, hypercholesterolemia and cancer. These functional characteristics are mainly due to the presence of dietary fibers like chitin and beta glucans. Some mushroom species have antitumor, antiviral, antithrombotic and immunomodulating properties.

Nutraceuticals **:** The term “Nutraceutical” was coined from “nutrition” and “pharmaceutical” in 1989 by Stephen DeFelice. Nutraceutical is “a food (or part of a food) that provides medical or health benefits, including the prevention and/or treatment of a disease” When functional food aids in the prevention and/or treatment of disease(s) and/or disorder(s) other than anaemia, it is called a nutraceutical. Examples of nutraceuticals include fortified dairy products (e.g., milk) and citrus fruits (e.g., orange juice).

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23 Project Opportunities for Setting Up of Food Processing Industries and CFTRI Technologies

T Jyothirmayi

Introduction

Detailed CFTRI technologies were given with categorical heads with special emphasis on technology of fruits and vegetables as these are highly perishable. Advantages of food processing, opportunities, constraints, socioeconomic development, various drivers for food processing, nutritional aspects, safety aspects were given. Technology transfer from CFTRI, Analytical service facilities, testing facilities were described. Some latest trends and minimizing the nutrient losses with special reference to fruits and vegetables were provided.

Advantage in India for Food Frocessing

- Abundant and large variety of farm produce due to diversified (26 types) climatic conditions
- Largest Livestock Population
- 3rd largest food producer in world
- Largest producer of pulses
- Leading producer consumer of milk and milk based products in world.
- 5th in poultry production
- Ranks Second in production of wheat, rice and groundnut and fourth in coarse grains
- Second largest producer of fruits and vegetables.
- Abundant skilled and unskilled work force at cheaper cost
- Leading Producer of coconut, cashew nut, ginger, turmeric and black pepper

India confronts a situation in which the surplus and the starvation exist together. Uneven distribution, wastage and spoilage of food mainly contribute to such an anomaly. Prof. M.S. Swaminathan, Chairman, National Commission on Farmers (India) "Having mountains of grains on one side and hungry millions on the other, by 2020, the demographic divide, economic divide and the nutritional divide will widen unless we address them with our existing technologies."

Lack of proper Post-harvest infrastructure and adequate supply chain results in losses of harvested farm produce worth approx. Rs. 30000 crores annually in the country. To improve farmer's economy and save nation's wealth, need of the hour is to build sustainable supply chains to link the farmer to the processing and marketing centres and also to develop integrated post- harvest technology and infrastructure.

Food Processing Industry and Socioeconomic Development

- Labour intensive (Employs 18 – 20% labour force) offer major employment opportunity
- High Priority Area (Thrust Area)
- Optimal utilization of agro resources
- Highly decentralized small and Cottage scale industries
- Dominate, Predominance of primary processing units
- Enhancement of farmer's economy, improvement in quality of life of rural Contributes to food security and price stabilization

Constraints for Food Industrial Growth

- Raw material availability (price, suitability, consistency)
- Higher logistics cost
- Large number of marginal farm holding
- Huge gap between farm gate price and price to consumer (80%)
- Varietal suitability for processing and price / yield factor.

MOFPI Vision 2015 Document (2005) Targets

Increase level of processing of perishables from 6 to 20% (3 times)

Increase value addition from 20% to 35%

Increase India's share in global food market from 1.5% to 3% by 2015

- 1.1 billion population base with 1.6% annual population growth, who spend over 50% income on food
- 350 million urban middle class with its growing purchasing power
- Changing food habits (preference to convenience, processed food)
- Growing need for convenience foods due to urbanization

Favourable Market Drivers for Packaged Processed Foods

- Increasing proportion of urban working women, growing organized retails.
- Shift on house hold expenditure on Cereals, Pulses, edible oils, salt, sugar, spices declined.
- Milk and milk products, meat, egg and fish, fruits, vegetables and beverages increased
- Increased food safety and hygience consciousness. Growing health and wellness consciousness.
- Paradigm shift of joint families to nuclear familie.
- Emergence of wide range of innovative, safe and reliable quality branded foods.

Product Modification Matching to Consumer Demands

- Products having lesser synthetic ingredients, preferably no additives Foods and ingredients healthier for him
- Local flavour and taste at modest price
- Existing product modified to address lifestyle disorders like obesity, hypertension, diabetes, heart ailments, etc. (Health and wellness based products)
- Low sugar, low fat, reduced calorie, low sodium foods
- Probiotic enriched dairy products and baby foods
- Products having much needed essential nutrients
- Nutrient and nutraceutical enriched food products

Examples

Fruit juices/beverages (Tropicana/Real), Sport drink (Gatorado), High fibre biscuits, Flaxseed biscuit (Benne Vita), Multigrain biscuits, Low sugar/sugarfree products confectionary, beverages, ice-cream), Nutrichoice Diabetic Friendly, Essentrals XXX Energy drink, Cereal bar (Horlick, Nutirbar), Mother Horlicks, Junior Horlicks, Complan Memory, Amaze Brain Foods.

Ingredients Used

Omega-3, Vitamin B1 and B 12, antioxidants, protein ingredients, vital minerals and phytochemicals such as Ginko bilola, brahmi extracts, carotenoids, fibres, probiotics.

Causes of Food Deterioration

- Decomposition by microorganisms (bacteria, yeast and moulds)
- self-decomposition of the food (by enzymatic biochemical reactions and chemical reactions like oxidation)
- Damage by insects, pests, rodents and other animals, mechanical causes, etc.

Methods of Food Preservation

- Reduction of water activity
  a) Drying and Dehydration
  b) Preservation by adding sugar
  c) Preservation by salt
- High temperature processing
- Low temperature preservation (refrigerated/cold storage)
- Freezing preservation
- Preservation by using chemical preservatives
- Adjustment of pH/ Acidity
- Oxygen removal
- Preservation by hurdle technique
- Radiation preservation
- Packaging

Central Food Technological Research Institute (CFTRI) is a constituent laboratory of Council of Scientific and Industrial Research, New Delhi. The focus of the institute is mainly toward development of low cost effective technology, utilization of indigenous raw materials, and bio-friendly technology with emphasis on integrated technology, high level pursuit for total technology, underpinning food safety, health and nutrition to all sections of the population. CFTRI developed number of Technologies for commercial exploitation, which were categorized as follows:

Animal Products

Fish products: thermal processed, Instant gravy mixes (dehydrated), Meat gravy (concentrate), Shark fin rays from dried fins, Shrimp: Canning of, Shrimp Freeze drying of, Extruded Shrimp Feed, Animal feed formulations: Cattle and Poultry, Bacon and Ham: preparation, Chicken products: Sticks, Curried, Kabab, Egg: extension of shelf-life, Meat pickles: Fish, Prawn, Chicken, Mutton, Fish waste silage (acid), Poultry intestine silage, Fish viscera silage, Mackerel: salt curing, drying, Meat soup cube, Meat tenderization Mutton: conditioning of, Dehydration of Meat, Sausage casings: natural, Sausage preparation (Meat, Chicken, Fish and Pork), Traditional products HAE/RTC (all 7):- Chicken Tandoori, Chicken kabab, Mutton shami kabab, Breaded chicken kabab, Chicken sandwich spread (HAE), Frozen Curry Chicken, Fish, Mutton (HAE), Biryani and Chicken (HAE), Meat/Fish/Poultry wafers (Chicken/Fish/Prawn/Pork/Egg/Meat), Marinating paste- Fish fry, Marinated – Tandoori chicken including marinating paste, Meat paste from layer chicken, Meat/Chicken/Fish/Prawn/ Pork/Egg wafers, Fermented Silkworm pupae Silage, Chicken soup mix, Tenderization of layer chicken muscle, Shelf-stable chicken biriyani, Shelf-stable chicken tit-bits, Meat burger, Egg loaf, Shelf stable kabab mix with chicken meat.

Bakery Products

Biscuit formulations: Cocoa, Cocoa cream, Nutro, (all 3), Sugar free Biscuit, Baking power, Biscuit production:

Salt/Sweet, Cardamom flavour, High fiber, Wheat germ, Sunflower seed grits, Low sodium, Therapeutic, Bread: Production (Brown, plain, Sweet, Milk, Whole wheat, Fruit, High fiber, Ragi, Bajra, Premixes – baked foods-Bread, Biscuit, Cookie, Composite Ragi Rusk, Onion flavoured biscuit, Wheat Germ Stabilization, Sugar free cup cake, Sugar free cake rusk, Instant Payasam Mix, Bar cake, Whole wheat flour biscuit, Egg-less Cake, Sugar free layer cake Sugar free rusk, High protein rusk and buns, High protein Upma mix, Cake rusk, Instant cake mix, Vermicelli (wheat and whole wheat flour), Fortified protein rich vermicelli, Ragi based biscuit, Layered parotta (South Indian), Suruchi meetha–health food snacks (burfi), Honey based Bakery products, Sugar free bread, Egg less cake premix, High protein biscuits, Improver mix for bread, rolls and buns etc. (yeast leavened bakery products).

Beverage Products

Coffee beverage, Cola flavour concentrate, Orange flavour concentrate for manufacture soft beverage, Liquid fruits (Apple, Banana, Grapes, Guava),Malted beverage, Carrot juice beverage and RTS, Ginger cocktail, Groundnut milk/Soya milk curd, Honey beverage, Orange comminuted: beverage base, Pan supari nectar, Pomegranate juice and products, Fruit syrups and squashes, Litchi products, Lactic beverage-Cereal based, Sugarcane juice bottling, Clear Lime-Lemon flavour, blend for soft drink manufacture, RTS fruit juice and beverages Neera bottling.

Cereal Products

Cereal flakes: rice, jowar, Instant traditional foods: Bisi bele bhath, Puliogere, Sambar, Rasam, Pongal, Urd bhath, Imlipoha, Quick cooking rice, Curing of new paddy, Parboiling of paddy: dry heat/hot soak method, Paushtik atta, Refined millet flour, Basmati Rice (Staining technique), Maize and Wheat flakes (dry heat process), Detoxification of kesari dhal, Husk free cereal malt flour, Maize chips, Vermicelli noodles - Rice, Jowar, Ragi, Maize, Bajra, Navane and Samai, Ready to eat low fat snack like “Chakli and Tengolal”, Improved maize flour, Ready to eat low fat flaked spices Maize/Corn-snacks, Legume based ready-to-fry-snacks, Ragi based papads, Pulse based papads, Decortication of Ragi, Malted ragi flour – enzyme rich, Ready-to-eat low fat maize snacks form milled maize grits, Flaking of fox tail millet, Composite lentil chips, Flaked jowar RTE sweet and savoury snacks, Quick cooking, germinated and dehydrated pulses, Fermented and dehydrated ready mixes for Idli and Dosa, Foods for diabetics, Shelf-stable jowar flour, Processed besan for sev and boondi preparation, Puffed moth bean based sweet and savoury snacks.

Convenience Foods

Ready Mixes – Idli, Vada, Dosa, Chakli, Jamoon, Jelebi, Cake, Maddur vada, Pakoda, Flavoured flan, Cake Doughnut, Combination dough mix, Upma, RTE convenience foodKhakra, Snack food (soya/maize), North Indian (Punjab) Halwa Mix, Bombay Halwa Mix, Chutney paste (spreads), Low fat expanded Snacks,Soya based instant sambar mix, Low sugar milk Burfi, Deep fat fried and flavoured cashew kernels, Shelf-stable and ready to eat foods thermo processed in retort pouches (non-veg. and veg. Foods), Canned (Aluminium cans) mixed vegetable curry and rice based convenience products, Canned (Aluminium cans) vegetable chunks in tomato soup, Tamarind candy.

Food Machinery Design Drawings

Hot air drier-(cabinet/tunnel type for Arecanut, Cardamom, Cashew kernel), Modern dhal mill, Parboiling plant: paddy, Roller flaker, Single effect evaporator: 1000 kg, 500 kg, 200 kg), Simple rice milling systems (Double pass single huller, Single pass double huller, Centrifugal sheller huller), Chapati making plant, Heat sealer: continuous, Leaf cup machine (hand/pedal operated), Paddy crack detector, Papad press (Hand/Leg operated), Pest proofing machine, Simple pulse dehusking machine (hand opera-ted and mechanized), Strip lacquering machine, Triple roller extractor, Vegetable slicer, Chicken dressing line, Quick test kit for FFA, Mini dhal milling system, Versatile Dal mill, Automatic Idli making unit, Automatic Dosa Making unit, Design on Spouted Bed Coffee Roaster, Paddy crack detector, Gota Separator, Integrated rubber roll sheller huller rice mill, Design on retort control system for sterilization of packaged foods, Vibro fluidized bed roaster, Dry maize milling plant, Device for Pneumatic extrusion of dough and device useful for dusting and cutting of dough into geometrical shapes (Chapati sheeting machine), Laboratory freeze dryer, Infrared heating of Cashew kernels for testa removal, Combined infrared hot air heating system for food processing, Hot hair popping machine using flue gas, Parboiling and Drying plant 4 TPH and 2 TPH, Desiccated coconut drier, Electronic sterility index monitor, Continuous bio-plate casting machine, Automatic continuous cooker, Sugarcane de-skinning machine, Chutney dispenser, Integrated hot air roasting machine, Production of virgin coconut oil, Continuous vada making machine.

Fruit and Vegetable Products

Fruit bars: Mango, Banana, Guava and Apple, Fruits and Vegetables dehydration: Grapes, Banana, Onion, Potato and Peas and green chillies, Instant Pickles: Mango, Lime, Pectin from pectinaceous materials, Oyster Mushroom: production, dehydration, culture, spawn, Rural and Urban model – with paddy straw, coir pith and coffee pulp and with cotton seed meal supplementation, Amla products- Juice/ concentrate/RTS beverage, Technology Protocol for Export of Alphonso, Banganapalli and Kesari by ship, Anti-fungal paste, Curried vegetables: canning, Fruit jams and jellies: prepn, Fruit preserves and candies, Tutti-fruity (papaya/carrot), Ginger candy, Amla candy, Fruit toffees, Fruit and vegetables: canning of, refrigeration and freezing, Mango pulp: bulk preservation for RTS beverage, Mango ripening, Muskmelon seeds (dehulling), Pickles and Chutneys, Osmo-air dried: Jackfruit/ Pineapple/ Amla segments (sweet and salted), Potato products, Tomato products, Wax emulsion, Chilli Sauce, Jamoon fruit products: (squash, RTS beverage, syrup, carbonated beverage), Dehydrated drumstick powder, Fruit jams and jellies including mixed fruit jam containing amla, Instant dehydrated vegetables curry mixes (Cauliflower, Cabbage, Beans and Carrot), Amla spread, Modified atmosphere packaging of minimally processed vegetables, Value added products from Figs (*Ficus carica* L), Pre and post-harvest technology protocol for export of fresh pomegranate – Ganesh variety and mango - Neelam variety by ship , Protocol for export of Banana variety Dwarf Cavendish by ship, Dehydrated bitter gourd, Fruit spread: fruit juice, fruit concentrate and honey, Fruit spread: fruit juice and honey, Fruit spread: fruit juice, sugar and honey, Dehydrated whole lime, Instant mushroom soup mix, Preparation of cashew apple candy, Bio-preservation of RTE sugarcane chunks, Amla paste

Microbiology and Fermentation Products

Microbial production of amyloglucosidase enzyme by solid state fermentation, Microbial production of pectinase enzyme by submerged fermentation, Aflatoxin decontamination (filtration method), Biosensor from Glucose and Sucrose, Ready to use idli batter in retail packs, Ready to use dosa batter in retail packs, Protocol for assembly of Aflatoxin detection kit, The production of Fructo-oligosacharides syrup and powder, Kit for the detection of aflatoxins by improved Dot-ELISA technique, Kit for the detection of deoxynivalenol by improved Dot-ELISA technique, Cultivation of *Dunaliella*, â-carotene rich micro algae, Production of steviosides extract and crystals from *Stevia rebaudiana*, Simple detection kit for endosulfan residues in plant foods (Elisa Process), Cultivation of *Botryococcus braunii* – biomass production .

Plantation and Spice Products

Annatto dye: preparation, Processing of cocoa beans to: Cocoa mass, Cocoa butter, Cocoa powder, Compounded Asafoetida, Coriander dhal supari, Encapsulated flavours, Garlic powder, Kokum: concentrate and powder, Mustard powder, Making superior quality White pepper, Dehydrated of Green pepper, Plant growth promoter: n-triacontanol, Spice oleoresins: Pepper, Ginger, Turmeric, Chillies, Tamarind: juice concentrate and powder, Sterilization of Black Pepper, Cardamom: fixation of green colour, Cherry coffee: Monsooning, Processing of coca (Theobroma cocoa pods to dried cocoa beans, Desiccated coconut, Ginger: dehydration/ bleaching, Red chillies: fractionation, Red chillies: drying of (incl. dipsol formulation), Turmeric: curing and polishing, Ready spice mixes (Sambar Rasam and Pulao), Zink - EDTA Chelate, Garlic paste, Ginger paste, Gravy paste for different Indian Cuisine, Spray dried coconut milk powder, Sugarcane juice spread, Removal of smoky odor from bhatti cured large cardamom capsules, Green pepper in brine, Green tamarind spice mix - paste and powder, Production of encapsulated spice/citrus oils and spice oleoresins, Dipping oil formulation for grapes, Faster curing of vanilla beans Preparation of radical scavenging conserve from tea leaves-normal/coarse/pruned, Chlorogenic acid rich coffee conserve from green coffee beans.

Protein Specialty Products

Mustard/rape seed integrated processing, Protein isolates: Groundnut and Soya, Sesame: dehulling, (dry and wet processes), Sunflower seed: beneficiation, Weaning food roller dried, Spirulina, Rural based biotechnological production of spirulina, Production of a blue pigment from Spirulina, Spirulina process with enriched iron content of high bio-availability, Balahar, Groundnut flour: edible, Malted weaning food), Multipurpose food, Full fat Soya flour: edible, Enteral Foods, Minimizing the drip loss in frozen peeled and de-veined shrimps, Spray dried refined papain, Low cost Nutrient supplement for malnourished children, Low fat high protein snack foods, Mass propagation of Vanilla by tissue culture technique, Mass propagation of Banana by tissue culture technique, Bland soy protein concentrate, High protein soya cereal ready mix for the preparation of kesari bhath, upma, porridge and others, Energy food: new formulation, Dehulling of Niger seeds, Nutro crispo-sweet and savoury, Heat resistant white Sesame seeds, Groundnut butter.

Emerging Range of Food Products

Ready mix foods: Idli Mix, Dosa Mix, jamun Mix, Jelebi Mix, Sambhar Mix, Rasam Mix

Therapeutic foods: Yogurt,Acidophiluss Milk, Tempe

Ready to Cook Foods: Idli and Dosa Batter, Vermicelli

Bio-processed foods: Kanji, Cheese, Sauerkraut, Malted Ragi Flour Enzyme Rich

Ready to eat foods: Thermal Processed Foods in Retort Pouch

Energy food: Malted weaning food, Paushtik Atta, High Protein Soya Cereal Mix , Iron Rich Spirulina, Energy Food Amylase Rich

Health drinks: Clarified Juice (Banana, Guava, Grapes, Pomegranate), Pine Apple Juice, Amla drinks, Honey Beverage and Sugarcane Juice

Foods for Diabetic: Sugar Free Bread, Biscuits, Rusk, Cake Mix and Low Sugar Milk Burfi

Hypocholesterolemic foods: Low Fat Expanded Snacks, RTE Low Fat Maize Foods, Low Fat *High Protein Snacks Health foods*: High Protein Upma Mix, Suruchi Meetha, Protein Rich Vermicelli, Soya Based Instant Sambar Mix.

Other Process Control Tools

Pest control programme is one of the important activities in the entire production and process as pests pose a threat to the entire system, right from incoming raw material to storage of finished goods. Installation of fire-control and alarm systems and periodic inspection and maintenance thereof. Air curtains maintain the constant interior temp of cold room chambers / ice cream chambers these high-velocity airflow air curtain block entry of hot air, insects, dust, dirt, fumes by creating invisible curtain of high pressure air when the doors are open. Metal detection and seperation systems CIP (clean-in process) systems.

Oganic Foods

Organic foods (product of farming system avoids use of man-made fertilizer, pesticides, growth promotor) it relies. After 3 years such treatment, first produce is ‘organic’. ‘organic’ product – min 95% organic agri ingredients. E.g. Corn flake made with organic ingredients –min. 70% organic agri. Ingredients e.g. Ketchup, grape wine.

Selection Criteria for Food Packaging System

- Packing requirements of food product
- Barrier, strength and product compatibility properties of packaging system
- Intended shelf-life
- Cost

Package forms Flexible, semi-rigid, rigid, metal, glass, plastic, wood, paper, al-foils, composites, laminates, coextruded films, coatings, different forms.

Marketing pattern of processed fruit and vegetable products in India sector market share (value based)

- institutional 40%
- house holds and housewives 40%
- export 20%

Quality safety nutrition sensory, physical, kinesthetic and other dimensions macro- and micro- nutrients microbiology, additives, contaminants, toxins, environmental pollutants, adulterants food issues.

Food safety is an important issue globally. Food manufacture needs to assure safe and quality food at affordable and competitive price to the consumer. Food safety and quality encompasses the entire food chain starting from farm products on to processing transportation and distribution, till consumption.

Food Standards

a. Safety standards a - gives protection to health of consumers minimum quality requirements as laid down under "prevention of food adulteration act, 1954 and rules thereof, 1955". This will be replaced by food safety and standards act

b. Quality standards* mandatory b - to improve the quality at the manufactures level and encourage the food industry viz., BIS, AGMARK, FPO etc., * voluntary

Nutrition Information Panel

Total calories, calories from fat, total fat, saturated fat Transfat, cholesterol, vitamin content, mineral content etc.,

Support Through Various Promotional Agencies

Capital investment subsidy - random support - quality control support - market development assistant - export incentives - establishment of food parks, food clusters, agri export zone - cold chain incentive schemes and storage infrastructure.

Technology Transfer from CFTRI

Identification of the CFTRI technology by the entrepreneurs - payment of premium to CFTRI by the entrepreneurs (remittance by DD favouring director, CFTRI, Mysuru. Signing of license agreement, Technical dossier to the licensee - demonstration of process know-how at CFTRI, Mysuru - participation of two authorized representatives in the demonstration-cum- training - one to one discussion with the concerned faculty and quality control procedure.

User Oriented Services of CFTRI

- Analytical and quality control for food industries
- Industrial consultancy to industries
- Contract research for product development and trouble- shooting in food processing sectors
- Sensory assessment and consumer acceptance studies
- Packaging materials testing and food packaging assistance
- Need based bibliography in food science and technology
- Detailed Project Report for establishing food industry/food clusters
- Human Resource Development and training

Analytical Capabilities

Physico-chemical and microbiological analysis of processed and primary foods as per FPO, PFA, BIS, AGMARK, FDA-USA and CODEX specification/ guidelines.

- Nutrition facts (FDA, CODEX, EEU, ICMR)
- Additives (preservatives, colours, sweetners, antioxidants)

- Food contaminants (toxic metals, pesticide residues, mycotoxins)
- Vitamins and minerals
- Sensory analysis (quantitative descriptive analysis, product positioning) odour profile, texture profile)
- Microbiological analysis packaging materials(incl. Migration tests for food grade nature)
- Shelf-life studies

Special Emphasis on Fruits and Vegetables Processing as they are Highly Perishable

- India Second largest producer of fruits and vegetables in the world with low levels of current yields
- Mostly consumed fresh
- Less than 2% is processed with appropriate raw material availability as constraint
- Farmer, the base of economy, gets much lower returns due to too many intermediaries between farmer and consumer
- Need to establish farmer - processor linkages.

Fruit and Vegetable Processing in India

- Fresh consumption 96%
- Processed – 4% Processing,
- Cottage scale -70% medium and large scales -30%

Technology for Fresh Fruits and Vegetables

- Pre and Post- Harvest Technology Protocols for Export of Fruits by Sea Mango – Alphonso, Banganapalli, Kesar, Neelum Banana – Dwarf Cavendish Pomegranate – Ganesh Variety
- Mango Ripening – Accelerated Process
- Minimally Processed Vegetables
- Antifungal Paste for Banana
- Wax Emulsion – Formulation and Use

Minimally Processed Vegetables Under Map

- Ash gourd
- Coriander leaves
- Mint leaves
- Beet root
- Curry leaves
- Okra
- Beans
- Cucumber
- Onion
- Bitter gourd
- Drumsticks
- Plantain
- Carrot
- Field Beans
- Ridge gourd
- Cabbage

- Fenugreek leaves
- Snake gourd
- Cauliflower
- Green peas
- Spinach leaves
- Cluster beans
- Green chillies
- Tomato
- Coccinia
- Knol-khol
- Turnip

Opportunities for Handling Fresh Vegetables

- Sorting, Washing Preparation (Removal of inedible portions) Cutting (Manually or using a cutting machine)
- Treatments (Minimal treatments with safe chemicals)
- Surface drying (Preferably in a mechanical drier near ambient temperature) Weighing, filling into pouches and sealing Filling the pouches into secondary package
- Cold storage

Technologies Pertaining to Fruits

- Post- harvest protocol (mango, banana, pomegranate)
- Fruit pulps/juices and concentrates (chemically preserved, bottled, canned, aseptically bulk packed, frozen)
- RTS fruit beverages (bottles, tetrapack): mango, pineapple, guava, litchi, carrot, sugarcane, ginger tea, honey based, nutri beverage / mix fruit and vegetable, juice based
- Clarified fruit juices
- Squashes, syrups, cordials, nectars, crushes
- Fruit cereal flakes
- Fruit juice powders (mango, banana, orange, lime, amla, tomato)
- Dehydrated products (sun dried, oven dried, vacuum dried, accelerated freeze dried, osmo dehydrated) – raw mango, grapes, amla, ber, jack fruit, whole lime, citrus peels, onion potato, green chillies, drum stick, bitter gourd, cauliflower, cabbage, carrot, beans
- Jams, jellies, marmalades
- Candies and preserves (amla, papaya, ginger, swallow root cashew apple)
- Pickles and chutneys.
- Sauces and pastes
- Brine preserved fruit pieces (mango, lime)
- Fruit bars and toffees
- Pectin
- Papain
- Pomegranate/custard apple/fig/jamun/amla products
- Dipping oil formulation for grape dehydration

- Wax emulsion/antifungal paste
- Amla paste
- date syrup concentrate
- Honey based fruit spreads

Technologies Pertaining to Vegetables

- Instant pickles, strained baby food
- Dehydrated vegetable (slices, flakes, cubes, powder)
- Canned/ bottled vegetables (in brine, curries)
- Gravy pastes for Indian cuisines
- Soup powders
- Carrot juice beverages
- Minimally processed vegetables packed under map
- Ready to eat foods (meals) in retort pouches
- Mushroom cultivation and processing
- Tomato products (puree, paste, ketchup, chutney)
- Potato products (chips, powder, fried wafers)

Flow Diagram for the Production of RTS Beverage, Squashes, Syrups and Cordials

RTS beverage

- Fresh juice - heating to 90^{o}C - pH adjustment - filling into clean, sterilized hot bottles - crown corking - pasteurization at 85^{o}Cfor 25 to 30 minutes - air cooling- packing and storage

Squashes, syrup and cordials

- Pasteurization at 85^{o}C for 25-30 min - cooling - mixing with sugar syrup, citric acid, essence colour and preservative - cooling – bottling – crown corking - storing

Ready-to-serve banana beverage

- Clarified banana juice/juice concentrate - sugar syrup addition - colour + flavour addition - mixing / blending - homogenization - filling in clean bottles and capping - processing in boiling water - cooling and storage
- Capacity of suggested unit : 5000 bottles (200 ml) /day; Total project cost : Rs. 25 lakhs.

Liquid fruits (clarified fruit juice)

- Substitute from synthetic soft drinks by pulpy fruits like banana, guava etc. can be processed banana - washing and peeling - cutting and pulping - heating - partial cooling - enzyme treatment – filtering - hot filling into bottles - pasteurization

  * optional – concentration to 70^{o} brix
- Capacity of suggested unit : 300 kg/day total project cost : Rs.15.75 lakhs

Aseptically packed banana pulp

- Ripening banana fruit - ripe and sound banana - washing and peeling - pulping -homogenization - deseeding - deaeration - pasteurization - cooling - aseptic filling -storage

Frozen banana pulp/clarified juice/concentrate

- Ripe banana fruits-washing and peeling -pulp / juice extraction - standardization and heating (pasteurization) - filling in flexi bags in vertical pockets - multi-plate contact freezing at -32°C - frozen storage (-28°C) container packaging - transportation in refrigerated container - distribution in cold chain

Individually quick frozen of (IQF) banana slices

- Ripe banana - washing and peeling - slicing - IQF freezing at -32°C frozen - storage - container packing - transportation in refrigerated container

Dehydration of fruit and vegetables

- Fresh fruit /vegetables - sorting and washing (manual/mechanical) – preparation (manual or mechanical) - blanching (for vegetables) - treatments - dehydration – packing - dehydrated product - dehydration of fruits and vegetables

Spray-dried/drum –dried/vacuum shelf–dried banana powder

- Banana pulp - mixing with functional additives - homogenization - spray drying/drum drying/vacuum shelf drying - size reduction and screening - dehydrated banana powder packaging and storage

Fruit bars

- Nutritious and ready to eat product with good shelf life
- Marketed as confectionery items

Example: Banana - washing and peeling - cutting and pulping - mixing with other ingredients - heating pulp - partial cooling and addition of preservative - spreading in trays - drying and cutting - packing and storage

Dehydrated Whole Lime

Lime fruit - washing - pre-treatment - dehydration - dehydrated whole lime - packaging and storage

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24 Primary and Secondary Processing of Food Grains for Value Addition and Nutrients Improvement

B Sanjeeva Reddy

Introduction

Almost all agriculture and allied sectors produce are processed in some way or other before it is consumed. Commercially, the main reasons to process food are to reduce roughage, eliminate micro-organisms (which may cause disease), to extend shelf life and value addition in terms of quality and nutrients availability. In simple terms cleaning, grading, cooking or combining one type of food with other foodstuffs to create a recipe is also considered a form of food processing. Whatever the case may be, the nutrients value of any food is often altered by the processing (Connie *et.al.*, 2014).

A timeline shift in food processing over a period of 1.5 million years ago to present half century is given in Table 1.

Table 1. Timeline shift in food processing

1.5 Million years ago	**700,000 years ago**	**700,000 years ago**	**19th century**
Diet primarily unprocessed plant foods.	Added meat- cooking, drying, salting, smoking.	Agricultural revolution- more verities of grains, dairy foods.	Canning and milk pasteurization-increased shelf life.
20th century	**21st century-1st Half**	**21st century - 2nd Half**	
Dehydration, freezing, Ultrahigh temperature, refrigeration, vacuum packaging, fast freezing and use of additives and preservatives-increased shelf life and variety.	Both home and commercial processing and preservation soared.	Increased reliance on commercially processed food supply and globalization of food supply.	

Different Food Based Agricultural Produce and Its Importance in Indian Food Chain

Cereals : These can be defined as a grain or edible seed of the grass family, Gramineous. Cereals are grown for their highly nutritious edible seeds, which are often referred to as grains. Some cereals have been staple foods both directly for human consumption and indirectly via livestock feed since the beginning of civilization. Cereals are the most important sources of food, and cereal- based foods are a major source of energy, protein, B vitamins and minerals for the world population. Generally, cereals are cheap to produce, are easily stored and transported, and do not deteriorate readily if kept dry.

Pulses : Majority of grain legumes, also called pulses belong to Leguminosae family, in addition to its food value to vast majority of human population and animal feed, the root system of these crops contribute to soil fertility. Pulses are cheapest and rich source of protein which can be considered as lifeline for vegetarian population of India. Apart from being the good source of protein, pulses also contain substantial quantity of minerals, vitamins, crude fiber etc. Amino acid composition of pulses is complementary to that of cereals. Mixed diet of cereals and pulses, which form staple diet to majority of Indian population, is of the superior biological value than either taken separately. In India, pulses are the second major source of dietary protein (27%) after cereals (55%).

Oil Seeds : Oilseeds are rich sources of energy and nutrition. The proteins present in some oilseeds and their cakes are edible to humans while the others are useful as animal feeds. Oilseeds also contain carbohydrates, vitamins and minerals. Oilseeds and oilseed meals have an important role in relieving the malnutrition and calorie nutrition of human and animal population. In addition, these some of vegetable oils are useful as lubricants, surface coatings, in cosmetics products and as a raw material for various industrial products. In the agricultural economy of India, oilseeds are important next only to food grains in terms of area, production and value. The diverse agro-ecological conditions in the country are favorable for growing all the nine annual oilseeds, which include seven edible oilseeds (groundnut, rapeseed, mustard, soybean, sunflower, sesame, safflower and niger, and two non-edible oilseeds (castor and linseed).

Importance of Primary and Secondary Processing Stages in Agriculture and Allied Sector Produce Importance of Processing

The food processing activity in the country is mainly handled by the unorganized sectors till recent past. About, 42% of the output comes from the unorganized sector, 25% comes from the organized sector and the rest of it comes from the small scale players. The small-scale food processing sector is a major source of employment and add value to food grains by processing. To meet the growing demand of food materials, the present industrial based food processing sector has emerged and gaining popularity among rural and urban population alike in India. The food processing is very essential in any civilized country to take care of the following aspects.

- Ensures food is safe to eat
- Makes food available all year round regardless of season
- Extends the shelf life of many produce and resultant foods
- Increases the convenience for consumers by reducing preparation time
- Makes some foods ready to edible, example, making oven fried chips from potatoes
- Makes some food palatable and more enjoyable to eat, for example, soy beans.
- Add extra nutritional benefits (e.g functional foods) or meet specific nutritional needs (e.g gluten free)

Primary food processing has not always been given the specific attention of policy makers that it may deserve given its key role in the food supply chain. Primary food processing is an economic activity within the food supply chain, which focuses on first-stage processing of agricultural raw materials. Primary food processing industry takes in-plant based agricultural raw materials and converts them into ingredients of consistent and defined quality for use by consumers, secondary food manufacturers, compound feed manufacturers and industrial users. First stage processing generally involves low level of transformation and extraction of different components from the raw materials to prevent in certain cases its deterioration, for use as ingredients for food, feed or bio - based products.

Secondary processing is a series of actions that change primary products into other derived food products. This can occur by changing the product's physical and chemical properties, such as producing skim milk from full-cream milk, or by combining ingredients that alter properties to create a food such as cheese, or by combining many different ingredients to create a vastly different product such as a strawberry, cheese cake. Secondary processing is the conversion of various ingredients into other useful edible food products. The unit operations involved in primary and secondary processing of various agricultural produce is presented in Table 2.

The small-scale food processing sector is, however, under increasing threat in India and competition from the large manufacturers who, through economies of scale and better presentation and marketing. Good packaging lies at the very heart of presentation and thus overall customers appeal.

Ensuring Quality and Safety in Processing

Food processors rely on modern quality management systems to ensure the quality and safety of the products produced. The three key systems in use to maintain quality and safety are :

Good Manufacturing Practices. These entail the processing conditions and procedures that have been proven to deliver consistent quality and safety based on long experience.

- Hazard Analysis Critical Control Points (HACCP).While traditional quality assurance programmes focused on the quality of the finished product, HACCP, a recent proactive technique used in the food industry, focuses on preventing defects in the production process itself, rather than identifying them.
- Quality Assurance Standards. Adherence to standards established by the International Standards Organization (ISO 9000) and the Indian Standard (IS11536:2006) ensures that food processing, catering and other food-related industries conform to prescribed and well-documented procedures in sampling and quality testing. The effectiveness of these programmes is regularly assessed by independent experts, in order to sustain consumer confidence in the producer's quality assurance procedures.

Table 2. Processing stages for various produce/products

Produce	Primary processing	Secondary processing	Tertiary processing
Grain	Cleaning, Sieving and grading	Size Reduction :Milling, grits, flour & malt	Biscuits, noodles, flakes, cakes, savory
Fruits & Vegetables	Cleaning, sorting, blanching and cutting	Slices, pulps and paste	Pickles, juices, Ketchup and jam
Milk	Grading and refrigerating	Cottage cheese, cream, simmered & dried milk	Processed milk, spreadable fats, yogurt
Meat & Poultry	Sorting and refrigerating	Cutting, fried, frozen & chilled	Ready-to-eat meals
Marine products	Chilling and freezing	Cutting, fried, frozen & chilled	Ready-to-eat meals
Beverages	Grading, Sorting and bleaching	Leaf, dust & powder	Tea bags, flavored coffee, soft drinks, alcoholic beverages

Primary Processing on Quality of Food Based Agriculture Produce

Drying: The drying of agricultural produce to bring it to safe storage conditions is one important step in agriculture processing. After threshing, the moisture content of most of the grains are too high for safe storage (12-13 percent, db) and preservation. "Drying" is the phase of the post-harvest system during which the product is rapidly dried until it reaches the "safe-moisture" level. The aim of this activity is to lower the moisture content in order to guarantee conditions favorable for storage or for further processing of the product. Drying permits a reduction of losses during storage from causes such as: (i) Premature and unseasonable germination of the grain; (ii) Development of moulds and (iii) Proliferation of insects.

With the advent of grain combines, drying is coming into very prominence in recent years and may gain further importance. Different fuel based and retrofitted models are available in the market, but they are rarely suitable at field level to fit into Indian farming systems. Examples based on fuel (i) Biomass based, (ii) Kerosene / Diesel fuel based (iii) Gas based (iv) Electric power based. Based on active process (i) Bin dryer (ii) Continuous flow process dryer. The primary requites characteristics of grain dries are suitable capacity, transportability from one field to other, easy loading and unloading and stirring of grain periodically.

Cleaning and Grading

Air screen cleaner : It uses three cleaning principles viz., aspiration, scalping and grading. A common air screen cleaner for processing seed uses two air blasts and two screens. The first air system removes dust and light chaff before the seed reaches the first screen. The first screen allows the good seed to drop onto the second screen. The large foreign material rides over the first screen and is discarded. The second screen is a grading screen.

Specific gravity separator: Seed of same size and general shape can often be separated because they differ in specific gravity. This difference is very useful in removing light immature seed or heavy sand and rocks to improve the purity.

Indented rotary cylinder separator: Seed of the same width and thickness can sometimes be separated by taking advantages of difference of length. Indented rotary screen cylinder can do very precise separation by using length difference. The indented cylinder separator is a rotating almost horizontal cylinder with a movable horizontal separating trough mounted inside it. Thousand of half round indents are lined inside surface of cylinder. Indented cylinder seed graders are used for additional separation or up-gradation of seeds, grains of various crops on length basis after sieve cleaning. They are also used for removing weed seeds, broken or cut, round grains, materials longer than the desired crop seeds.

Influence of Agricultural Produce Secondary Processing on Nutrients Cereals Processing

Many studies show that, consumption of whole cereals grain can protect against diabetes, obesity and many other lifestyle disorders. The changes in composition and matrix of grain due to milling process can explain why whole grain consumption can be advisable. The nutrients available in the food grains associated with health status include lignin, tocotrienols, phenolic compounds, and anti-nutrients including phytic acid, tannins, and enzyme inhibitors. In the first stage of secondary processing of grain, mainly the bran is separated, resulting in the loss of dietary fiber, vitamins, minerals and other nutrients. Thus refined grains are more concentrated in starch, since most of the bran and some of the germ is removed in the process. Cereal foods have for long been known to be and important source of vitamins, such as thiamine, vitamin E and folates. Recently the knowledge of also other biologically active compounds in the grain has increased substantially, as these have been suggested to be among the factors contributing to the protective properties of whole grain foods (Kaisa Poutanen *et al.,* 2009).

The phyto-chemicals are involved in health improving activities, which are very important for stressful life. So, whole grain milled flour without sieving and separating different portion can be highly beneficial for human health (Brigid Mc Kevith, 2004).

In secondary processing like milling, polishing most of the bran and some of the germ are removed, resulting in loss of dietary fiber, vitamins, minerals, lignin, phyto-estrogens, phenolic compounds, and phytic acid. Milled cereal grains have higher starch content than whole grains. Most vitamins and minerals (44%) are found in the germ and bran portion of grains. Milling of grains results in major losses (in descending order) of thiamine, biotin, vitamin B6, folic acid, riboflavin, niacin, and pantothenic acid; there are also substantial losses of calcium, iron, and magnesium. A considerable 70–80% of the original vitamins are lost when grains are milled. The larger the portion of the grain portion removed in processing, the greater is the nutrients loss (Morteza Oghbaei and Jamuna Prakash, 2016).

The process of parboiling, puffing, and flaking causes alteration in nutrient content of rice grain and puffing, flaking in maize and jowar. Cereal grain can be flaked to different degree of thickness following a process of soaking in hot water and roller pressing. Flaking alters the phosphorus, phytin, and dietary fiber content of flaked rice with a decrease in proportion to thickness of flakes; the lesser the thickness, the lower was the constituent, whereas the iron and calcium contents were not affected. In rice flakes, the starch digestibility varied from 78 to 84% in different thickness ranges.

Milling and particle size reduction : The dehulling and milling process of cereals and pulses improves the starch content in the obtained grain products and its digestibility. Milling and particle size reduction method related to the starch content of grain flour. The results pointed that, as the size of milled particle decreases, the starch content increases. This could be possibly due to the fact that as the size of mesh used decreases to make finer flour, more of fiber portion is separated and finer flour with higher starch content passes through sieve. As fiber is difficult to pulverize in comparison to endosperm with higher starch content, it is separated as coarse fraction. It is observed that reduction in bran during milling leads to improved starch digestibility.

Pulses Processing

Effect of soaking: Generally soaking in water, oil and water application, mixing of sodium bi-carbonate solution and thermal applications are commonly recommended and adopted as pre-milling treatments for pulses processing (Rajiv Ratan Lal and Prasoon Verma, 2007). Soaking studies on vitamin contents of chick pea and lentils showed that ; in general there were losses of thiamine (6.2–17.1%), riboflavin (2.5–34.2%), and niacin (2.0–61.2%) to varying extent in soaked legumes. Losses were higher when beans were soaked in alkaline media than in acidic media or water alone. This loss was obviously due to leaching of water soluble vitamins in soaking media.

Puffed Chickpea, Peas and Redgram: Puffed chickpea and peas widely and redgram upto some extent are used in India as a snack foods. The process involves three stages as (i) Soaking chickpea or peas or red gram in water for about 15-20 minutes and draining of water (ii) Keeping the wet grains in a closed vessel for the moisture to equilibrate in the grain (iii) Puffing the wet grains in a hot iron vessel containing sand at 190-200 for 60-80 sec. The grains puff and the husk is split off. For efficient puffing, the temperature just before explosion must be sufficient to create a high enough water vapour pressure without burning the pericarp and the temperature increase must be fast enough to build up the required pressure before the water evaporates. Moisture content of the kernel has a pronounced effect on popping behaviour. The kernels, which are too dry, often pop up feebly.

Parching of pulses: Legumes such as bengal gram, peas and redgram are parched to give highly acceptable products. Bengal gram is tied in a moist cloth in small bundle and kept overnight before it is parched. Red gram and peas are soaked in water for 30 minutes dried partially in the sun for 2hours and then parched. Salt and turmeric powder mixture paste is sometimes smeared to the soaked grains of pulses before they are parched. Parching is done in a hot iron vessel containing sand at 190-200 for 60-80 seconds. Parched bengal gram has been used in the treatment of protein calorie malnutrition in children. To get much palatable and tastier parched pulses for immediate consumption, the grain extracted from wet matured fresh pods also being used. However, extraction of large quantity of grain from fresh pods is a problem.

Oilseed Processing

Sesame seed and oil have long been used widely as healthy foods to provide nutraceuticals and nutrients, increase energy and prevent aging. Sesame is a good source of edible oil and widely used as cooking oil and confectionery products. A combination of a number of minor constituents such as tocopherols and phenolic components in the sesame seed oil may have a synergistic action in increasing the antioxidant activity against diseases caused by oxidative stress.

In sesame cultivars, tocopherol content increases significantly with the rise in roasting temperature and time; until 200 °C for 10 min, but it decreases by roasting at 220 °C for longer time. It is also reported that, the amount of total phenolic compounds (TPC) increased significantly as the roasting temperature and time; until 200 °C for 20 min, and they will be decreased by roasting at 220 °C, so the highest activity and content will be achieved by roasting at 200 °C for 20 min.

From all these above explanation it is noted that mixing cereals and pulses increases the nutritional value. Partially cooked cereals can be stuffed in paranthas or use them as batter for dosa or uttapam.

Mixing grains is a healthy option as each of them has their own unique nutritional value and composition. If a certain nutrient is lacking in one, it can be compensated by adding another. Moreover, the fibre content in a mix of multigrain atta is generally higher. Too much frying of grain at higher temperatures will alter the nutrients composition making them ineffective.

Grains are healthiest when sprouted with more protein, vitamins and minerals. Sprouting spikes up the fiber content almost three times and lowers the level of gluten. One can sprout any kind of whole grains but it's important that the germ and bran are intact.

How Safe the Commercially Available Processed Foods?

In spite of their pledges to reduce unhealthy foods marketing to children, the large ready to eat food processing companies continue to target children with their least healthy products. Some studies showed that, processed ready to eat products of cereals contain 85% more sugar, 65% less fiber and 60% more sodium when compared to adult cereals. Notably promotions, in-store marketing and product packaging, that represent 29% of cereal company marketing expenditures.

The majority of child and family cereals offered by the smaller companies have significantly less sugar, more fiber and no food dyes. Clearly, such products are more nutritious options for children to eat. Based on these findings, current food industry self-regulation does not protect young people from the unhealthy influence of cereal marketing and much stronger action is needed. If the food industry wants to be a true partner in the fight against childhood obesity, food companies must also accept responsibility for the results of their actions.

In developed countries, the Nutrition Profiling Index (NPI) score, which is based on the nutrition rating system established by Rayner and colleagues for the Food Standards Agency in the United Kingdom is used. In addition, the product is examined for the sugar, fiber, saturated fat and sodium content separately to highlight differences between individual nutrients within the NPI score. The model has also been approved by Food Standards Australia and New Zealand to identify products that are permitted to utilize health claims in their marketing. The NP model provides one overall nutrition score for a product based on total calories and proportion of both healthy and unhealthy nutrients and specific food groups or items, including saturated fat, sugar, fiber, protein, sodium, and unprocessed fruit, nut and vegetable content.

Conclusion

- Expanding the level of processing in the food grains, fruits and vegetables and dairy sectors on priority giving emphasis on nutrients quality.
- Raising the level of processing from primary/secondary to secondary/tertiary for all commodities.
- Modernizing the food processing sector using the efficient equipment and processes for cost competitiveness and better quality products.
- Ensuring adequate training of workers, supervisors and managers in food processing industries to ensure efficient operations and product quality.
- Providing skills and knowledge to farmers for ensuring quality of produce through adoption of Good Agriculture Practices.
- Promoting seamless value chain including post harvesting management and value addition in production catchments to obviate the quantitative and qualitative losses.

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25 Monitoring, Evaluation and Impact Assessment of Food and Nutrition Security Programmes

G Nirmala and Ch Srinivasa Rao

Introduction

Improving Nutrition through Agriculture and Food Systems

Food systems provide primary food needs of the ever growing population through availability, affordability consumption of diverse, safe, nutritious foods and diets (FAO, 2015). Current food systems are challenged to provide safe and nutrient rich foods due to constraints posed by degraded soils and resource poor soils. Men and women had significant differences in participation in various farm activities of crop cultivation, dairy production milk sales, crop produce sales and cattle sales. They have varied differences in decision making towards expenditure of money obtained from sales of farm produce, cattle sales and milk sales, resulting in wide gap in production and consumption of healthy food (Baker, *et al*., 2015).

Huge investments in agricultural programmes in areas of natural resource management of soil, water, vegetation which are critical to livelihoods and food and nutritional security to whole group. Facilitating diversification and increase production of nutrition rich crops like cereals, millets, pulses, fruits and vegetables. Investments in markets, storage and processing, value addition of millets and food related products provide good market value and fetch high prices.

Development of healthy people is the key to sustainable development. Good health of a human being starts with good nutrition right from womb to first 1000 days after birth is critical to healthy life. Child nutrition play important role for nations' development economically and socially. Malnutrition affects many countries. There is great need to improve nutrition faster and integrate the objective into every countries sustainable development goals for 2030. These goals need to be more realistic and doable. However many countries have not geared up to meet the challenges of nutritional security faster but have made some progress in these lines. High quality case studies are needed to understand the progress and learn about the implying factors for development, one such learning is to extend coverage of program and throw some guidelines on resources needed and how to improve design and implementation aspects about accountability. (Steve *et al*., 2014).

According to UN the global nutrition targets set are to be achieve a 40 percent reduction in the number of children under 5 who are stunted, achieve a 50 percent reduction of anemia in women of reproductive age, achieve a 30 percent reduction in low birth weight, increase the rate of exclusive breastfeeding in the first 6 months upto at least 50 percent and reduce and maintain wasting in children under 5 at less than 5 percent. The targets set manifest itself from high levels of malnutrition prevailing world over has lead to committment from the policy making bodies of FAO, WHO and other UN agencies.

Key Recommendations for Improving Nutrition

The Key recommendations for improving nutrition through agriculture helps sustain development and there is need to monitor and evaluate at every stage the outcomes in order to reduce loss of investment. Concepts of monitoring and evaluation process have been discussed here mainly in context of food and nutritional security program.

First step for monitoring and evalution

- To establish ability and readiness for evaluation.
- Focus on the evaluation which includes purpose and scope.
- Implement the evaluation.

The first domain is the readiness to evaluation. Before implementation of evaluation plan, assessment of ability and preparedness of the team have to be assessed. The second is the focus on evaluation, comprises steps to determine the purpose and scope of evaluation such as agree on the evaluation purpose like the downward accountability or upward accountability. It clearly informs about the evaluator purpose of evaluation, what he intends to achieve, indicates the primary user of information, whether the evaluator likes to inform the donors, manager of programme, which is the upward accountability; or the evaluator wants to show the grass root beneficiaries the utility of programme, how the programme benefits reaching them in downward accountability. The third, important evaluation part is the 'Implement the evaluation which comprises of steps: 1) Plan and organize the evaluation, develop evaluation Matrix; identify key indicators and other information needs; identify baseline information; collect and process data; analyse and critically reflect on findings and communicate and make sense of findings.

Under step two of evaluation process, proper clarity on the types of questions the evaluation process need to answer. These questions are related to :

- Who needs what information?
- What are the broad areas of concern for stakeholders?
- What questions need to be addressed?
- How can we summarise the key issues and steps in the evaluation process?

It was mentioned that evaluations often assess impact, relevance, sustainability, effectiveness and efficacy.

- Impact indicated what changes have resulted?
- Relevance painted out the whether doing the right things?
- Sustainability meant whether changes last?
- Efficacy looks into the initiative taken whether the whole programmee working as expected?
- Effectiveness indicated whether doing things right? Efficiency indicated the initiative being worthwhile?

Stakeholders Analysis

It is an important to engage 'right stakeholders' in evaluation of programme. The right stakeholders involved in project can be assessed employing key questions such as who the stake holders are, what are the stakes and who has these stakes? Why encourage stakeholder engagement, how much participation and what is the role of self-evaluation, who to engage and what are the consequences of these choices, what evaluation roles are needed in balancing content and people processes? How to engage stake holders effectively?

Articulate the Theory of Change

The logical frame work (logframe) has traditionally been used widely as a tool in development planning to systematically structure development interventions. In recent times, however, other frameworks and approaches have gained popularity, such as the theory of change, due in part to the limitations of the logframe. In this theory of change it uses the same basic elements of the logical frame work which gives broader perspective of the development initiative. A theory of change requires one to have a well articulated and clear testable hypothesis about how change will occur that will allow one to be accountable for the results.

The theory of change can be used to check milestones, document lessons about what really happens, keep the evaluation implementation process transparent and prepare reports of findings, policy, etc. In this theory, critical assumptions will need to be evaluated and more attention to be paid. The different methods of theory of change conceptualization were taught in this training like the deductive approach, inductive approach and user focus approaches. One relatively simple way to develop visualization map of change is by intended cause-effect relationships and underline assumptions. The intended cause-effect relationships should indicate the following key elements as well clarify how they are inter linked and what factors might influence these linkages.

- *Activities* : What the development initiative sets out to do.
- *Outputs* : What the development initiative was directly responsible for delivering
- *Outcomes*: What changes/effects were expected as a result of the outputs. This may include changes in awareness, motivation, skills, knowledge as well as behavior and performance.
- *Impact*: Changes in socio-economic and/or environmental conditions the programme sought to contribute towards.
- *Assumptions*: External factors that could affect the progress or success of a development programme. They help to explain the causal linkages. Not all elements of a theory of change can be visualized, for example our values that influence our thinking about how change happen.

Develop the Evaluation Matrix (EM)

The evaluation matrix usually developed after an initial literature review and discussions with key stakeholders and primary users, or when conceptualizing the theory of change. In doing so, it is important to understand the wider context (environmental, political, economic, etc.) and, if necessary, to work with individuals who do.

The evaluation matrix is defined as a key tool used in designing evaluations and helps you to summarise the implementation of the evaluation process. It assists in focusing the key evaluation questions and clarifying ways in which these key questions will be addressed during the evaluation. Flexibility is required in using this evaluation matrix, particularly where issues are complex in nature and clear objectives and indicators cannot be defined. An example of an evaluation matrix is provided.

Key Elements of the Evaluation Matrix May Include:

- *Evaluation focus/key performance areas* : Key areas to be explored during the evaluation
- *Key evaluation questions*: Broad question that help to focus the evaluation on the information needs of the primary intended users of the findings
- *Key information needs*: These may include a range of different types of information to answer the key evaluation questions. Often referred to as indicators but can be broader
- *Baseline information*: What baseline information already exists?
- *Data gathering*: What sources and methods are going to be used for data collection?
- *Planning and resources*: What tools, planning, training, expertise are required and who does what?
- *Information analysis, critical reflection, reporting and feedback*: How will analysis of the findings take place? How will feedback and reporting take place? Who is responsible for what?

Information Use, Influence and Consequences

How will the findings be put to use? Who are the users of the findings? How will the evaluation be used to influence change at different levels? What can be the possible consequences of the evaluation? Who is responsible for what? These are questions need to be answered and a poster, usually referred to as Infographs, are prepared to communicate to the end users with all the details of success factors and findings of the program.

Case Study

Ghana School Feeding Program

Tackling Children's malnutrition through a national school feeding programme

Background

Country, region, districts

The Ghana School Feeding Program (GSFP) covers the whole of Ghana. The program began in late 2005 with 10 pilot schools, drawn from each region of the country. By August 2006, it had been expanded to 200 schools covering 69,000 pupils in all 138 districts of the country. The plan proposed here will scale up the program gradually to cover 1.04 million primary school and kindergarten children in the most deprived communities and schools of the country by December 2010.

Main nutritional problems

Food security in the marginal agricultural and arid areas in Ghana varies with the seasons. The peak hunger season for the south of Ghana is from May to August whereas the North of Ghana experiences a peak hunger seasons between July and October.

The incidence of malnutrition in Ghana has been assessed through the Ghana Demographic and Health Surveys (GDHS) conducted every five years since 1988. From 1993 to 2008 the country made some progress in reducing the rate of chronic malnutrition, with rates of stunting decreasing from 34% to 29%. According to the 2003 and 2008 GDHS the prevalence of anaemia among children 6-59 months of age has increased marginally from 76 percent in 2003 to 78 percent in 2008. The prevalence of anaemia among rural children (84 percent) was higher than in urban areas (68 percent) in 2008. The overall prevalence of stunting among school age children was 17 percent, ranging from 13 percent in the Forest-Savanna Transitional Zone to 21 percent in the Northern Savanna. The same study estimated that the prevalence of anaemia among school aged children was 39 percent. This however varied widely across ecological zones. Anaemia rates were highest in the Northern savannah (65 percent) and the Coastal savanna zones(59 percent) and least prevalent in the transitional zone (16 percent).

Economic situation

Ghana is a lower-middle income country with a population of 25 million people, over 40 percent of whom are under 15 years of age. Despite the high rates of economic growth occurred in the past two decades, Ghana is ranked 138th in the 2014 Human Development Index table, with an average life expectancy at birth of 61 years, 7 mean years of schooling and a Gross National Income (GDP) per capita (PPP) of $3532 USD. Around 25% of the country's population live in poverty based on the national level poverty line, with this percentage increasing to 38% in rural areas in contrast to 10% in urban ones.

Agricultural production

The domestic economy is centred on subsistence farming which accounts for nearly 40% of the GDP and employs over 50% of the workforce. Agriculture is thus predominantly on a smallholder basis in Ghana. About 90% of farm holdings are less than 2 hectares in size, although there are some large farms and plantations, particularly for rubber, oil palm and coconut and to a lesser extent, rice, maize and pineapples. The main system of farming is traditional. The hoe and cutlass are the main farming tools. There is little mechanized farming, but bullock farming is practiced in some places, especially in the North. Agricultural production varies with the amount and distribution of rainfall. Soil factors are also important. Most food crop farms are intercropped, mono cropping is mostly associated with larger commercial farms (*From 'Agriculture in Ghana- Facts and Figures 2012', Ministry of Food and Agriculture).*

Project Background

Ghana set up the GSFP within the wider context/framework of the 'Comprehensive Africa Development Plan '(CAAP) Pillar3 – The Millennium Development Goals (MDGs) on hunger, poverty and primary education, and the Ghana Poverty Reduction Strategy (GPRS).

According to the projects rationale, a hungry child is not a healthy child and therefore cannot learn properly. This leads to less productive adults, hence creating a cycle of poverty for future generations. By tackling children's' malnutrition through School feeding, the GSFP aims to contribute to Ghana's national development objectives on hunger, poverty reduction and primary education. The GSFP is a complex intervention and was designed as a strategy to increase domestic food production, household incomes and food security in deprived communities.

Goals, objectives, sub-objectives

The goal of this project is to contribute to poverty reduction and improved nutrition status of school age children in Ghana. The objectives of the project are (1) to increase school enrolment and improve cognition and learning achievement in public primary schools; (2) to increase the diversity of the diets of children in public primary schools and kindergartens; and (3) to increase incomes of households in deprived communities.

The Project Aims to Achieve These Objectives Through the Following Sub-Objectives

- Increased school enrolment, attendance and reduced school drop-out
- Children in public primary schools and kindergartens are provided one hot nutritious meal per day Domestic agricultural production is boosted

The Main Activities

- Procure and distribute locally produced food to public primary schools and kindergartens
- Provide children in public primary schools and kindergartens one hot nutritious meal per day
- Mobilising community support

Target group

The GSFP is targeted essentially at children in primary schools and attached kindergartens in government-controlled establishments in Ghana. These will be the direct beneficiaries. The programme will be scaled up gradually to reach 1.04 million of the pupils in the poorest areas by the end of 2010. In addition, various other stakeholders should benefit from the programme, most notably:

- Agricultural enterprises/food crop farmers, especially women. Over 1.35 trillion cedis (Ghanese valuta) (or US$147 million at current exchange rates) - should accrue to these through food purchases by the end of 2010
- Other private sector firms – including suppliers of agri-inputs, vehicles including motorbicycles, capital equipment, amounting to over 750 million cedis
- Caterers/Outsourcing firms who may gain opportunities to provide private sector support to the feeding programme
- School teachers - who are routinely fed with the children
- Parents/Guardians of pupils in participating schools
- The community (through employment and infrastructure)

Main Activities

Co-ordination and implementation of the GSFP are undertaken by a GSFP National Secretariat (NS), with programme oversight provided by the Ministry of Local Government and Rural Development (MoLGRD). Partnering Ministries offer technical support through the programme steering committee (PSC), although a number of NGOs and bilateral agencies are also involved with technical support. The MoLGRD will co- ordinate all inputs, activities and outputs. The projects works with two main implementing structures and district level, the District Implementation Committee (DIC) and the School Implementation Committee (SIC) (see also 'Partners and stakeholders'). These two bodies are installed to oversee implementation of the project at district level. The DIC's and SIC's are set up by the District Assembly (DA), which receives program funding for the district. DIC's get support from the GSFP National Secretariat (NS).

The School Implementation Committee (SIC): is responsible to supervise programme activities at school level:

- Cash transfers to caterers: SIC
- Mobilising community support
- Facilitate preparation of food + make sure all inputs needed are procured
- Link between school feeding and community level wealth creation (eg. Value added farming)
- Sustainability initiatives including, e.g. conducting feeding in least costly manner by for example involving parents/the community in food preparation

Caterers: are procured at National level by the GSFP National Secretariat (NS). They procure food from farmers, store food, prepare meals at school. Private caterers who are awarded contracts by the GSFP to procure, prepare and serve food to pupils in targeted schools.

Food procurement: each caterer is responsible for procuring food items from the market, preparing school meals and distributing food to pupils. Cash transfers are made from the District Assemblies, under the supervision of the District Implementing Committees (DICs), to caterers based on 40 Ghana pesewas (circa US$0.33) per child per day. Caterers are not permitted to serve more than three schools each, and profit is derived from savings made after food has been procured, prepared and distributed. Supervision at the school level is by the School Implementing Committee (SIC) and funds are intended to be released to caterers every 2 weeks.

The caterers are not restricted or guided in their procurement and are able to procure on a competitive basis without commitment to purchasing from small-scale farmers. The GSFP project document prioritizes procurement from the community surrounding the assisted schools, broadening the focus to the district and national levels when food items are not available. In some cases food is procured at national level, depending on the benefits of economies of scale and bulk purchases.

Storage: storage of food is the responsibility of caterers and no rigid tendering process is enforced.

Complementary_activities: it is also expected that collaborative institutions like the District Assemblies, MOH, and MOFA will also spend $102.3m to complement the programme budget and support related activities like deworming, construction of kitchens, cooking areas, and platforms for water tanks, and supporting labour at the district (dedicated liaison officer) and sub-district levels (e.g. cooks and helpers).

Partners and Stakeholders

The programme is directly funded by the Government of Ghana, with a 4 year programme budget of over 200 million USD. The following are the key-actors in the implementation of the GSFP:

lnter-Ministerial Committee (IMC): For the start-up phase and program establishment period up through the end of 2007, the IMC will be the decision-making and oversight authority over the GSFP and all other feeding programmes in the country. lt will provide policy guidance, direction, and policy decisions to the GSFP National Secretariat and also serve as an advisory body to the MLGRDE on the GSFP. Membership will consist of Ministers from Collaborating Ministries. and will be chaired by the Minister for MLGRDE. lt is envisaged that the IMC will be phased out at the end of 2007 and its Ministerial membership fused into a Programme Steering Committee (PSC).

Programmes (Steering) Committee (PSC): The PSC will replace the IMC at the end of 2007. Membership of the PSC will consist of the sector Ministers (or Chief Directors or Directors appointed by the Ministers of Collaborating Ministries as representatives), and the Executive Director of the GSFP National Secretariat to provide the direct programme link between each ministry and the GSFP. The PSC will be chaired by a Minister appointed by the President

Ministry of Local Government and Rural Development & Environment (MLGRDE): The ministry directly responsible for all local government and development activities carried out at District and sub-district levels. Coordination of all inputs, activities, and outputs within the programme of cooperating ministries (Agriculture, Education. Health. Wamen & Children Affairs, etc.). MLGRDE is the oversight Ministry for the GSFP, and government partner to funding agencies supporting the programme.

Collaborating Ministries (CMs) and MDAs (MoFEP, MoFA, MoESS, MoWCA, MoH, MoFARC&N, GHS, GES, etc.): - The Ministers of these CMs or their representatives will serve on the PSC, and link between the PSC and sector related teams at district level to ensure the district level teams execute their roles and implement the activities they are responsible for to support the GSFP objectives.

GSFP National Secretariat (NS): The NS is a program implementation unit under the Ministry of Local Government and Rural Development & Environment (MLGRDE). lt will be staffed by senior experts and consultants under contract to act as a programme coordinating and management unit (PCMU) for all aspects of the school feeding initiative:

- Technical oversight and support for district level implementing structures (DIC, SIC),
- Advising on program content, implementing sensitization and outreach,
- Supporting capacity building needs of district level structures,
- Executing and coordinating national level procurement,
- Ensuring programme accountability and reporting and
- Providing technical and policy inputs to the MLGRDE and the PSC.

The NS will be under the leadership of an Executive Director (ED) who will also be a member of the PSC. The ED, senior experts and consultants staffing the NS and support staff will all be contracted by the program for the duration of the 4- year period, GSFP 2007-2010.

GSFP Regional Coordination Offices (RCO): The RCO is staffed by a Regional Coordinator (RC), supporting monitors and secretariat to oversee district coordinators at the DIC level. The RCO will play a key role in ensuring accountability and reporting to NS. The RC and support staff will all be contracted by the program for the duration of the 4-year period, GSFP 2007- 2010.

Office of the Regional Coordinating Council (ORCC): The ORCCs reviews and helps harmonize and coordinate District Assembly (DA) development activities. The ORCC will provide support for the GSFP Regional Coordination Offices directly and also provide linkage to district leadership and facilitate the RCO's coordination efforts.

District Assembly (DA). The DA is the core implementing body for the GSFP: It has the key responsibility for setting up the District Implementation Committee (DIC), ensuring that the School Implementing Committees (SIC's) are properly set up, ensuring the provision of specified infrastructure, coordinating the sectoral cooperating activities of other district level MDAs, and mobilizing community support and inputs for SICs and the schools. The DA receives the programming funding for the district and enforces appropriate procedures under the Financial Management Acts to ensure transparency and accountability in the use of the funds for designated purposes.

District implementation Committee (DIC): The DIC is the district level coordinating unit for the GSFP that exercises direct oversight over all the schools in the programme. It directly disburses funds to School Implementation Committees (SICs) and holds the SICs accountable for use of the funds for the feeding and related activities. The DIC will also implement district level procurement that can benefit from economies of scale if sufficient number of SICs come together to support the bulk purchase. The DA will appoint or second a dedicated District GSFP Liaison (DGL) to link the DIC to the DA, the SIC's, the RCO, as well as the NS.

The DGL will be the focal person for the GSFP and also serve as the secretary to the OIC. He/she will be responsible for the proper documentation and reporting of the committee's activities, as well as collating feedback from the SICs.

The DIC will also be formalized as a sub- committee of the DA to coordinate all school feeding programs at the district level. The DA may suggest representatives of other school feeding programmes in the district to serve as ex-officio members of the DIC, as well as other experts and district level actors in related or collaborative programmes including NGOs.

School implementation Committee (SIC): The school level implementing unit plans and executes the actual feeding. It receives funds from the DIC. It procures needed inputs, supervises the food preparation and feeding activities, and accounts back to the DIC.

The SIC directly manifests ownership of the programme by local communities who are its ultimate beneficiaries. The SIC will also lead community mobilization to support and sustain the feeding program. It will also contribute to building food security at the community level through linkage between the school feeding initiative and community level wealth creation activities including value added farming.

The SIC will also be at the fore-front of sustainability initiatives, starting with innovation in arrangements to conduct the feeding in the least costly manner, including piloting community-or-parent-assisted strategies to do the actual cooking. The SIC is also encourages to link with other, ongoing school feeding programmes by the World Food Programme and CRS, to reduce costs and improve outreach.

Other GSFP PARTNERS and External Support Agencies (ESAs): This includes the Dutch Government which is co-funding the GSFP with GoG, other GSFP strategic and technical partners implementing or supporting the implementation of school feeding programmes including CRS, WFP, SNV, WVI, ADRA, SEND, and donors like USAID supporting school feeding programmes and sectoral activities directly supporting school feeding (e.g. water, sanitation, school infrastructure, etc.,).

Conclusion

Conducting Evaluation as per the procedure would add value and validity to the results of evaluation of agriculture and nutritional security programme. It would also throw light upon the programme implementation, its achievements and constraints so that an appropriate action plan chalked out for addressing constraints in future, if possible and reduce investment and transaction costs.

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26 Efficient Cropping Systems Under Farm Pond Technology in Semi Arid Regions for Nutritional Security

K S Reddy

Introduction

Food availability for a growing world population would increase the global water demand. Rainfed agriculture constitutes 55% of total net cultivable area in the country and contributes to production of major coarse cereals, pulses and oil seed production. The environment of rainfed agriculture is enrolled with regular climate constraints like long dryspells, high intensity rainfall, high evaporation losses, soil degradation etc. Moreover the annual average rainfall varies from less than 100 mm to 2500 mm in different rainfed agro-ecological regions of the country. Its distribution is erratic with CV varying from 30 to 80% during crop growth period and it varies in both space and time. The present level of land productivity is about 1t/ha in the country. Therefore, all the above vagaries of the climate necessiates for immediate measures for adaption of rainwater harvesting technologies for climate resilience by mitigating the drought in rainfed agriculture. Rainwater harvesting technologies like check dams, drop spillways, gabion structures, percolation tanks, sunken pits etc. have been implemented across the Indian states as a drought mitigation measures in the watershed programmes implemented by Govt. of India. These technologies have resulted in the increase of recharge potential of shallow wells and tube wells. However, in the hard rock areas and long distances for access to water by the farmers in the watersheds, it is imperative for on-farm rainwater harvesting through farm ponds is necessary for enhancing the field scale water productivity to basin level.

Rainwater harvesting is the collection and storage of excess runoff generated from small scale farmers land, ephemeral streams and hill slopes in rainy season for productive purposes (Wang *et al.,* 2011; Kahinda *et al.,* 2007; Ngigi *et al.,* 2005). Enhancing the water productivity in rainfed areas using supplemental small-scale irrigation is an important tool to increase green water flows (Fraiture *et al.,* 2007). Many researchers around the world mentioned that, the rainwater harvesting concept has become key component in production technology to enhance livelihoods of rainfed farmers and reduce the yield gap between irrigated and rainfed agriculture with water scarcity under changing climate conditions (Oweis and Hachum, 2006; Stephen., 2009; Gunnell and Krishnamurthy, 2003; Pandey *et al.,* 2003;).

The optimal design of rainwater storage structure, catchment cammand area ratio for giving supplemental irrigation to different cropping systems, depends on runoff potential of farm and the amount of water that is needed for supplementing irrigation at critical stages of rainy season crops and deficit irrigation to vegetable and rabi crops. A challenge in design and construction of on-farm water storage structures, such as farm ponds, is to minimize water losses (mainly due to seepage and evaporation) by way of linning (Ngigi *et al.,* 2005). Evaporation rate and water spread area is directly relates to evaporation losses and it also depends on type of soil, climate and underlying formation material. The limited runoff collected in farm pond may not allow full irrigation in rainfed condition but it permits supplemental irrigation to mitigate long dryspell during critical stages of most rainfed crops. Excellent responses to supplemental irrigation have been reported from several locations in India (Gunnell and Krishnamurthy, 2003). The yield responses of crops to supplemental irrigation in different locations of India and indicated that one supplemental irrigation at the critical stages of crop growth considerably increased crop yields (Singh and Khan, 1999). However, the information on catchment cammand area ratio, runoff coefficients for on from rainwater harvesting on cropping system approach with net water availability area could be irrigated with supplemental irrigation and different storage capacities of farm ponds are seldom available in the country. Therefore, a systematic methodology and economical analysis under cropping system approach is presented in the paper.

Study Area and Climate

The field experiments were conducted from 2008 to 2015 in a model rainwater harvesting through farm ponds in Gunegal Research Farm (GRF) of ICAR - Central Research Institute for Dryland Agricultural (CRIDA), which is located at 45 km away from Hyderabad. The farm is located at 78˚ 40¹ 18º N and 17º 2¹ 5º E with mean sea level of 621 m. The daily climate data on rainfall, maximum and minimum temperature, solar radiation, relative humidity and wind speed are recorded from an automated weather station (AWS) installed in the farm. The average annual and seasonal rainfall of the study area is 701.87 and 478.05 mm, respectively. The average temperature of study area is 25.5 ºC with average minimum and maximum of 8.94 and 42.06 ºC respectively. The land was relatively flat with a slope of 2 per cent or less and it has deep to moderately deep well drained red soils. The soil physical properties such as field capacity ($è_{FC}$), permanent wilting point ($è_{PWP}$), total available water (TAW) and its texture is analyzed using standard procedure. The soil physical characteristics such as field capacity ($è_{FC}$), permanent wilting point ($è_{PWP}$) and total available water (TAW) were 11.6 per cent , 4.1 per cent and 75 mm m^{-1} respectively. Soil texture was sandy clay loam with Sand (70.96 %), Clay (22.32 %) and Silt (6.72 %) with soil depth varying from 50 to 100 cm.

Rainfall Runoff Relation in Semi Arid Alfisols

A rainfall and runoff relation was developed by busing 7 years data of observations in the research farm on rainfall and runoff collected in the farm pond with different catchment areas varying from 1.5 to 14.5 ha. The water balance was worked out for both lined and unlined farm ponds considering the evaporation and seepage losses in unlined farm pond upto 2010 and only evaporation losses in lined farm pond with HDPE 500 micron geo-membrane sheet.

The relationship between rainfall and runoff in rainfed alfisols was developed using the regression analysis by using the data collected during 2008 to 2010 and presented in Fig 1. From the three years experimental data, it was observed that, there was a quadratic relation between rainfall and runoff with a coefficient of R^2= 0.82 in rainfed alfisols. Though the alfisols has high infiltration characteristics, the soils have the crust formation immediately after sowing having the runoff coefficient of 2 to12% depending upon the AMC of the catchment area and the rainfall intensity and its duration.

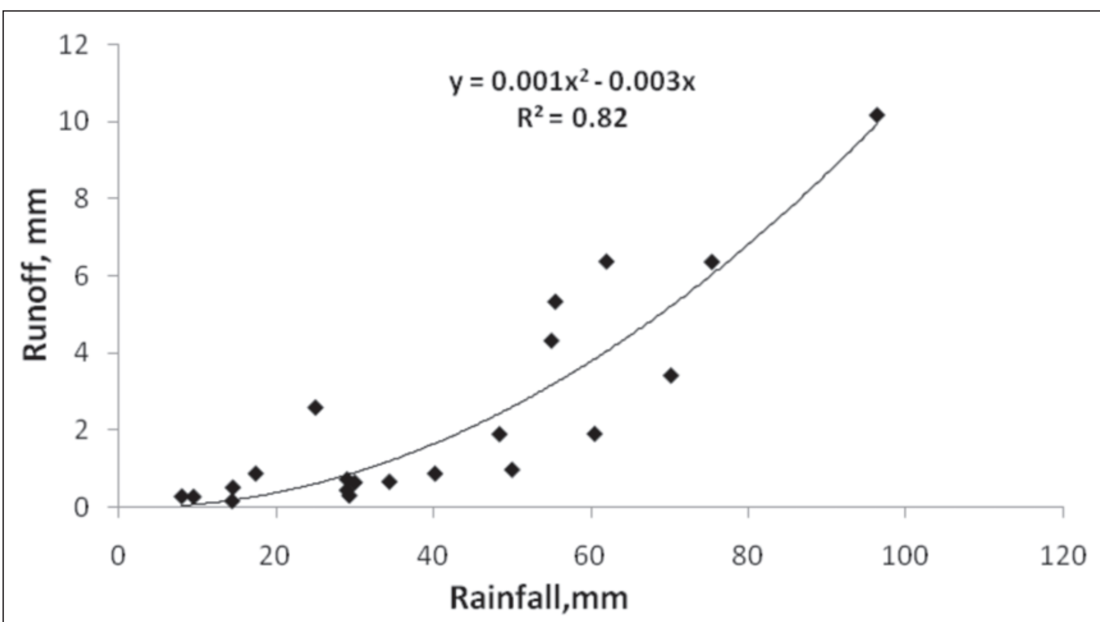


Fig. 1. Rainfall and runoff relationship in rainfed alfisols during 2008 to 2010

Farm Pond Technology

Three farm ponds having top dimensions of 17×17×3m, 20×20×3m, and 26×26×3m for the capacities of 500, 750 and 1500m^3, respectively (considering suitability to small farm of less than 1.0 ha, medium farm of 2-4.0ha and large farm of more than 4.0 ha, respectively in rainfed areas) were considered with lining of HDPE 500 microns thick geo-membrane film. The structures were provided with inlet spill way, silt trap (1.5x1.5x1m) and rectangular outlet (1x1 m). The depth of maximum storage was of 3 m with side slopes of 1.5:1. On an average the evaporation losses were observed at 3 mm/day in kharif and 5 mm/day in rabi. The net water availability for critical irrigation in different farm ponds were calculated by reducing the evaporation losses up to the critical stage of the groundnut and maize. The yield data for rainfed as well as supplemental irrigated were considered for two irrigation depths of 50 and 30 mm. It was observed that, there is a chance of two fillings of farm ponds for three out of five years after lining in 2010. Similarly, there is a chance of single filling of the farm pond, four out of five years. It indicates that, the risk level is 20 % for single filling and 40 % for two fillings of farm ponds. Rabi crop was grown only after second filling of farm pond. In single filling, the water available is sufficient to provide two critical irrigations for groundnut and maize along with vegetables (tomato/okra) with 30 mm of irrigation depth weekly once.

Farm Pond Construction and Lining

The economics of farm pond construction involves earth excavation, slope stabilization, digging of field channels, silt trap, inlet and outlet structures along with bund formation. Beside the earth excavation for digging of farm pond an extra of earth removal of 22 %, 20 % and 17 % are added for 500, 750 and 1500 m^3 respectively. Based on the field experience of digging the farm pond using machinery with big bucket having capacity of 1 m^3 can cost Rs. 30/m^3 as per the recent market prices of hiring the machinery. Lining of farm pond with 500 micron HDPE thick film is about Rs.100/m^2 plus labor charges for anchoring and laying of the film in the trench along the side bund of the farm pond. The cost of the lining are: Rs. 30000, Rs.41500 and Rs.70000 for 500, 750 and 1500 m^3 respectively. The life of the lining film is taken as 5 years. The cost of the earth excavation are: Rs.18300, Rs.27000 and Rs.52650 for 500, 750 and 1500 m^3 capacities of farm ponds respectively.

Water Application System

The cost of the water application system was estimated using two rainguns with one full circle and one half circle at an operating head of 30 m with 50% over lapping in the spray pattern and the discharge rate of 150 lph. One full circle would cover an area of 1258 m^2 by Hidra model of raingun. The life of the system was taken as 15 years for the 5 hp monoblock diesel pumpset, HDPE pipes with accessories for 1 ha irrigation at a time(50 HDPE pipes at 4kg/cm^2) . It was assumed that the plot size of 100 x 100 m^2 for all calculations of irrigation cost. The system will be operated on shifts immediately after meeting the irrigation depth criterion. The time of irrigation estimated for 30 and 50 mm depths were 2.5 hr and 4.2 hr respectively. The total market price of the system was estimated as Rs. 80,000/-. It is proposed to run the system on custom hiring basis with 100% benefit on annualized cost with 9% bank interest rate for loan repayment by the entrepreneur. The annual operation and maintenance cost of the system was taken as 12% over the annualized cost of the system including transport etc. It is presumed that the system will be in operation for 840 hrs in the field in a year taking care of kharif and rabi irrigation from the farm pond or any water source in a cluster of 5 - 6 villages. The unit irrigation cost of the system was arrived at Rs. 350/hr. The cost of supplemental irrigation at two critical stages of crop growth at different levels of irrigation depths of 30 mm and 50 mm of water application was worked out as Rs. 1900/ha and Rs. 3204/ha respectively under the custom hiring module by using rainguns. It includes hiring charges of irrigation system and diesel cost with consumption of 0.5 l/hr of operation. On an average, the cost of the diesel is taken as Rs. 60/litre.

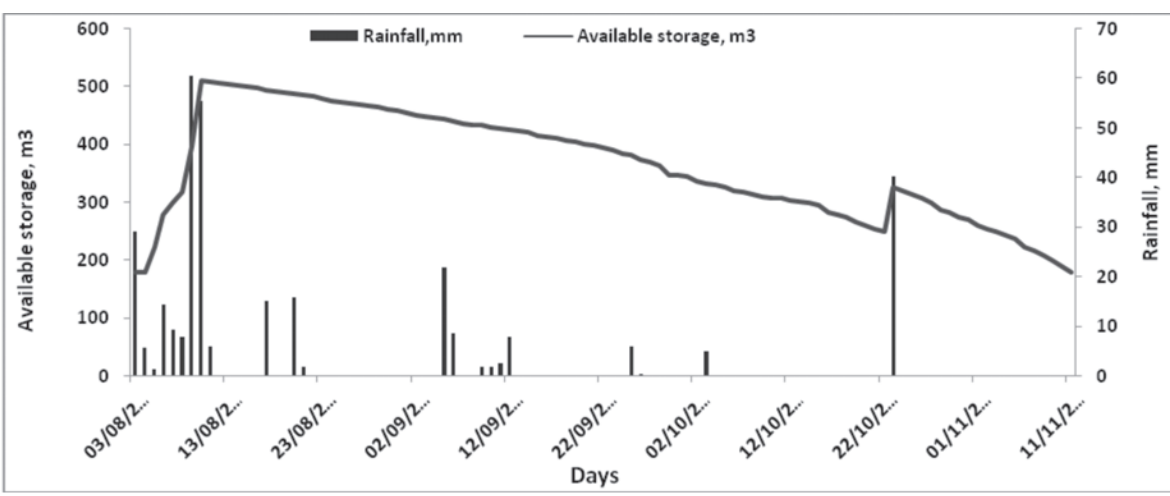
Water Balance Analysis

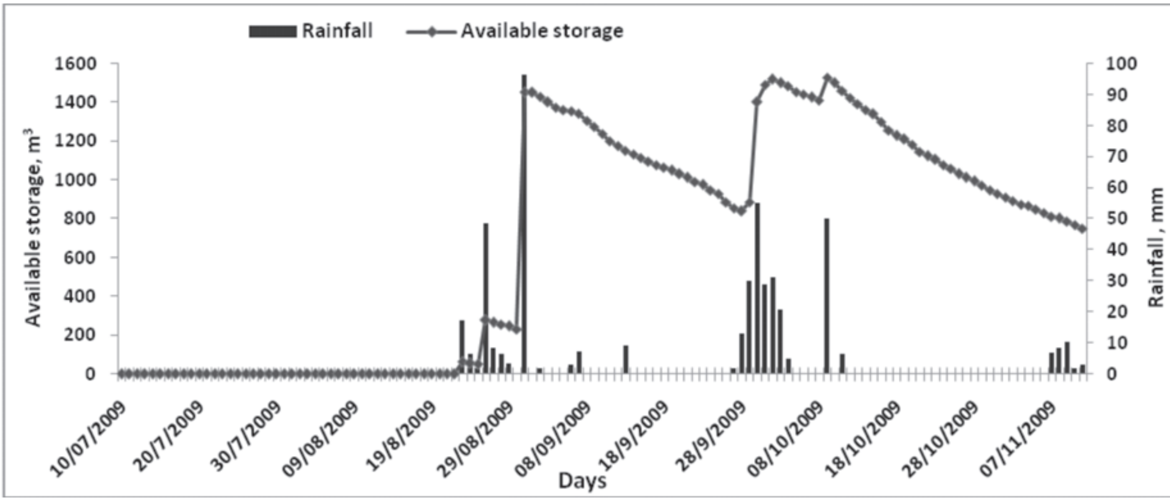
The results of water balance analysis for three years during 2008 to 2010 are presented in Table 1. The water balance includes daily rainfall, runoff, available storage, seepage loss, evaporation loss and collected water used for supplemental irrigation applied during dry spell. The seasonal rainfall was 320.5, 581.4 and 406 mm with total water harvested of 1179, 2592 and 1992 m^3 for 2008 to 2010 respectively. The run off potential of rainfed alfisols was ranged from 2.57 to 3.72 %. The highest seepage losses was observed in 86.73% (2248 m^3) followed by 81.26 % (958 m^3) and 75.11% (1496.2 m^3) during 2009, 2008 and 2010 respectively. The highest evaporation losses were observed during 2008 with 14.16 % (167 m^3) followed by 13.88 % (276.49 m^3) in 2010 and least was in 2009 with 7.48 % (193 m^3). Supplemental irrigation was applied in dry spell days with a quantity of 18 and 150 m^3 during 2008 and 2009 respectively. A pre sowing irrigation was given with a quantity of 219.12 m^3 during 2010 as there was no dry spell occurred in that year. Out of seepage and evaporation losses, the 75 to 85 % water losses through seepage. It is suggest that, lining of farm pond would increases the available storage to cope with water stress during dry spell at critical stages. The study also suggests that, the rainfed alfisols had good potential for rainwater harvesting and utilization. The collection of excess rainfall runoff in small farm ponds by reducing seepage and percolation losses from stored water has been found a suitable option for management of rainwater in alfisols**.**

Table 1. Water balance analysis during 2008 to 2010 in rainfed alfisols

S.l No.	Parameters	2008	2009	2010
1	Total rainfall (mm)	320.5	581.4	406
2	Total water yield (mm)	9.3	21.6	16.6
3	Water yield to rainfall (%)	3.07	3.72	2.57
4	Total harvested water yield in a pond (m^3)	1179	2592	1992
5	Total seepage loss (m^3)	958 (81.26 %)	2248 (86.73 %)	1496.2 (75.11 %)
6	Total evaporation loss (m^3)	167 (14.16 %)	193 (7.48 %)	276.49 (13.88 %)
7	Total water used (m^3)	18 (4.58 %)	150 (5.79 %)	219.12 (11 %)

The available storage and dry spell during 2008 to 2010 are presented in Fig 2. In 2008, it is observed that, there was a good rainfall event during second week after sowing with a 60.5 and 55.5 mm consecutively two days which increased available storage from 317 to 511.49 m^3 and thereafter there was no runoff producing event which causes deceasing trend in available storage. During 2009, it was observed that, there was two long dry spell during initial and development stages and two supplemental irrigations were applied during these dry spells with a quantity of 50mm each. Fig 2(c) shows that, throughout season there was good rainfall distribution during 2010 and there was no scope for supplemental irrigation. There was two good runoff producing events were observed before the sowing with a quantity of 70 and 62 mm on 11 and 13th of June month. The collected water was utilized during the rabi season. The total harvested water in farm pond was depended on depth and pattern of the rainfall received. The water balance analysis would enhance the utilization of collected runoff for improvement of water productivity of rainfed crops.





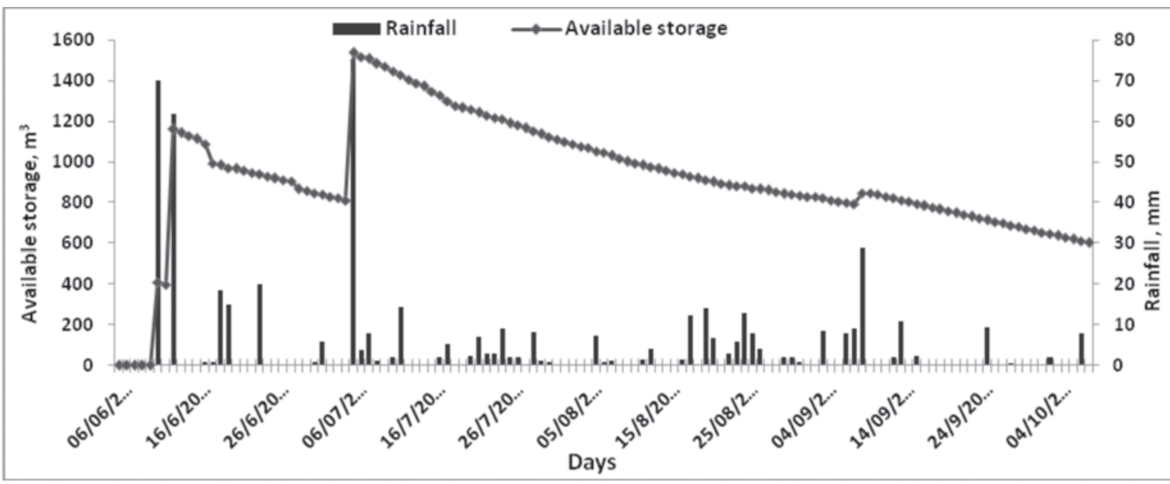


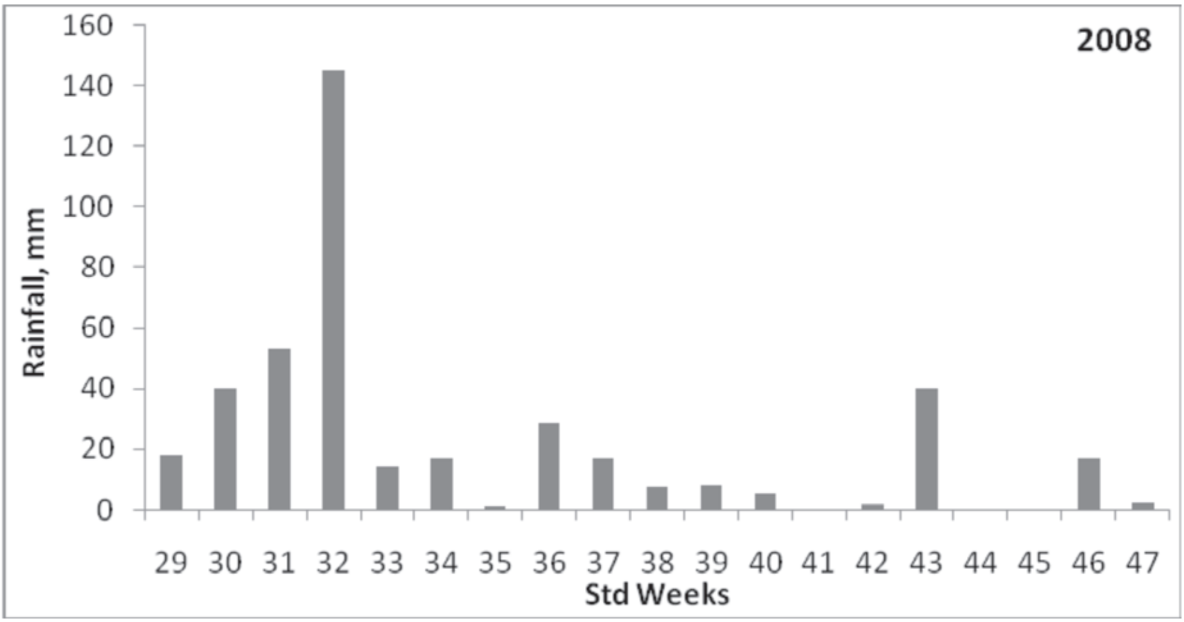
Fig. 2. Available storage and dry spell during 2008 to 2010

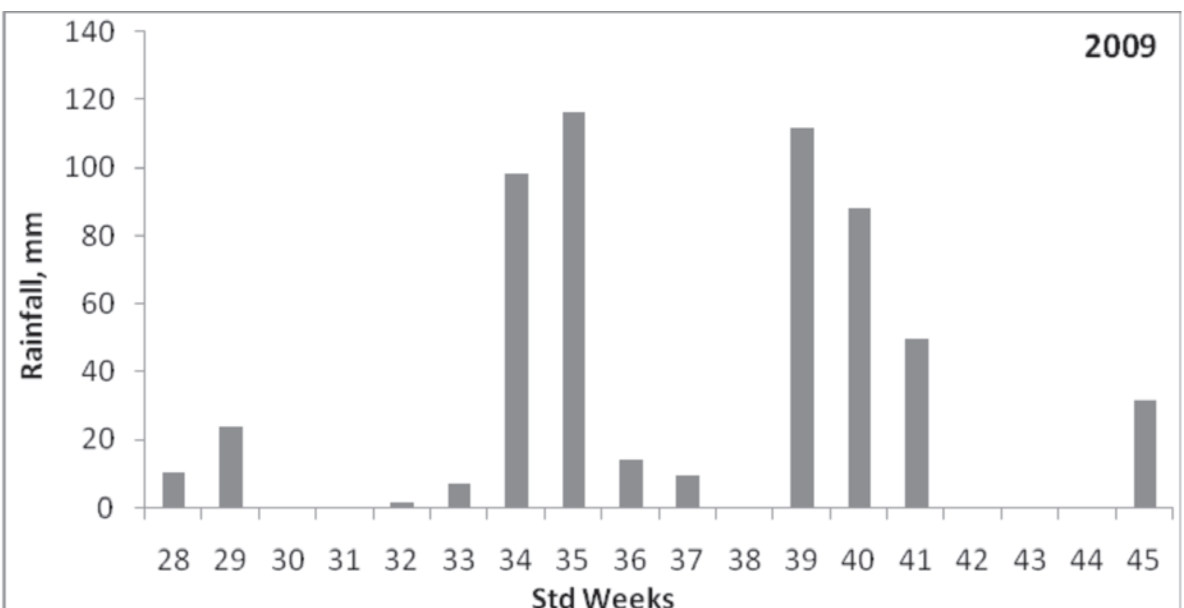
Water and Cropping System Yield Dynamics Under FPT

The long term data generated through field experimentation has been used in the present analysis for cropping systems like groundnut (GN)+ okra. During 2008-11, the groundnut based cropping system was tested during 2012-15 under farm pond imposing different irrigation depths in the alfisols.

The weekly total rainfall distribution from sowing to harvest during 2008 to 2010 are presented in Fig 3(a, b and c). Dry spells were identified during sowing to harvest to apply supplemental irrigation during crop critical stages. In 2008, there was good rainfall distribution during first four weeks and two dry spells occurred during 41-42 and 44-45th of weeks (Fig 3(a)). From the Fig 3(b), it was observed that, there was two long dry spell occurred during 30 to 33 and 42 to 44 weeks, while there was good rainfall distribution from 34 to 41 weeks during 2009. In 2010, from sowing to harvest it experienced good weekly rainfall distribution and there was no dry spell occurred. In 2010, from sowing to harvest, it experienced good weekly rainfall distribution and there was no dry spell occurred. As there was no dry spell occurred during 2010, a pre sowing irrigation of 219.4 m^3 was applied for groundnut and okra.

The groundnut and okra yield obtained under rainfed and supplemental irrigation during 2008 to 2010 are presented in Table 2. The highest ground nut and okra yield (1147 kg ha^{-1} and 2610 kg ha^{-1}) was obtained in tank silt followed by (844 kg ha^{-1} and 2370 kg ha^{-1}) in no tank silt under supplemental irrigation as compared to rainfed (633 kg ha^{-1} and 1490 kg ha^{-1}) in tank silt and (500 kg ha^{-1} and 895 kg ha^{-1}) in no tank silt respectively during 2008. There was a yield increase of (81.20 and 68.8 %) in ground nut and (75.16 and 164.8 %) in okra under supplemental irrigation as compared rainfed. During 2009, the maximum yield in groundnut and okra (1783 and 3200 kg ha^{-1}) was obtained in tank silt and followed by (1595 and 2663 kg ha^{-1}) under supplemental irrigation as compared to rainfed of (917 and 1525 kg ha^{-1}) in tank silt and (845 and 965 kg ha^{-1}) in no tank silt respectively. Application of supplemental irrigation during critical stages increased groundnut and okra yield (94.50 and 109.83 %) in tank silt and (88.75 and 175.95%) in no tank silt as compared to rainfed. In 2010, the maximum groundnut yield (3360 and 2940 kg ha^{-1}) obtained in tank silt and no tank silt under rainfed condition.





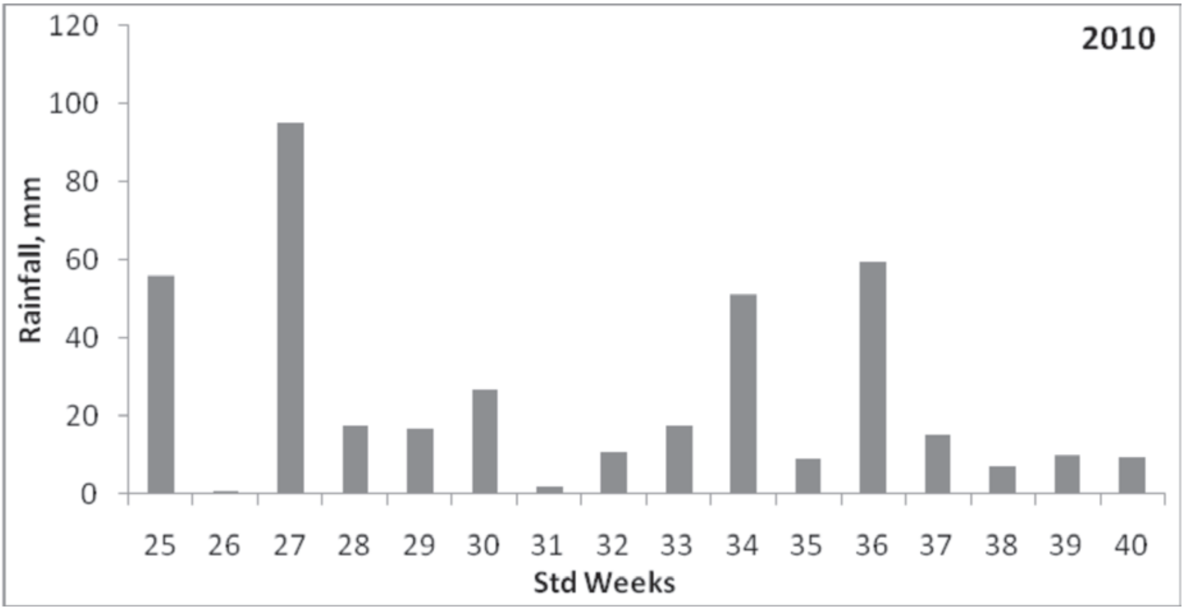


Fig. 3. Weekly rainfall distribution from sowing to harvest during 2008 to 2010.

The maximum okra yield (4095 kg ha^{-1}) followed by (3391kg ha^{-1})in tank and no tank silt application under supplemental irrigation as compared to rainfed (3941 kg ha^{-1}) and (3008 kg ha^{-1}) was observed in tank and no tank silt application respectively. This shows that groundnut and okra under rainfed conditions usually suffers from water stress which may benefit from supplemental irrigation in order to get optimal yield.

Table 2. Average ground nut (ICGV 91114) and okra (Anamica) yield (kg/ha) under supplemental irrigation and rainfed during 2008 to 2010.

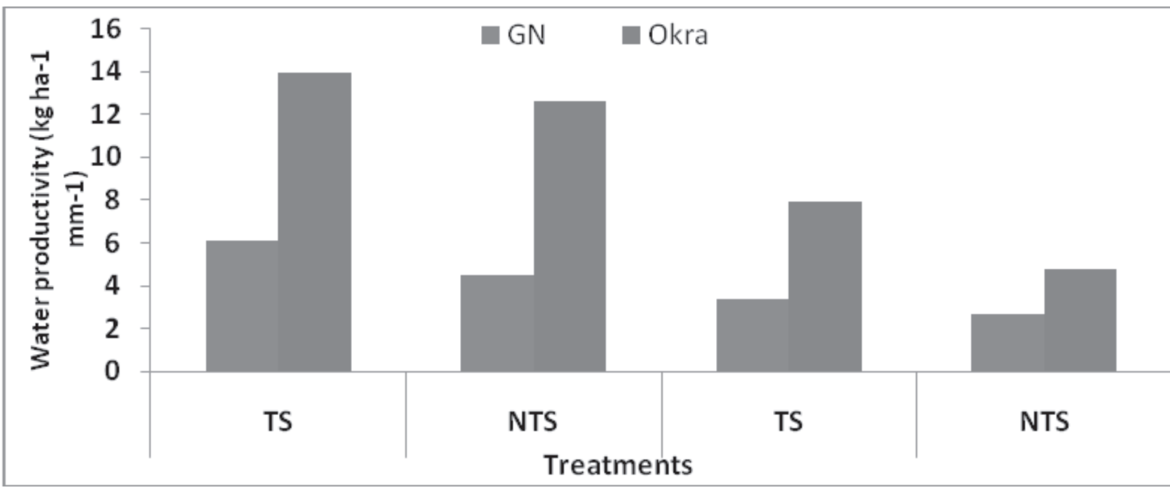
Years	Crops	SI		Rainfed	
		TS	NTS	TS	NTS
2008	Groundnut	1147 (81.20)	844(68.8)	633	500
	Okra	2610 (75.16)	2370 (164.8)	1490	895
2009	Groundnut	1783 (94.50)	1595 (88.75)	917	845
	Okra	3200(109.83)	2663 (175.95)	1525	965
2010	Groundnut	3340 (-0.68)	2853 (-3)	3360	2940
	Okra	4095 (3.90)	3391 (12.73)	3941	3008

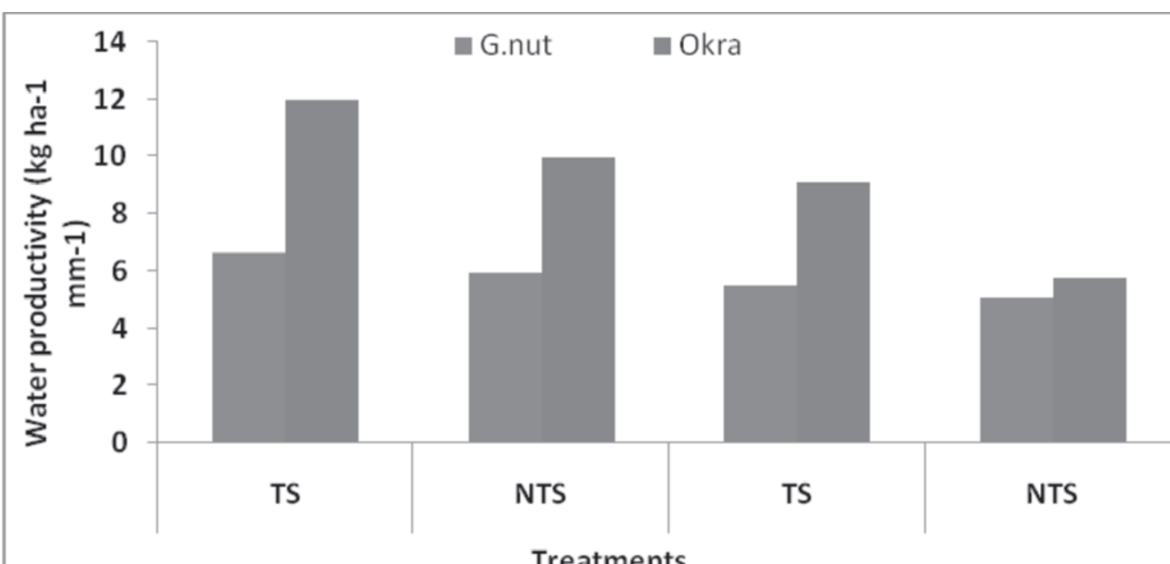
Percent increase over rainfed due to application of supplemental irrigation

The current study revealed that supplying SI to the existing rainfed groundnut and okra during the late season could be as an efficient strategy to mitigate the dry spell occurrence during the growing season and to sustain yield production. Shortage of soil moisture in the dry rainfed areas occurs during the most sensitive growth stages (flowering and grain filling) of cereal and legume crops. As a result, rainfed crop growth is poor and yield is consequently low. SI showed a large potential to improve yield potential especially in semi-arid cropping systems with uneven rainfall variability and high intra seasonal dry spell occurrence .

Water Productivity

The water productivity of groundnut and okra observed during 2008 to 2010 were presented in Fig 4(a, b and c) under supplemental irrigation and rainfed condition with management practices of with and without tank silt application. From the Fig 4(a) it is observed that, maximum water productivity in groundnut and okra was (6.10 and 13.88 kg ha^{-1} mm^{-1}), followed by (4.49 and 12.61 kg ha^{-1} mm^{-1}) and least (2.66 and 4.76 ka ha^{-1} mm^{-1}) was in tank and without tank silt application under supplemental irrigation and rainfed condition respectively during 2008. During 2009, it is observed that, the maximum water productivity in groundnut and okra was (6.67 and 11.96 kg ha^{-1} mm^{-1}), followed by (5.96 and 9.96 kg ha^{-1} mm^{-1}), (5.48 and 9.11 kg ha^{-1} mm^{-1}) and lowest (5.05 and 5.76 kg ha^{-1} mm^{-1}) was in tank and without tank silt under supplemental irrigation and rainfed condition respectively. The maximum water productivity in groundnut (23.91 kg ha^{-1} mm^{-1}), followed by (20.93 kg ha^{-1} mm^{-1}) in tank and without tank silt under rainfed condition as compared to supplemental irrigation of (23.77 kg ha-1 mm-1) and (20.31 kg ha^{-1} mm^{-1}) in tank and without tank silt application (Fig 4c). The water productivity of okra was 29.15>24.14 kg ha^{-1} mm^{-1} and 28.05>21.41 kg ha^{-1} mm^{-1} in tank and without tank silt under supplemental irrigation and rainfed condition respectively during 2010. Supplemental irrigation can, using a limited amount of water, if applied during critical crop growth stages, result in substantial improvement in yield and water productivity.





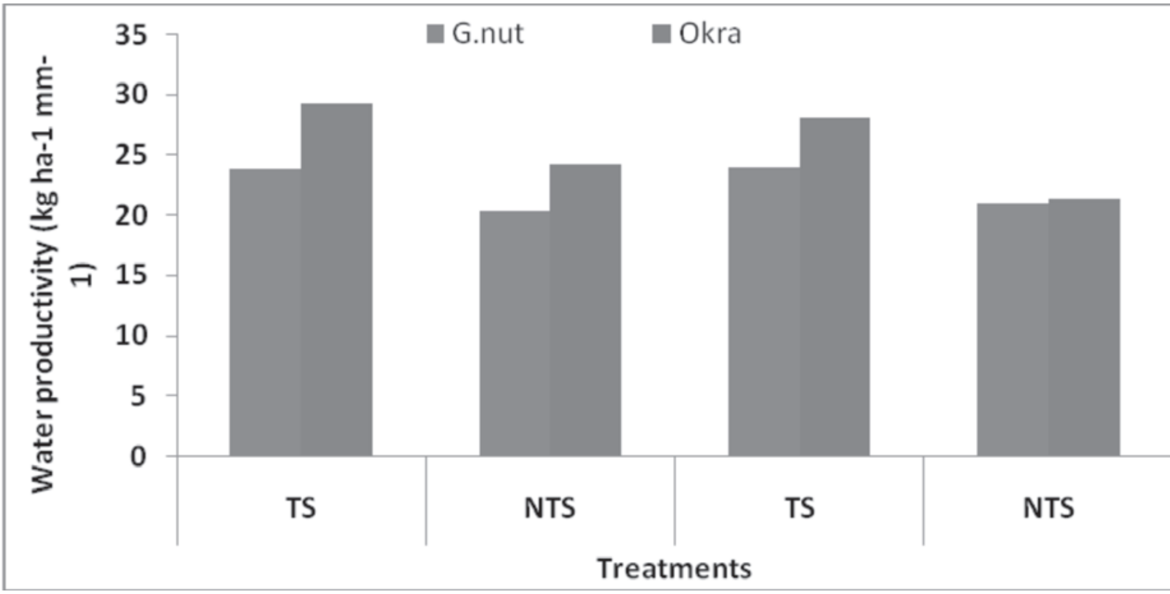


Fig. 4. Water productivity in ground nut and Okra with tank silt and no tank silt application under supplemental irrigation and rainfed conditions in alfisols

Conclusion

Farm pond technology has been tested in groundnut and okra crops in combination and proved to increase the yields substantially with raingun irrigation system in semi arid alfisols of South Central India. The oilseeds of groundnut is good protien rich oil seed which is mostly cultivated in rainfed conditions and the farm pond technology can alleviate the stress conditions due to weather aberrations in the semi arid regions. It is recommended that minimum of 250 m^3 capacity of size 14x14x3 m must be constructed on farm as rainwater harvesting structure and for providing critical irrigation.

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27 Nutritional Quality of Organically Grown Food Crops

KA Gopinath, V Visha Kumari, G Ravindra Chary, M Jayalakshmi and G Venkatesh

Introduction

In India, with less than 42,000 ha under certified organic farming during 2003-04, the area under organic farming grew by almost 25 fold, during the next 5 years, to 1.2 million ha during 2008-09. Later, however, the area under certified organic farming has fluctuated between 0.78-1.1 million ha. Presently, about 0.7 million ha area is under certified organic cultivation and India ranks 4th in terms of largest areas of organic agricultural land (Willer and Julia, 2016). During 2014-15, India had the largest number of organic producers of about 0.65 million and accounted for 1.35 million tons of certified organic produce. India exported 135 products during 2014-15 with the total volume of 263687 MT. The organic food export realization was around 298 million USD.

Among all the states, Madhya Pradesh has covered largest area (2,32,887 ha) under organic certification followed by Maharashtra (85,536 ha) and Rajasthan (66020 ha). Realizing the potential of organic farming in the North Eastern Region (NER) of the country Ministry of Agriculture and Farmers welfare has launched a Central Sector Scheme entitled "Mission Organic Value Chain Development for North Eastern Region" during the 12th plan period. It is estimated that about 50,000 ha land of NER will be converted to Certified Organic with marketable commercial organic farming within three years period. Entire state of Sikkim has already converted to organic farming. Meghalaya has set a target of converting 0.2 m ha to certified organic farming by 2020. Other potential areas for organic farming include hill and mountain regions in Uttarakhand, Himachal Pradesh and NEH; tribal areas which are organic by default (e.g. Chhattisgarh, Jharkhand, Andhra Pradesh, Rajasthan).

The term "organic" to consumer in today's life signifies quality and nutrition. It has rather become a status symbol. The interests and preferences of consumers have gone high. Certified organic produce are those which are produced in accordance with given organic farming standards. The key principles and practices of organic food production try to support and enhance biological cycles within the farming system. This in turn maintain and increase fertility of soils, minimize pollution, avoid the use of synthetic fertilizers and pesticides, maintain genetic diversity, consider the wider social and ecological impact of the food production and processing system, and produce food of high quality in sufficient quantity (IFOAM, 1998). In the consumer's mind, organic produce must be better and healthier than that produced under conventional farming system. This image is also the main motive for consumers who are willing to pay premium prices for purchasing organic food. Organic agriculture can be viewed as an attempt to overcome contamination of food supplies with pesticides, pollution, and radioactive fallout etc., associated with processed food and a chemically-based agriculture. From a scientific point of view, however, it is difficult to provide or substantiate the supposed health benefits, since food quality is composed of various partial aspects and without uniform evaluation standards. Several investigations have clearly shown that the type of fertilizations, contrary to the principle of organic farming, does not significantly affect crop quality. Crop quality is not dependent on the principle difference between inorganic fertilization and organic manuring. Side effects caused by synthetic pesticides and drug feeding are not found in organic farming, which is a positive result. The use of herbicides has been documented to increase cyanide, potassium nitrate, and other toxins in crops. The evaluation of food quality by taking into account the criteria such as appearance and nutritional value exclusively is not satisfying. Even though, a range of factors has been investigated comparing organic and conventional food production systems which majorly includes economics, crop yields, soil properties, soil microbiological activity, insect-pest and disease burdens etc, nutritional comparison is one which has gained momentum. Nevertheless, the link between organic products and their enhanced nutritional/environmental values is far from being fully understood (Maggio *et al*., 2013).

The Nutritional Value of Organic Food

A large number of studies have been reported that attempt to investigate if there is a difference in the nutritional value of organically and conventionally grown food. There is considerable variation in the types of studies and study designs. However, the majority involve one of four main approaches (Bourn and Prescott, 2002).

- The chemical analysis of organic and conventional foods purchased from retailers
- The effect of different fertilizer treatments on the nutritional quality of crops
- The analysis of organic and conventional foods produced on organically and conventionally managed farms
- The effect of organic and conventional feed/foods on animal and human health (predominantly reproductive health)

However, it is very difficult to have a comparison with the first approach mainly because of the study design, consideration of limited production design and unknown about the origin. Different fertilizer treatments are easy to be conducted, but has not resulted in any clear picture. The third approach is found highly useful because the effects of whole systems of production on nutritional value are essentially being evaluated.

Nutritional Quality

Macronutrients

There is not much on effect of different production systems on starch/carbohydrate to have a comparison between organic and conventional produce. But, protein content as influenced by organic farming has received importance. In wheat it was found that organically grown and conventionally grown one have comparable protein content (Shier *et al*., 1984) but somewhat lower levels of protein than the conventional ones (Woese et al. 1997). Gopinath *et al* (2008) also reported that in the first year of transition, protein content of wheat grain was higher (85.9 g/kg) for mineral fertilizer treatment, whereas, in the second year, there were no significant differences among the mineral fertilizer treatment and the highest application rate (150 kg N/ha) of three organic amendments (FYM, vermicompost and lantana compost). The grain P and K contents were, however, significantly higher for the treatments involving organic amendments than their mineral fertilizer counterpart in both years. Similarly, Saha *et al* (2007) reported that the protein content in rice grains was the highest (8.98%) in the inorganic treatment (100:60:40 kg N, P, K/ha) compared to organically grown rice. Another study showed that organic virgin olive oil had a higher oleic acid level (Gutierrez *et al*., 1999). Similarly dairy products *viz*., hen eggs (Kouba *et al*., 2002) and raw cow's milk (Toledo *et al*., 2002) did not show any noticeable change in protein levels. However, a study conducted in Sweden showed that organically-bred cows had more lean meat than their conventional counterparts (Hansson *et al*., 2000). More qualitatively, meat from organically-grown cows had more polyunsaturated fatty acids (Pastsshenko *et al*., 2000).

Minerals and Vitamins

Worthington (2001) reported a 21% increase in iron content, 29% increase in magnesium and 13.6 and 15% higher phosphorus and nitrate in organic produce of different crops. A detailed review by Lairon (2009) also showed that organic food had 21 and 29% more iron and magnesium than non organic food. Among the vitamins, ascorbic acid (vitamin C) was found higher in many organic fruits and vegetables. Hajslova (2005) reported lower levels of nitrate and higher levels of ascorbic acid and chlorogenic acid in organically grown potatoes. In an organic orchard of yellow plums with soil left as natural meadow, ascorbate, tocopherols, and beta carotene were found highest. However total polyphenols were higher in conventional farm (Lombardi *et al*., 2004). Higher vitamin E level in organic olive oil was reported by Gutierrez *et al*. (1999). In rice, Saha *et al* (2007) reported significantly higher iron content of 52.2 ìg/g with organic fertilization than inorganic fertilization (42.1 ìg Fe/g). However, inorganic fertilization was superior in terms of copper content (4.1 ìg Cu/g) compared with organic treatments (3.1–4.0 ìg Cu/g). In another study, Saha *et al* (2010) reported higher P and K contents in organically grown rice compared to conventional rice (Table 1). Similarly, iron, Cu, and Mn contents were slightly more in organic treatments, unlike the Zn concentration, which was more in inorganic treatments.

Table 1. Mineral contents of rice grain grown under different manure and fertilizer treatments

Treatment	P (%)	K (%)	Fe (μg/g)	Zn (μg/g)	Cu (μg/g)	Mn (μg/g)
Control	0.215a	0.256a	30.17a	14.30a	1.18a	4.52a
FYM 5 t/ha	0.233abc	0.272abc	35.16ab	14.69a	1.48b	7.13bc
FYM 10 t/ha	0.239abc	0.281bc	41.15ab	16.07b	1.82d	9.36de
FYM 15 t/ha	0.246abc	0.302d	43.85bc	16.66b	1.87de	10.19e
FYM 20 t/ha	0.261c	0.313d	53.39c	18.00cd	2.06g	10.38e
Fertilizer eq. FYM 5 t/ha	0.228ab	0.258a	30.42a	17.46c	1.42b	6.53b
Fertilizer eq. FYM 10 t/ha	0.234abc	0.266ab	32.20ab	18.63de	1.64c	7.37bcd
Fertilizer eq. FYM 15 t/ha	0.237abc	0.277bc	35.15ab	19.28e	1.80d	8.40bcde
Fertilizer eq. FYM 20 t/ha	0.249bc	0.286c	37.40ab	19.30e	1.98fg	8.75cde

Source: Saha *et al* (2010); Means in the same column with different letters are significantly ($P < 0.05$) different

Other Phytomicronutrients

Phytomicronutrients were treated one among the other micronutrients. However, it has gained importance in last two decades. They include carotenoids, flavonoids and other polyphenols. Flavonoids are good antioxidants (Pietta, 2000) and carotenoids have been found to reduce cancer risk (Karppi *et al*., 2009). It has been anticipated in a recent review that organic plant foods overall contain double the amount of phenolic compounds (Rembialkowska, 2007). One study reported higher levels of resveratrol in organic wines (Levite *et al*., 2000). Anthocyanic compound in berries have been reported to reduce neuronal and cognitive brain functions (Zafra-Stone *et al*., 2007). Because of the importance they play in human health more focus is now being given for phytomicronutients. In a study done by Wang et al (2008), higher percentage of sugar, malic acid, total phenols, total anthocyanin and antioxidant activity were recorded in organically grown blueberries than the one conventionally grown. Pragya *et al* (2007) compared the quality characteristics and sensory quality in fresh green peas grown by organic, inorganic and integrated methods and found higher copper and zinc levels as compared to inorganically grown peas and peas grown by integrated method of cultivation.

Food Safety

Pathogenic microorganisms

Since organic production systems rely on animal manures and vegetable/crop wastes for supplementing nutrient requirement there is always concern about the possible contamination of food products. Organic farming has fascinated the notice of the entire food production sector around the globe since it restores on eco-agricultural principles that consider soil, water and air quality. However, organic produce is more exposed to microbiological contamination than conventional produce, since organic fertilizers often consist of manure, and manure may harbor pathogenic microorganisms such as *Salmonella* spp., *Listeria monocytogenes* and *Escherichia coli* (Johannessen et al. 2004; McMahon & Wilson, 2001). Of all organic foods, vegetables stand out as important sources of food borne illness. Use of manure as such may invite more pathogens, but if composted properly would avoid the contamination of food stuff by pathogenic microorganisms. While reporting for dairy products, we have some contradicting results. A Danish study reported that about 100% of poultry samples were contaminated by *Campylobacter* sp in organic farms, whereas 36–49% of samples in conventional farms were (Heuer *et al*., 2001). In contrast, in a survey conducted in France in four different regions found comparable levels for total bacteria count or butyric microorganisms in milk produced with the two husbandry systems (Echevarria, 2001). Since we have more of incomparable results, it is really difficult to conclude the supremacy of organic food over conventional one with respect to pathogenic microorganisms.

Phytochemical Contaminants

No use of chemicals is a clear advantage for organic agriculture. However, the question has repeatedly been raised of the level of contamination of organic food by environmental pollution. In a study of the potential of vegetables to suppress the mutagenecity of various environmental toxins, including benzo pyrene (BaP the main carcinogen in cigarette) organic vegetables were found more active (Ren *et al*., 2001). Against the chemical 4-nitroquinoline oxide, organic vegetables suppressed 37-93% of mutagenic activity (Olsson *et al*., 2006). A study performed on vegetables and strawberries in Sweden did not show any contamination of organic ones, while 17–50% of conventional ones contained pesticide residues (Bourn and Prescott, 2002). A survey conducted in Italy in the 2002–2005 period on 3500 samples of food of plant origin also concluded that the vast majority (97.4%) of organic farming products do not contain detectable pesticide residues (Tasiopoulou *et al*., 2007). It is meaningful mentioning that only some natural extracts are used in organic agriculture for pest and disease control such as neem oil, fly ash, garlic extracts, chilli and ginger extracts etc which are quickly degraded and hence no contamination (Moore *et al*., 2000). The two major fungicides of mineral origin permitted for used in organic farming for disease control are sulphur and copper salts and their various compounds. However, these are allowed with certain restriction. It is also noteworthy that copper being an inorganic compound, does not breakdown like organic compounds and may accumulate in soil over several years resulting in toxicity.

Mycotoxins

Mycotoxins are poisonous compounds produced by the secondary metabolism of poisonous fungi (moulds) like *Aspergillus*, *Penicillium* and *Fusarium*, which occur in food products (Kouba, 2003). They have a negative impact on human health, i.e. are carcinogenic and disabling to the immune system. Mycotoxin production is mainly dependent on temperature, humidity and other favorable environmental conditions. Recent studies have not shown that organic food is more susceptible to mycotoxin contamination than conventional food (Kouba, 2003; Benbrook, 2006; Lairon, 2009).

Conclusion

Organic farming practices largely avoid synthetic fertilizers, pesticides, growth regulators and livestock feed additives. Organic farming systems rely on crop rotations, manures, organic wastes and biological pest controls to maintain soil productivity, supply nutrients to growing plants and control pests. Several studies do reveal some differences in quality between conventionally and organically produced foods. In general, many reviews have concluded that organic plant products contain more dry matter, minerals (Fe, Mg) and Vitamin C; and contain more anti-oxidant micronutrients such as phenols and salicylic acid. Organic animal products contain more polyunsaturated fatty acids. However, data on carbohydrate, protein and vitamin levels are insufficiently documented. Almost all of the of organic food (94-100%) does not contain any pesticide residues. Organic vegetables contain far less nitrates, about 50% less. In addition, there were several trends showing less protein but of a better quality, more nutritionally significant minerals, and lower amounts of some heavy metals in organic crops compared to conventional ones. Organic agriculture has the potential to produce high quality products with some relevant improvements in terms of contents of anti-oxidant phytomicronutrients, nitrate accumulation in vegetables and toxic phytochemical residue levels.

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28 Enhancing Potential of Animal Agriculture for Food and Nutritional Security in India: Tradeoffs and Strategies

D B V Ramana

Introduction

Food production through crops and animal agriculture is the base for food security. “Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 2003). In 1947, India’s population was 330 million and in those days, feeding people was biggest challenge and mostly relied on supplies from the United States during initial decades. High yielding varieties (HYV) of wheat from Mexico during 1966 brought green revolution and today, India is not only self sufficient but also a net exporter of food grains and largest exporter of rice, milk and meat in the world. Production of wheat gone up by 15 times, rice by 5 times, maize by 14 times, milk by 8 times, meat by 6 times, eggs by 38 times and so on during the last 60 years. Inspite of many folds increase in food production, food security is still a serious problem in India and poverty makes the people inaccessible to have sufficient nutritious food. Poverty leads to malnutrition as a result of low protein and micro and macro nutrient intake. The percentage of persons below the Poverty Line in India for the year 2011-12 has been estimated as 25.7% in rural areas, 13.7% in urban areas and 21.9% for the country as a whole. Further, India with 1.34 billion population and population growth rate of 1.2% needs to produce more and more food from diminishing per capita arable land and irrigation water resources and expanding abiotic and biotic stresses to have food security at national level.

Contribution and Scope of Animal Agriculture to Food Security

Availability of an adequate quantity of nutritious and balanced food is a primary requisite for food security at national level. Livestock are an important source of food, particularly of high quality protein, minerals, vitamins and micronutrients. The value of dietary animal protein is in excess of its proportion in diets because it contains essential amino acids that are deficient in cereals. Eating even a small amount of animal products corrects amino acid deficiencies in cereal-based human diets, permitting more of the total protein to be utilized because animal proteins are more digestible and metabolized more efficiently than plant proteins (Winrock, 1992, De Boer *et al*, 1994). Protein digestibility corrected amino acid score (PDCAAS), protein efficiency ratio (PER) and biological value (BV) of animal and plant proteins are 0.9-1.0 and 0.42-0.70; 3-4 and 1.5-2.6; 74-94 and 65-73 respectively.

Bovines are the second largest source of meat in India after poultry, and ahead of goat and sheep. According to the Department of Animal Husbandry, Dairying and Fisheries (DAHDF), total meat production in 2012-13 stood at 5.95 million tonnes (MT), of which poultry contributed 2.68 MT followed by beef (1.43 MT: 1.1 MT from buffalo and 0.33MT from cattle) and mutton (1.38MT: 0.94 MT from goat and 0.44 MT from sheep). Pork or pig meat accounted for slightly over 0.45 MT for current year 2016, total chicken meat consumption is forecast at 4.19 million tons, up by approximately eight percent over 2015. India’s per capita consumption of poultry meat is estimated at around 3.1 kg per year, which is low compared to the world average of around 17 kg per year. India occupies the first position in milk production (146.3MT) and eighth in world’s meat production. Buffalo in India contributes about 30% of total meat production. The contribution by cattle, sheep, goats and poultry is 30%, 5%, 10%, 10.2% and 11.5%, respectively. Per capita meat consumption in India is low and is around 5 kg as compared to the world average of 47 kg. This shows the huge potential for expansion. The meat industry is likely to grow at a good pace, say, at a compound growth rate of 8% over the next five years. The processed meat industry is growing even much faster, at about 20%. India ranks third in the world in fish production and second in inland fish production. Processing of marine fish offers immense potential. In the world poultry market, India ranks ninth. The domestic poultry industry is the fastest growing segment with a compound growth rate of 15%. Egg production has increased from 30 billion in 2000 to 66 billion in

2012, with per capita egg consumption increasing form 28 to 55 per year during the period. India now ranks as one of the fastest growing major world poultry markets. Per Capita Availability (gm/day) of milk is 322, meat is 4.46 kg (beef 0.5, Pork 0.2, mutton 0.5 and chicken 3.26 kg) and eggs is 58 number in the country.

Animal Agriculture as a Source of Income and Livelihoods Provider

India has vast livestock resources, first in the total buffalo population in the world, second in the population of cattle and goats, third in the population of sheep, fifth in in the population of ducks and chicken. Animal agriculture plays an important role in Indian economy. Animal farming is a source of subsidiary income for many families in India especially the resource poor who maintain few heads of animals. Cows and buffaloes if in milk will provide regular income to the livestock farmers through sale of milk. Animal farming with sheep and goat serve as sources of income during emergencies to meet exigencies like marriages, treatment of sick persons, children education, repair of houses etc. The animals also serve as moving banks and assets which provide economic security to the owners. About 20.5 million people depend upon livestock for their livelihoods. Animal agriculture sector employs eight percent of the countries labour force, including many small and marginal farmers, women and landless agricultural workers. Milk production alone involves more than 30 million small producers. Livestock contributed 16% to the income of small farm households as against an average of 14% for all rural households. Livestock provides livelihood to two-third of rural community. It also provides employment to about 8.8 % of the population in India. Animal agriculture sector contributes 4.11% GDP and 25.6% of total Agriculture GDP. The bullocks are the back bone of Indian agriculture. The farmers especially the marginal and small depend upon bullocks for ploughing, carting and transport of both inputs and outputs. In rural areas dung is used for several purposes which include fuel (dung cakes), fertilizer (farm yard manure), and plastering material (poor man's cement).

Tradeoffs in Exploitation of Potential of Animal Agriculture

Trade-offs become particularly acute when resources are constrained and when the stakeholders' goals conflict (Giller *et al.*, 2008). In animal agriculture, trade-offs may arise at all hierarchical levels, from the crop (such as grain versus feed), the animal (milk versus meat production), the field (mulch versus crop residue), the farm (ruminants versus monogastric), to the landscape and above (animal production versus land for nature). Individual farmers face trade-offs between maximizing short-term production and ensuring sustainable long-term production. Within landscapes, trade-offs may arise between individuals' competing uses of natural resources. Some of these trade-offs are avoidable reconciling the short-term imperative of increasing food and agricultural production as well as incomes for the current generation with the need of conserving natural resources for meeting the requirements of future generations. Poor farmers will trade off immediate food production even though it may involve some resource degradation, against a less tangible but "sustainable future".

The world food problem is now recognized as being largely a failure of effective demand on the part of people with inadequate nutrition. In other words, it is not a problem of production but one of demand and of distribution. However, in developing countries, there is no clear separation between demand and supply of food, as inadequate growth of demand reflects that of incomes of most of the populations whose very incomes depend on the growth of agriculture and allied sectors. Given that the food security problem is concentrated in rural-based and poor countries, it is also appropriate to speak of it as being a problem of production.

The chances of minimizing the trade-offs grow if we consider available technologies and development pathways without prejudice. Trade-offs are being diluted by (Louise and Henning, 2013):

- Growth in income which, most importantly, must alleviate poverty since degradation of natural resources is both a cause and a result of poverty; higher incomes also increase the ability to pay for environmental goods and mitigate the trade-offs between short-term production objectives and long-term resource protection;
- Equitable and safe resource access, that makes livestock holders accountable for resource use and responsible for its protection;

- Policy reforms to remove incentive distortions which work against optimal efficiency in the production process, taking into account the real (intrinsic) scarcities of production factors;
- Wider acceptance and further progress in environment-friendly technologies.

Strategies for Sustainable Growth of Animal Agriculture Sector

In view of the immense potential of the meat, poultry and fisheries sector, policymakers have recommended certain critical measures to support this vital segment of the Indian animal agriculture. Modernization of abattoirs, setting up of rural abattoirs and registration of all slaughter houses in cities/towns are essential for quality meat production. Besides, setting up of large commercial meat farms have been recommended to address the traceability issues necessary for stringent quality standards of CODEX. It has also been suggested that the goat sector has immense potential and needs to be supported in terms of higher investment, community approach and establishment of proper linkages between the processing industry and the market. Similar approach is needed for sheep sector which has remained almost static for a long time. Poultry sector in the country has now emerged as organized industry and important issues like breeding farms, hatchery, feed mills, equipment manufacture, feed supplements, drug and vaccine production, etc. have been addressed in a very satisfactory way. However marketing of the final product still remains mostly in the hands of traders which need to be addressed properly. The other important issues for the poultry sector are improved Feed Conversion Ratios (FCR) and quick control measures for tackling disease outbreaks. The overall growth rate in livestock sector is proposed to be revised to 5 per cent during the current Plan with a 4 per cent growth rate for milk sector and 6-8 per cent for poultry and meat sector.

The marine fisheries sector is expected to grow at the rate of 2.0 percent annually and it is estimated that 3.669 MMT of marine fish would be harvested by the year 2016-17. With this production, the country will be exploiting about 83 percent of its potential harvest of 4.419 MMT. The developments and trends in fish production in the inland sector suggest that a growth rate of 8.0 percent can be achieved by the inland sector. With this growth rate, it is estimated to reach a fish production target of 7.910 MMT by the end of the Twelfth Plan Period (2016-17). The strategies adopted for achieving the targets are to include integrated approach for enhancing inland fish production and productivity with forward and backward linkages right from the production chain. This has to also include input requirements like quality fish seeds and fish feeds and creation of required infrastructure for harvesting, hygienic handling, value addition and marketing of fish. It is proposed to revamp the Existing Fish Farmers Development Authority (FFDAs) and cooperative sectors, besides actively involving the self-help groups and youths in intensive aquaculture activities. Sustainable exploitation of marine fishery resources especially deep sea resources and enhancement of marine fish production through sea farming, mariculture, resource replenishment programme like setting up of artificial reefs etc are the other measures that could enhance marine fisheries sector.

Conclusion

Indian government is striving to provide food security to all its citizens through various policies and programs. Despite rapid economic growth during the past decades, India’s average per capita calorie and protein intake has grown only modestly. Calorie and protein source in the Indian diet is diversifying with fruit/vegetable and animal-based food share increasing and cereal and pulses declining. The implication is that in coming years with rising per capita income and urbanization, India’s demand for various animal food products will continue to increase necessitating a possible change in the food production system and agricultural trade with more intense integrated animal agriculture systems and stringent food safety and quality standards.

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29 Plant Breeding and Nutrition with Special Reference to Legumes

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Introduction

Yesteryears, the main focus of crop improvement was sustainable production. But in the current agriculture scenario, the focus is all on nutritive quality along with economic production. The nutritional quality of a product determines the effect on human or animal health on continuous consumption of the product. It includes protein content, protein quality, protein digestibility, oil content, oil quality, vitamin content, mineral content and absence of antinutritional factors**.** Henceforth, agriculture must now prioritize on reducing "hidden hunger" by enhancing the nutritive value of the produce rather than producing more calories to reduce the hunger. One in three people in the world suffers from hidden hunger, caused by a lack of minerals and vitamins in their diets, which leads to negative health consequences (Kennedy *et al.*, 2003).

Since ancient times, cereals and legumes are domesticated together and it's been our regular routine to complete our food with a blend of cereals and legumes. Legume seeds provide exceptionally varied nutrient profiles, including proteins, fibers, vitamins and minerals (Mitchell *et al.*, 2009).Several plant breeding and biotechnological methods are used to enhance the nutritive quality. Furthermore, proof of concept' studies has been published using transgenic approaches to biofortify staple crops (e.g. high beta-carotene golden rice' grain, high ferritin-Fe rice grain, etc.,).

Biofortification is a relatively recent addition to breeding goals in plants based on improving the nutritional quality of the edible portion of the plant through conventional or transgenic approaches (Dwivedi *et al.*, 2012). To date most biofortification work has concentrated on micronutrients and vitamins (as although conceivably protein content, amino acid distribution and beneficial secondary metabolites could all be considered as goals of biofortification (Welch, 1999).

Unlike agronomic biofortification which depends on the duration and dosage of mineral fertilizers, genetic bio fortification serves as a onetime investment in plant breeding, which yields nutrient rich planting materials for the farmers to grow for years. Once the nutrient rich varieties are bred, it can be evaluated, adapted and introduced into the food chain by multiple location trails, thus combating "hidden hunger". This paper is a modest contribution to the ongoing discussion about enhancing nutritional quality of legumes with possible breeding methods.

Sources of Quality Traits

A Cultivated Variety: In general, most quality traits are available in the current or old varieties. These are the most preferred source for quality since they are the easiest to use in the breeding programs.

Germplasm Line: In case of extensive search, a quality trait not available in the cultivated variety may be found in a Germplasm line.

A Mutant: Many quality traits have been contributed by spontaneous and induced mutants. In some cases desirable mutants for quality traits will be isolated from the mutant lines.

A Somaclonal Variant: Sometimes Somaclonal variants may show an improvement in a quality trait.

A Wild Relative: Latent traits of wild relatives act as a source in some cases.

A Transgene: Transgenes provide a powerful means for the modification of quality traits. In order to use transgenes effectively and successfully, the biosynthetic pathway or at least the key enzymes involved in the pathway, leading to the production of concerned trait should be known.

Breeding Approaches

Breeding approaches to improve the quality includes screening of germplasm, mutagenesis, hybridization, interspecific hybridization, Somaclonal variation, genetic engineering and biofortification

Screening of Germplasm

Screening of germplasm, including cultivated varieties, often yields a source for a quality trait. Further breeding efforts will be made to combine the quality trait with good agronomic features, since germplasm lines are expected to be inferior in these features.

Mutagenesis

A desired quality trait might be present in a spontaneous or induced mutant. Often a quality mutant may have some undesirable features associated with the desirable quality trait. Firstly, the mutant allele may be transferred into several diverse genotypes with excellent agronomic and yielding characteristics. Alternatively, the mutant line may be subjected to mutagenesis and mutants lacking the undesirable characteristics with desired quality traits, may be isolated.

Hybridization

This is the most widely used breeding approach to develop high yielding varities with desirable quality traits. If both the parents of a cross are high yielding varities having good agronomic features, pedigree method will be most suitable breeding scheme. But where one parent has inferior agronomic features, backcross scheme will be the most appropriate; only 2-3 backcross may be made if the inferior parent has some desirable agronomical features. The segregating generation may be subjected to sib-mating, in place of selfing and selection in an effort to break undesirable linkages with the quality trait, especially when it is governed by oligogenes. Quality traits governed by polygenes may be improved by subjecting the segregating generations to a form of recurrent selection.

Interspecific hybridization

Wild relatives often contribute useful nutritive quality genes. The quality lines derived from such crosses will usually serve as parents in hybridization programmes; it is unlikely that they will be used directly as varieties.

Somaclonal variation

Genetic variation present in tissue culture –raised plants has been exploited for developing enhanced nutritional quality commercial varities.

Genetic engineering

It involves introduction of a gene by the technique of recombinant DNA technology and genetic transformation.

Biofortification

Biofortification, the process of breeding nutrients into food crops, provides a comparatively cost-effective, sustainable, and long-term means of delivering more micronutrients. This approach not only will lower the number of severely malnourished people who require treatment by complementary interventions, but also will help them maintain improved nutritional status. Moreover, biofortification provides a feasible means of reaching malnourished rural populations who may have limited access to commercially marketed fortified foods and supplements.

The biofortification strategy seeks to put the micronutrient-dense trait in those varieties that already have preferred agronomic and consumption traits, such as high yield. Marketed surpluses of these crops may make their way into retail outlets, reaching consumers in first rural and then urban areas, in contrast to complementary interventions, such as fortification and supplementation, that begin in urban centers. Biofortified staple foods cannot deliver as high a level of minerals and vitamins per day as supplements or industrially fortified foods, but they can help by increasing the daily adequacy of micronutrient intakes among individuals throughout the life cycle (Bouis *et al.*, 2011).

Work Lane on Nutrition Enhancement

a) Protein content

To improve seed protein content, there should be enough genetic variability for this trait. In soybean, seed protein content data vary from 26.5 and 57%; in common bean, it varies from 20.9 and 29.2%; in pea from 15.8 to 32.1%; in fababean from 22 to 36%; in lentil from 19 to 32%, in chickpea from 16 to 28%; in cowpea from 16 to 31%; in mungbean from 21 to 31% and in pigeonpea from 16 to 24%.A second important factor for efficient selection is the heritability of the trait. Seed protein content in grain legumes is strongly influenced by the environment. In pea, Mathews and Arthur (1985) underlined that environmental effects in seven environments had similar magnitude effects on protein content than genetic effects in 255 genotypes. Gueguen and Barbot (1988) found protein content varying from 18.1 to 27.8% for cultivar Amino depending on the environment. Significant environmental effects are reported for most grain legumes (cowpea: Oluwatosin 1997, Bliss *et al.*, 1973, chickpea: Frimpong *et al.*, 2009, lentil: Hamdi *et al.*, 1991, pigeonpea: Saxena *et al.*, 2002, groundnut: Dwivedi *et al.*, 1990). Environmental variability is probably caused by several factors.

Karjalainen and Kortet (1987) showed that protein content was positively associated with the sumof temperature from sowing to maturity, and with the temperature during flowering and beginningof seed filling, while it was negatively associated with July precipitations. In pigeonpea Saxena *et al.*, 1990 reported the role of both additive and non additive gene action in determining the protein content being controlled by 3-4 recessive genes. By using high protien source in secondary gene pool such as *Cajanus sericeus, C. lineatus and C.scarabaeoides* in breeding, developed high protein lines with good seed size and good seed yield. Evaluation of these lines revealed that from one hectare of field 350-450 kg crude protein can be harvested, reflecting additional harvest of 80-100kg protein per hectare.

b) Fiber content

Legumes have more dietary fiber than any major food group. One-half cup of cooked split peas provides 10 grams of dietary fiber or 40 percent of the daily recommended 25 grams (based on a 2000-calorie diet.) Servings of the most commonly consumed grains, fruits, and vegetables contain 1 to 3 grams of dietary fiber. Some fibers are soluble and others insoluble. Most plant foods contain some of each kind. Soluble fiber can slow the absorption of lipids and lower blood cholesterol. It can also slow the increase of fecal bile excretion, promoting reduced intestinal absorption of fat and cholesterol. Insoluble fiber assists in maintaining regularity and helps prevent gastrointestinal problems. When legumes are part of a diet low in saturated fat and cholesterol, dietary soluble fiber may actually reduce the risk of coronary heart disease.

c) Oil content

A reduction or elimination of long chain fatty acid in peanut oil would be a worthwhile objective of peanut breeding programmes since it will also increase polyunsaturated to saturated (P/S) ratio(Anderson *et al.*,1998). High oleic peanuts have a low which translates to the increased oil stability. Moore and Knauft (1989) identified that hi oleic content is controlled by 2 recessive genes ol_1 and $ol_{2.}$Following hybridization and wide scale screening efforts several high yielding oil lines(> 50%) are identified. Breeding for high oleic groundnut began with the discovery of F435 a high oleic acid spontaneous mutant with an oleic acid content of >80%(Norden *et al.*, 1987), and the first high oleic variety, Sun Oleic 95R with 82% oleic acid content was registered in 1997 (Gorbet and Knauft, 1997).

d) Vitamin content

Vitamin A deficiency is a primary food related health problem among population of developing countries. Biofortification serves as potential source to alleviate VAD. The golden rice has sufficient beta carotene to meet the total vitamin A requirements in developing countries with rice based diets. Apart from rice, transgenic peanuts are developed to enhance beta carotene content, owing to their oil content. Transgenic peanut developed with single or dual genes of plant origin show up to 20 fold increase in beta- carotene levels.

e) Mineral xontent

Iron deficiency is the most prevalent micronutrient disorder worldwide. Iron deficiency limits oxygen 11 delivery to cells, leading to fatigue, poor work performance, decreased immunity, and death. CIAT and NARES lead the development of iron beans, which are currently being grown and tested by partners in 17 countries in Africa and Latin America. More than 15 different iron bean varieties (bush and climbing beans) have been released and/or are being disseminated in Bolivia, Brazil, Colombia, DRC, El Salvador, Guatemala, Nicaragua, Rwanda, and Uganda. Released varieties have 50–90% of the target level of iron, 94 ppm. Iron retention in beans is close to 100% when beans are not presoaked and no cooking water is discarded, as in Rwanda.

The absorption of iron, however, is constrained by the presence of phytate (a fiber associated compound and iron absorption inhibitor), as seen in a study among iron-deficient, nonpregnant women by Petry *et al.*, (2012). Despite the inhibiting effect of phytate, biofortified beans have been demonstrated as efficacious in two different populations. Mexican primary school children were observed to have improved transferrin receptor levels after consuming biofortified black beans for 3.5 months. In Rwanda, iron-depleted university women showed a significant increase in hemoglobin and total body iron after consuming biofortified beans for 4.5 months (Haas, 2014).

ICGV 03137, a Virginia bunch variety with high blanchability (Janila *et al.*, 2012) and ICGV 06099 and ICGV 06040 with high kernel Fe and Zn (Janila *et al.*, 2014) were reported in groundnut.

f) Reduced anti nutritional factors

The nutritional value of legume crops is reduced due to the presence of anti-nutritional factors. High concentrations of phytic acid in foods can limit mineral micronutrient bioavailability, especially for human populations that are mainly dependent on cereal and legume diets. Soybean mutants with 10low phytic acid content (reduced by about 80%) were identified by Wilcox *et al.*,1999. Low phytic acid (2.5 to 4.4 g kg-1) concentrations in lentils were noted by Thavarajah *et al.*, at levels lower than reported for low phytic acid mutants of corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), common bean, and soybean (*Glycine max* (L.) Merr.). In a study of different legume crops including mungbean, black gram, soybean, pigeon pea (*Cajanus cajan* (L.) Millsp.), and chickpea (*Cicer arietinum* L.), the highest and lowest values for phytic acid content as a percentage of the total phosphorus content was recorded for soybean (85%) and mungbean (72%), respectively (Nair *et al.*, 2013) (Table 1).

Grasspea, popularly known as Khesari in India, has unique properties of drought and flood tolerance. The major research interest was to develop varieties with near-zero content of neurotoxin â-oxalyl amino alanine (BOAA)/ODAP in its foliage and grain which has been implicated to cause human lathyrism. The beginning was made with germplasm screening for BOAA content and other economic and agronomic traits, including yield. Mutation induction and hybridization were used to increase genetic diversity. The first low-BOAA (0.2%) variety, Pusa 24, was developed for commercial cultivation in 1974. It was followed by three more similar varieties of the LSD series i.e., LSD 1, LSD 3 and LSD 6 with low neurotoxin content ranging from 0.15% to 0.20% in seeds. The most significant achievement of *Lathyrus* research in recent years was isolation and development of the variety Bio L 212 (Ratan) in 1997 through exploitation of somaclonal variation, which has the lowest BOAA content (less than 0.02%) recorded so far in any cultivar (patil., 2010).

Table 1: Principal constituents of grain legume seeds: range of variation (% of seed weight)

Species	Protein	Oil	Starch	Fiber	Sucrose	Reference
Soybean	35.1 - 42	17.7-21	1.5	20	6.2	Hedley, 2001
	34.7-55.2	6.5-28.7	-	-	-	NGRP, 2001, USDA germplasm collection
	40-45	19-21.5	-	-	-	Hyten *et al*., 2004,
	15.2	-				RIL population
	41.8-49.4	20.7	-	-	-	Chung *et al*., 2003,

	13.4	-				RIL population
	40.4-50.6	21.2	-	-	-	Brummer *et al*., 1997, parents of RIL populations
	31.7-57.4	-	-	-	-	Jun *et al*., 2008, Association mapping population
	26.5-47.6	-	-	-	-	Vollman *et al*., 2000, 60 lines, 6 environments
Groundnut	25.8	49.2	-	8.5	-	Anonymous
	-	44-50	-	-	-	Lord and Wakelam 1950
	20.7-28.1	-	-	-	-	Dwivedi *et al*., 1990,
	16 - 34	-	-	-	-	64 accessions Jambunathan *et al*., 1985 ICRISAT collection
Common bean	20.9 - 27.8	0.9 – 2.4	41.5	10	5	Hedley, 2001
	23-29.2	-	-	-	-	Coelho *et al*., 2009, 20 accessions
Pea	18.3 - 31	0.6 – 5.5	45	12	2.1	Hedley, 2001
	24-32.4	-	45.5-54.2	8.9-11.9	-	Gabriel *et al*., 2008, dehulled seeds, 8 varieties
	21.9-34.4	1.4-4.7	18.6-54.5	5,9 -12,7a	1.3-11.11	Bastianelli *et al*., 1998, 213 or 54 (1) accessions
	20.6-27.3	-	-	-	-	Burstin *et al*., 2007, RIL population
	15.8-32.1	-	-	-	-	Blixt 1978, 2200 accessions
Fababean	26.1 - 38	1.1 – 2.5	37-45.6	7.5-13.1a	0.4 -2.3z	Duc et al., 1999 , 37 or
	22.4 - 36	1.2 – 4	41	12	3.3	12 (z) spring varieties
	29.4-32	1.3-2	41.2-44.3	8.7-9.9	-	Hedley, 2001 Duc *et al*., 2010, 8 varieties
	26-29.3	-	42.2-51.5	-	-	Avola *et al*., 2009, 15 accessions
Lentil	23 - 32	0.8 – 2	46	12	2.9	Hedley, 2001
	25.1-29.2	-	46-49.7	13.1-14.7	2.1-3.2	Wang *et al*., 2009,
	18.6-30.2	-	-	-	-	8 varieties Hamdi *et al*., 1991, 987 germplasm accessions
Chickpea	15.5-28.2	3.1 – 7	44.4	9	2	Hedley, 2001
	18.7-21.1	-	42-45.1	-	-	Frimpong *et al*., 2009, 7 Desi chickpea varieties
	17.1-19.8	-	48-54.9	-	-	Frimpong *et al*., 2009, 9 Kabuli chickpea varieties
	-	-	-	2.7-11.7	-	Cho *et al*., 2002, RIL population
	12.4-31.5	-	-	-	-	Hulse 1975
Cowpea	23.5	1.3	-	-	-	Hedley, 2001
	24.8	1.9	-	6.3	-	Kabas *et al*., 2006, mean of 8 varieties
	20.9-36	2.6-4.2	-	-	-	Oluwatosin 1997, 15 accessions
	16-31	2.4-4.3	-	-	-	Adekola and Oluleye 2007, 15 mutants
	23.1-27.3	-	-	-	-	Bliss *et al*., 1973, 11 varieties

Mungbean	22.9-23.6 21-31.3	1.2 1.2-1.6	45 -	7 8.9-12.9	1.1 -	Hedley, 2001 Anwar et al., 2007, dehulled seed, 4 varieties
Pigeonpea	19.5-22.9 15.9-24.1	1.3 – 3.8 -	44.3 -	10 -	2.5 -	Hedley, 2001 Upadhyaya *et al*., 2007, 310 accessions

Conclusion

Legumes provide exceptionally varied nutrient profile including proteins, fibres, vitamins and minerals. Higher yield was always prioritized by the breeders from times immemorial but the increased health consciousness of the consumers has paved the way for the extensive research on the legume nutrient enhancement. Up to date there has been considerable literature on the staple crop nutrition enhancement in comparison to legumes. This paper is a modest contribution to the ongoing discussion about enhancing nutritional quality of legumes with possible breeding methods. As highlighted in the present paper legumes have high potential for nutritional quality ,improvement of food being important sources of protein, starch, fibre and other health promoting components. Burgeoning population and increased malnutrition has forced breeders to shift their concern from yield to quality. A close interaction between nutritionist and breeders will enhance the rate of progress in breeding nutritional quality.

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30 Bioinformatics in Nutrition and Food Security

Arun K. Shanker

Introduction

Bioinformatics has been established as an important scientific discipline, bringing about a paradigm shift in various disciplines including molecular medicine, comparative genomics, molecular evolution, microbial genome applications, drug discovery and biotechnology. However, its applicability in the food science arena is less appreciated, despite the recognized potential for a significant contribution to this field (Desiere *et al*., 2001). Nutrition Informatics is the effective retrieval, organization, storage and optimum use of information, data and knowledge for food and nutrition related problem solving and decision-making. Informatics is supported by the use of information standards, processes and technology. Like other life sciences, nutrition science can benefit enormously from the techniques of bioinformatics. In this article, the steps necessary to enable bioinformatic approaches in nutrition research are outlined, from the short-range goal of immediately making data available in ad hoc author-defined formats to the longer range goals of full standardization of nutrition experiments and migration of all experimental data into databases. The greatest advances in life sciences during the past 20 years have arguably been made possible largely by the technologies of computing that are now brought to practice in scientific fields, from analytic chemistry to mathematical simulations. Nutrition, being a highly integrative science that draws from many disciplines, likewise has the potential to benefit enormously from the application of these computational techniques. An obvious prerequisite for the application of bioinformatic techniques in nutrition is the accessibility of bioinformatics discipline to integrate the different stages, nutrition data in machine-readable formats (Lemay, 2007). Nutri-informatics as a specialized aims,

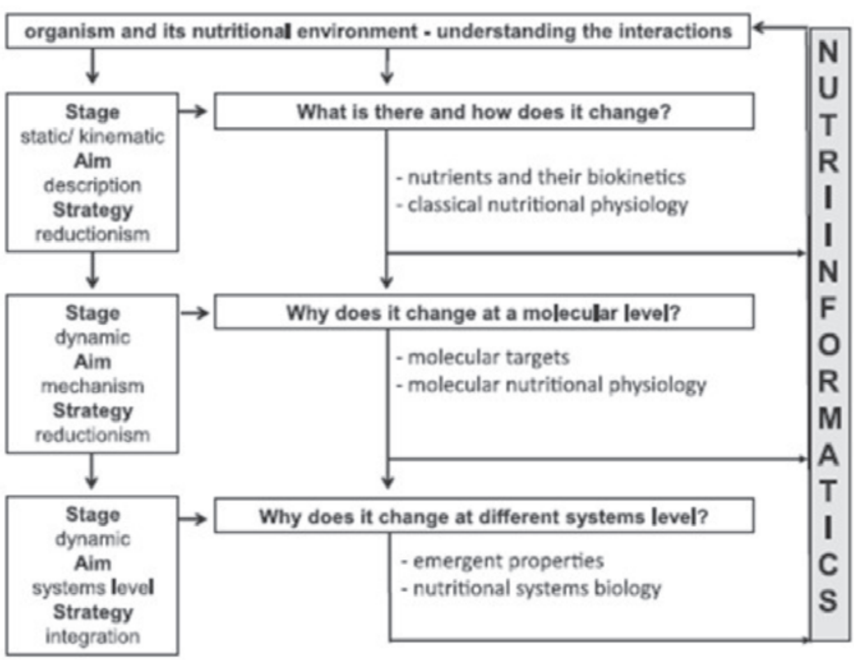

Fig.1. Nutri-informatics as a specialized bioinformatics discipline to integrate the different stages, aims, strategies and questions of basic nutritional science

strategies and questions of basic nutritional science is shown in Fig 1 adopted from Doring and Rimbach (2014).

Food plays a vital role in maintaining wellbeing by regulating metabolic, hormonal, physical and mental processes. Moreover, there is an ever-increasing appreciation of the role played by nutrition in the progression of various chronic diseases. Great efforts are now being focused to promote and augment the quality and nutritive potential of various food sources. Applications of Bioinformatics in the Food Industry are mainly found in proteins, microorganisms, flavours, probiotics and prebiotics, genetics disease control, enzymes, carbohydrates/sugars, DNA Breeding programmes, allergens, transgenics, and nutrition. The initiatives/ technologies requiring bioinformatics can be in microorganisms (bacteria, yeasts), identification; natural pops; traceability; food poisoning, spoilage, hygiene or processing; probiotics. In the case of Omics - genomics/ proteomics/nutriomics it is Gene regulation; disease prediction; protein interactions, functionality; enzymes; allergenicity; dietary affects; probiotics, prebiotics. The Initiatives/technologies requiring bioinformatics are in Protein analysis Interactions between proteins and other proteins, drugs or antibodies; functionality; protein structures, predictions of 3’ or 4’, modelling, prediction from sequences (DNA or amino acid), Profiling where in the use of DNA, protein or other metabolites to identify meat, fish, fruit, veg, cereals, microbes samples. The huge amounts of data that can be generated from these outlined projects will make bioinformatics an important area in the food industry.

Bioinformatics in Food Quality, Taste and Safety

Bioinformatics is also impacting on food science and nutrition in a more applied manner, playing a role in areas such as taste and flavour, food safety and food quality. In relation to taste, bioinformatics, in the context of molecular evolution, has been important in determining the evolutionary history of receptors for various tastes. GWAS studies have also been conducted with a focus on taste receptors, where a link has been established between bitter taste receptors and glucose regulation. Applied in a more functional framework, structural bioinformatics and docking strategies have been used to discern the mechanisms behind agonist binding to taste receptors, while recently electronic databases detailing the chemical properties pertaining to the taste and flavour of various compounds have been established. Additionally, bioinformatic sequence similarity algorithms have been used in relation to taste to determine homology between sweet taste receptors and brain glutamate receptors), as well as in the identification of sour taste sensors in mammals. Finally, through the study of the genetic sequences of lactic acid bacteria, which play a role in flavouring of various fermented foods, specific flavour forming potentials are being uncovered (Holton *et al*., 2013).

As many foodborne pathogens have been the focus of genomic sequencing projects, there is a growing appreciation for the potential of bioinformatics in the area of food safety and quality. For example, the Food and Drug Administration (FDA) have recently developed a bioinformatics based tool for detecting and identifying bacterial food pathogens. Further to this, the onset of next generation sequencing technologies has provided for a novel way to bioinformatically determine the source of outbreaks of foodborne illness. Other computational applications in this area have included the use of neural networks with the aim of predicting microbial growth within a given food source. With regard to food quality, great progress continues to be made in the area of computer vision which allows for the automated appraisal of various food properties (Holton *et al*., 2013).

Food Composition Databases

Although not explored extensively by the bioinformatics community to date, it would be remiss of us not to discuss the various, notable, food composition database (FCDB) efforts that are ongoing globally. Such databases are important tools for nutritional assessment by health professionals and are typically compiled on a national or regional basis. In the United States, the major food composition resource is the USDA National Nutrient Database for Standard Reference (NNDSR; http://www.ars.usda.gov/ba/bhnrc/ndl), which is a free, open access resource. The NNDSR is regularly updated and curated, and currently features data for more than 8000 foods making it one of the most comprehensive FCDBs. Accordingly, the NNDSR is utilised globally for nutritional assessment. In Europe, EuroFIR (http://www.eurofir.org/) provides standardised FCDBs for food and nutritional scientists. Moreover, EuroFIR lists software developers among its target users, demonstrating the progression towards computational based research in this area. Although run by a non-profit organisation, this resource does require a membership subscription to gain access to data. Finally, the FAO/INFOODS Analytical Food Composition Database (http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/) provides food composition data for foods that are commonly consumed globally. While not specifically driven by bioinformaticians, FCDBs do subscribe to one of the central tenants of integrative bioinformatics in that there is a major concerted effort to standardise and assimilate data appropriately. Drivers of such initiatives include collaborative networks like INFOODS and EuroFIR (http://www.eurofir.org/), while important historical initiatives include Eurofoods and the European Food Consumption Survey Method. The commendable work in this area serves as an important reference for food and nutritional sciences. Extension of these practices beyond food composition data could serve to greatly advance bioinformatic research in these domains (Holton *et al*., 2013).

Web Based Nutrition Management

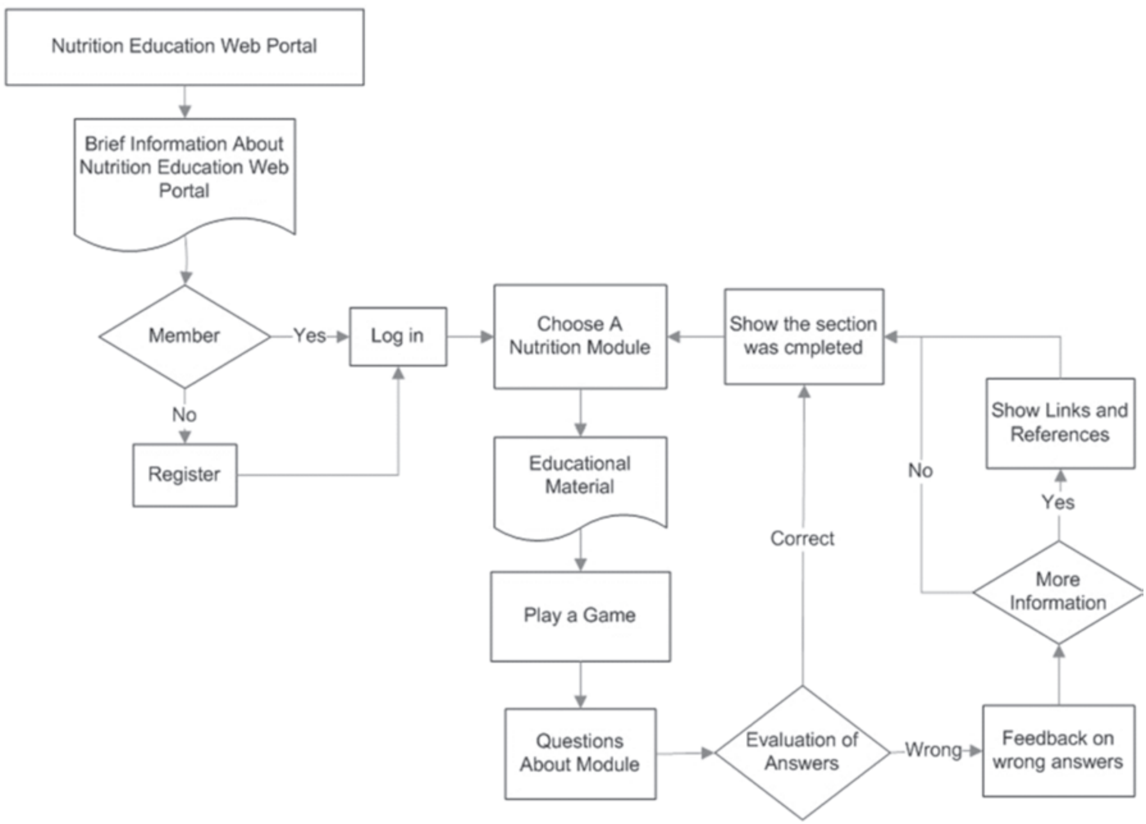

Fig. 2. Model of a Nutrition Web Portal adopted from Bozkurt *et al*., (2008)

Nutrition and weight management is a popular issue among web based health education and management studies. Likewise, this study focused on nutrition education and personal nutrition management because, obesity has become a heavy burden for populations worldwide. The World Health Organization estimates that around one billion people throughout the world are overweight and that over 300 million of these are obese and if current trends continue, the number of overweight persons will increase to 1.5 billion by 2015 (Must *el al*., 1999). Fig 2 shows a model of a nutritional web portal. The portal consists of two major sections; nutrition education and personal nutrition management tool. Its personalization was provided by membership. One, who wants to se the portal must registries by filling the user registration form and determines not only his or her user name and password but also his/her nutrition habits and physical characteristics. The goal of the Nutrition education is to provide basic nutritional knowledge to adults. Target population for educational modules of the Nutrition Portal is adults who have basic internet skills. The objectives of the educational program defined by nutrition expert are:

- Individuals understand basic concepts about nutrition,
- Define overweight and obesity and their bad effects on human life,
- Learns the ways to prevent from obesity,
- Be able to record, monitor and conclude nutrition measurements of themselves such as BMI, calorie intake,
- Learn how to plan healthy menus,
- Learn to ways to control their weight.

Nutrition education program was designed as modules on several topics. In each module, in order to motivate user and interact with the content, several learning activities, quizzes, games etc. planned. On the web site, there is also a feedback section which users can write their opinions about the education. These feedback forms will be used when evaluating the web site.

Bioinformatics and Food Processing

The most immediate application of bioinformatics to food processing will be in optimizing the quantitative compositional parameters of traditional unit operations. Food commodities are processed largely to achieve storage stability and safety with considerable excess of energy applied to ensure a large margin for error. This margin of error is necessary due to our inexact knowledge of the composition and structural complexity of biological materials, the natural variability of living organisms as food process input streams and the response of these materials to processing parameters. With the considerable knowledge of biological organisms from bacteria and viruses to plants and animals that is emerging from bioinformatics, food process design will become optimized with narrower margins of all cost-important inputs, especially energy. The great future for food processing however is not in simply processing for greater safety, but in merging biological knowledge of living organisms with the biomaterial knowledge necessary to convert them to foods. Traditional food processing relies on the aggressive input of energy to restructure the biomaterials of living organisms into simpler macrostructure forms of stable, relatively uniform foods. In most cases the inherent biological properties of the living systems are lost to the final food product in the need to eliminate potentially hazardous properties of some of the constituent molecules (protease inhibitors, etc.). The arrival of the knowledge base of modern bioinformatics, however, is providing a detailed description of the inherent complexity of biological macromolecules within living cells together with the structural properties of these molecules that provide much of their functions. Such knowledge is the cornerstone of functional genomics and proteomics. The arrival of such knowledge, however, provides an unprecedented opportunity to translate this knowledge into an equally accurate assessment of the biomaterial properties of each of the molecules in a complex mixture. It will soon be possible to use the inherent structural properties of natural food commodities to self-assemble new foods with a minimum of external energy retaining a maximum of biological and nutritional value (Desiere *et al*., 2001).

Conclusion

Nutri-informatics, as an emerging field, may bridge the gap between nutritional biochemistry, nutritional physiology and metabolism. We emphasize that Nutri-informatics should be developed into a basic scientific discipline to understand the interactions between an organism and its nutritional environment, one of the most noble objectives of nutritional science. In addition, Nutriinformatics has a heuristic potential to foster rather applied disciplines. However, the scientific success of Nutriinformatics depends primarily on the formulation of unsolved fundamental and interesting questions, an inherent problem in nutrition science. Nutrigenomics investigators seek to understand the organization and function of cellular components and characterize the various molecular phenotypes associated with health and disease. These studies are facilitated by omics technologies, which have created unprecedented opportunities. With the cost of sequencing decreasing steadily, the costs of data storage and analysis may prove to be the true bottlenecks in moving the field forward. A greater understanding of the genome at the level of individual variations could eventually lead to the development of the much anticipated paradigm of personalized nutrition and medicine.

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31 Role of Biochemical Constituents and their Influence on Insect Pests at *e*CO_2 and *e*temp Conditions

M Srinivasa Rao and O Shaila

Introduction

Global Mean Surface Temperature (GMST) and Global atmospheric CO_2 concentrations have been increasing at a significant rate since last 19th century. It is well known that 0.78°C increase in temperature was noted between average of the 1850-1990 period and the 2003-2012 period. The increase in the amount of CO_2 in the atmosphere will be by about 40% when compared with pre-industrial levels (IPCC, 2013). Increase in temperature and elevated CO_2 (*e*CO_2) influence crop growth significantly and in turn affect the insect herbivores both directly and indirectly. Though it is known that the increase in temperature will have a greater effect on insects than the rising CO_2 concentration (Harrington *et al.*, 2001), the interactive and combinational effect of both parameters is more evident. The fourth assessment report of IPCC observed that 'warming of climate system is now unequivocal and climate change is global in its occurrence and consequences, it is the developing countries like India that face more adverse consequences. Our agriculture sector is highly sensitive to climate change. These changes affect the growth and development of the crop plants. Environmental change is anticipated to negatively, affecting both plant and insect populations.

Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4°C with no substantial change in precipitation quantity. However, different regions are expected to experience differential change in the amount of rainfall that is likely to be received in the coming decades. It is projected that some parts of country will receive higher amount of rainfall. Another significant aspect of climate change is the increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones. All these expected changes will have adverse impacts on climate sensitive sectors such as agriculture.

Last three decades saw a sharp rise in all India mean annual temperature**.** Though most dry land crops tolerate high temperatures, rain fed crops grown during rabi are vulnerable to changes in minimum temperatures. Analysis of data for the period 1901-2005 by IMD suggests that annual mean temperature for the country as a whole has risen to 0.51°C over the period. It may be mentioned that annual mean temperature has been consistently above normal (base on period, 1961-1990) since 1993. This warming is primarily due to rise in maximum temperature across the country, over a larger part of the data set. The extent to which rainfall and temperature patterns and the intensity of extreme weather events will be altered by climate change remains uncertain, although there is a growing evidence that future climate change is likely to increase the temporal and spatial variability of temperature and precipitation in many regions. Rising carbon dioxide will increase the carbon-to-nitrogen balance in plants, which in turn will affect insect feeding, concentrations of defensive chemicals in plants, compensation responses by plants to insect herb ivory, and competition between pest species.

Insects are cold-blooded organisms the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing their behavior, distribution, development, survival, and reproduction. Generally the impacts of CO_2 on insects are thought to be indirect through the changes in the host crop i.e., the host mediated one. The information on influence of three major factors of climate change i.e., temperature, carbon dioxide and precipitation on insects is discussed under the following heads. Under *e*CO_2 conditions the variation of biochemical constituents *viz.*, reduction of nitrogen, increased carbon and C: N ratio was reported (Hoover and Newman, 2004) which can be the major causative factor in influencing the aphids

Variation of Biochemical Constituents at *e*CO_2

It is clear that nutrition can affect insect performance, Insects will try to compensate by increasing consumption when feeding from poor quality plants, which suggest the importance of nutrient content within the plant. In general, elevated CO_2 has been found to change the plant quality (Schadler *et al*., 2007) affecting the insect performance. Reduced N concentration (Taub and Wang, 2008) and increased content of carbon-based secondary metabolites such as phenolics or alkaloids (Bidart-Bouzat and Imeh-Nathaniel, 2008) can negatively affect the performance of herbivores, thereby affecting their feeding behavior, growth and development. Chemical composition of some plant species changes due to biotic and abiotic stresses. As a result, their tissues became less suitable for growth and survival of insect pests (Sharma, 2002). Insect-host plant interactions will change in response to the effects of CO_2 on nutritional quality and secondary metabolites of the host plants. Increased levels of CO_2 will enhance plant growth, but may also increase the damage caused by some phytophagous insects (Gregory *et al*., 2009). It was observed that in the enriched CO_2 condition the insect confront less nutritious host plants that may extend their larval developmental times. Increased CO_2 may also cause a slight decrease in nitrogen-based defenses (e.g., alkaloids) and a slight increase in carbon-based defenses (e.g. tannins). Succinctly, the information on CO_2 impacts indicated that the performance of the same insect varied from host to host-indicating host species specificity. The analyzed data on impact of elevated CO_2 on insect pests reported a general decrease in foliar nitrogen concentrations and increase in carbohydrate and phenolic (secondary) metabolites. The consumption by herbivores was related primarily to changes in nitrogen and carbohydrate levels. General increases in aboveground biomass, yield and carbon: nitrogen (C:N) ratios, particularly of C3 Plants (Rice, Wheat, Soyabean, Cotton, Groundnut etc) have been reported. Also, more CO2 enhances photosynthetic rate, plant growth and water use efficiency.

Brodbeck *et al*., (2004) reported that the total amino acid content in the xylem strongly correlated with the survival and development rates of xylem/phloem-feeding insects *viz.*, leaf hoppers. Chen *et al.*, (2004) indicated that spring wheat grown at elevated CO_2 generally had more sucrose, glucose, total non-structural carbohydrates, free amino acids and soluble protein and lesser fructose and nitrogen. Insects have mechanisms to cope with digesting protein-rich plant reproductive structures, carbohydrate rich leaves and even diverse unbalanced diets. As variation in biochemical composition in different plants parts *viz*., leaf and seed will also lead to the changes in nutritional quality of different crops. There were no effects of elevated CO_2 on nutrient composition and mineral nutrient in peanut kernels (Wu *et al*., 1997). The documented information by different authors reported that the elevated CO_2 increased accumulation of carbohydrates in soybean (Allen and Boote, 2000), dry bean (Sharkey *et al.*, 1985), and cowpea (Ahmed *et al*., 1993). Significant increase in starch, sucrose, reducing sugars content and concentration chlorophyll and soluble protein in soybean was observed by Vu *et al.*, 2001. Thomas *et al.*, 2003 studied effects of elevated CO_2 on composition of mature soybean seed at different temperature regimes and concluded that there was no effect of elevated on N, P, starch, total oil, fatty acids, and total nonstructural carbohydrates. Wu *et al*., (2007) reported that CO_2 level significantly influenced foliar total amino acids in cotton plants and foliar protein content significantly decreased under elevated CO_2 compared with ambient CO_2. These studies proved that elevated atmospheric CO_2 can alter plant growth and chemistry. The amount of protein content in different tissues of insects mainly depends on the metabolic activities. Few authors stated there will be no impact to animal and human health.

Variation of Biochemical Constituents at *e*Temp

Plants are exposed to a wide range of environmental conditions and one of the major forces that shape the structure and function of plants are temperature stresses, high temperatures cause an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth and development and may lead to a drastic reduction in economic yield. The staple cereal crops can tolerate only narrow temperature ranges, which if exceeded during the flowering phase can damage fertilization and seed production, resulting in reduced yield (Porter, 2005). Furthermore, high temperatures during grain filling can modify flour and bread quality and other physico-chemical properties of grain crops such as wheat, including changes in protein content of the flour (Wardlaw *et al*., 2002). Thus, for crop production under high temperatures, it is important to know the developmental stages and plant processes that are most sensitive to heat stress, as well as whether high day or high night temperatures are more injurious. Such insights are important in determining heat-tolerance potential of crop plants. It was reported that oil concentration increased with increasing temperature with an optimum at 25 to 28°C, above which the oil concentration declined.

Impact of *e*CO_2 on Insects

The impacts of CO_2 on insects are considered to be indirect i.e., impact on insect damage results from changes in the host crop. Some researchers found that rising CO_2 can potentially have important effects on insect pest problems. Recently, free air gas concentration enrichment (FACE) and Open top chamber (OTC) technologies were used to create an atmosphere with CO_2 concentrations similar to what climate change models predict for the middle of the 21^{st} century. The atmospheric CO_2 concentrations have increased by above 20% and elevated CO_2 effects the plant growth and range of physical and chemical characteristics of the plant/crop. These include reduction in the leaf nitrogen content, changes in the defense compounds, water content, carbohydrates and leaf thickness. Indications are that exposure to elevated CO_2 levels will increase the plant photosynthesis, growth, above ground biomass, leaf area, yield, carbon and C: N ratio. These changes can influence the food quality for herbivorous insects and was well reviewed. These changes in the leaf quality are likely to have varied effect on the performance of insect herbivores.

Impact of *e*Temp on Insects

Climate change resulting in increased temperature could impact crop pest insect populations in several complex ways. Although some climate change temperature effects might tend to depress insect populations, most researchers seem to agree that warmer temperatures in temperate climates will result in more types and higher populations of insects. Increased temperatures can potentially affect insect survival, development, geographic range, and population size. Temperature can impact insect physiology and development directly or indirectly through the physiology or existence of hosts. Increased temperatures will accelerate the development of several types of insects (cabbage maggot, onion maggot, European corn borer, Colorado potato beetle) and possibly resulting in more generations (and crop damage) per year. In addition to the above observations, additional information on prediction of pest incidence and pest shifts were reviewed (Srinivasa Rao *et al*., 2013.)

Insects that spend important parts of their life histories in the soil may be gradually affected by temperature changes as compared to those that are above ground simply because soil provides an insulating medium that will tend to buffer temperature changes more than the air. Insect species diversity per area tends to decrease with higher latitude and altitude, meaning that rising temperatures could result in more insect species attacking more hosts in temperate climates. It is to conclude that the diversity of insect species and the intensity of their feeding have increased historically with increasing temperature.

Findings of CRIDA

Several experiments were conducted using open top chamber (OTC) facility to study the impact of elevated CO_2 levels on insects. Three square type open top chambers (OTC) of 4x4x4 m dimensions, were constructed at CRIDA, Hyderabad, two for maintaining elevated CO_2 concentrations of 700±25 ppm CO_2 and 550±25 ppm CO_2 and one for ambient CO_2. An automatic CO_2 enrichment technology was developed by adapting software SCADA to accurately maintain the desired levels of CO_2 inside the OTCs. The concentration of CO_2 in the chambers was monitored by a non-dispersive infrared (NDIR) gas analyzer. Castor, groundnut plants were grown in the three OTCs and also in the open, outside the OTCs.

- Larval duration or time from hatching to pupation in larvae of both the species (*Achaea janata*, *Spodoptera litura* and *Helicoverpa armigera*) was significantly influenced by the CO_2 condition under which castor leaves offered to them. Larval duration of these species was extended by about two days when fed with elevated CO_2 foliage (Srinivasa Rao *et al*., 2009). Larvae ingested significantly higher quantity of elevated CO_2 foliage compared to ambient CO_2 foliage. For instance, *A. janata* consumed 62.6% more of elevated CO_2 foliage than ambient CO_2 foliage. The rate of consumption (RCR) was also higher in case of elevated CO_2 foliage. Thus, larvae fed with elevated CO_2 foliage consumed more each day and over a longer period, resulting in considerably increased ingestion.
- The efficiency of conversion of digested food into body mass (ECD) was lower with elevated CO_2 castor foliage for both species of larvae. The digestibility (AD) of elevated CO_2 foliage was significantly higher

than ambient CO_2 foliage for both the species, more so in case of *S. litura* (Srinivasa Rao *et al.*, 2009).

- Significant influence of elevated CO_2 on life history parameters of *S.litura* on groundnut was noticed and the percent variation of these parameters was significant (20-40%) under elevated CO_2 over ambient CO_2.
- The percent reduction of nitrogen content and increased percent of carbon, C:N ratio and TAE (Tannic acid equivalents) was significant in groundnut and castor foliage under elevated CO_2 in (Srinivasa Rao *et al*., 2008).

Conclusion

The major predicted results of climate change i.e., increase in temperature and atmospheric CO_2 can impact on growth and development of herbivore insects either directly or indirectly. Significantly lower leaf nitrogen, higher carbon , higher relative proportion of carbon to nitrogen (C: N) and higher polyphenols content expressed in terms of tannic acid equivalents were observed in foliage grown under elevated CO_2 levels. Similar alteration of biochemical constituents was reported at elevated temperature leading to variations in insect survival and development. Increased consumption, reduced growth rates, extension of larval durations were documented under elevated CO_2 conditions. With this background, the various feeding trials were conducted using foliage of castor, groundnut grown under elevated CO_2 (550 ppm and 700 ppm) concentrations in open top chambers (OTCs) at CRIDA, on different lepidopteran and homopteran insect pests. Significant influence of elevated CO_2 on life history parameters and insect performance indices of lepidopteran insect pests over four generations was noticed. Altered biochemical composition of crop plants under climate change scenario certainly effect incidence of insect pests.

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32 Biochar and Its Usefulness in Improving the Nutritional Quality of Food Crops

G Venkatesh, K A Gopinath, V Visha Kumari and Ch Srinivasa Rao

Introduction

"Biochar" is a recently coined term used to denote a carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated with little or no available air, have become increasingly the subject of scientific and public interest. The term biochar only applies to the material used as a soil amendment and is distinguished from charcoal used for fuel or as a reductant (Lehmann and Joseph, 2009). Several organic sources including biochar have shown potential to provide satisfactory amounts of nutrients to plants and its role in improving the nutritional quality of food grains (Lehmann *et al.*, 2003). As a rule, this practice is both more profitable and sustainable compared to the application of mineral fertilizers alone. It is claimed that biochar can improve soil properties, agronomic performance and nutritional quality of food crops, inspired by investigations of *Terra Preta* in Amazonia (Glaser and Birk, 2012).

Need for Recycling of Unutilized Crop Residues into Biochar for Efficient Utilization (adapted from Venkatesh *et al.*, 2015)

- To improve soil health through efficient use of crop residue as a source of soil amendment/nutrients
- To improve soil physical properties viz., bulk density, porosity, water holding capacity, drainage etc, through incorporation of biochar
- Substantial amounts of carbon can be sequestered in soils in a very stable form
- Addition of biochar to soil enhances nutrient use efficiency and microbial activity
- To enhance soil and water conservation by using the biochar in rainfed areas
- Minimize reliance on external amendments for ensuring sustainable soil and tree productivity
- Mitigation of greenhouse gas emissions by avoiding direct crop residue burning by farmers
- To enable destruction of all crop residue borne pathogens

What is Biochar?

Biochar is the carbon-rich solid product, produced by direct thermo-chemical decomposition (exothermic) of low-density residue matrix under low-oxic or anoxic conditions, and at relatively low temperatures (ranging usually from 45 - 55^{o}C) through a process called slow pyrolysis (Lehmann *et al*., 2006, Roberts *et al*., 2010). Biochar so obtained is porous, high in carbon-density, fine-grained solid material rich in paramagnetic centers having both organic and inorganic nature, possessing oxygen functional groups and aromatic surfaces. Biochar is not a pure carbon, but rather mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions (Masek, 2009). The central quality of biochar and char that makes it attractive as a soil amendment is its highly porous structure and high surface area, potentially responsible to increase the rate of soil carbon sequestration, for improved water retention, soil fertility and crop yield (Venkatesh *et al.*, 2015) .The beneficial effects of biochar on soil properties have been reported by many and includes chemical (Yamato *et al.*, 2006), physical and biological changes in soil (Rondon *et al.*, 2007, Venkatesh *et al.*, 2013). Biochar appears to be one promising source of renewable and stable carbon to increase the rate of carbon sequestration in soil.

Biochar Production - a novel Strategy for Efficient Recycling of Crop Residues

Biochar can be produced from a number of methods. For as long as human history has been recorded, heating or carbonizing wood for the purpose of manufacturing biochar has been practiced (Emrich, 1985). There are different ways to make biochar, but all of them involve heating biomass with little or no oxygen to drive off volatile gasses, leaving carbon behind. This simple process is called thermal decomposition usually achieved from pyrolysis or gasification. Pyrolysis is the temperature driven chemical decomposition of biomass without combustion (Demirbas, 2004).

The ancient method for producing biochar was the “pit” or “trench” method (Odesola *et al.,* 2010). The common processes include slow and fast pyrolysis, and the most successful approach for high-yield biochar production is via slow pyrolysis. Under slow pyrolysis, a biochar yield between 25 - 35 per cent can be produced (Hussein *et al*., 2015); fast pyrolysis processes aim at production of bio-oil and the amount of biochar formed is nearly 12 per cent of the total biomass (Cheng *et al.*, 2012). The cook stove, earth mound kilns and drum kilns are the traditionally used for biochar production in India (Srinivasa Rao *et al.*, 2013). Number of biochar kiln has been designed, developed and used for making biochar from the crop residue (Reddy, 2012, Gangil and Wakudkar 2013, Venkatesh *et al.*, 2013) in India.

Biochar can be produced at scales ranging from large industrial facilities down to the individual farm and even at the domestic level through a distributed network of small facilities that are located close to the crop residue source. Small facilities to produce biochar are less complicated than larger units. Biochar production protocols are yet to be standardized in India. To make biochar technology popular among the stakeholders, it is imperative to develop low cost biochar kiln at community level or at individual stakeholder’s level.

Biochar Production Processes

In commercial biochar pyrolysis systems, the process occurs in three steps: first, moisture and some volatiles are lost; second, unreacted residues are converted to volatiles, gasses and bio-char, and third, there is a slow chemical rearrangement of the bio-char. A summary of biomass conversion processes is presented in Fig 1.

At the instant of burning, the biomass carbon exposed to fire has three possible fates. The first, and least possible fate of biomass exposed to fire is that it remains un-burnt. The other two possible fates are that it is either volatized to carbon dioxide or numerous other minor gas species, or it is pyrolised to bio-char (Graetz and Skjemstad 2003). These methods can produce clean energy in the form of gas or oil along with biochar. This energy may be recoverable for another use, or it may simply be burned and released as heat. It is one of the few technologies that are relatively inexpensive, widely applicable and quickly scalable.

To differentiate between the different pyrolysis reactors, nomenclature recommended by Emrich (1985) is given below.

Kiln: Kilns are used in traditional biochar making, solely to produce biochar.

*Retorts and converters***:** industrial reactors that are capable of recovering and refining not only the biochar but also products from volatile fractions (liquid condensates and syngases) are referred to as retorts or converters.

Retort: The term retort refers to a reactor that has the ability to pyrolyze pile-wood or wood log over 30 cm long and over 18 cm in diameter (Emrich 1985).

Converters: produce biochar by carbonizing small particles of biomass such as chipped or pelletized wood.

*Slow pyrolysis***:** refers to a process in which large biomass particles are heated slowly in the absence of oxygen to produce biochar.

*Fast pyrolysis***:** refers to reactors designed to maximise the yields of bio-oil and typically use powdery biomass as feedstock.

Pyrolysis conditions which favor high biochar yields are: (i) high lignin, ash and nitrogen contents in the biomass, (ii) low pyrolysis temperature ($<40^0$C), (iii) high process pressure, (iv) long vapor residence time, (v) extended vapor/solid contact, (vi) low heating rate, (vii) large biomass particle size, and (viii) optimized heat integration (Demirbas 2001, Brownsort 2009, Masek, 2009). Production of biochar can be categorized into batch, continuous and novel processes Table 1.

Brazil is by far the largest biochar producer in the world producing 9.9 million tons per year. Other important biochar producing countries are: Thailand (3.9 million tons per year), Ethiopia (3.2 million tons per year), Tanzania (2.5 million tons per year), India (1.7 million tons per year) and Democratic Republic of Congo (1.7 million tons per year).

Table 1. Biochar production process

Process type	Reactor type	Biochar yield
Batch process	Earth pits and mounds	>10%
	Brick, concrete and metal kilns	20-25%
	Retorts	30%
Continuous processes	Retort (Lambiotte)	30-35%
	Multiple hearth reactors	25-30%
	Screw type reactor (Pro-Natura)	25-30%
Novel processes	Flash carbonization	40-50%

Source: Masek (2009)

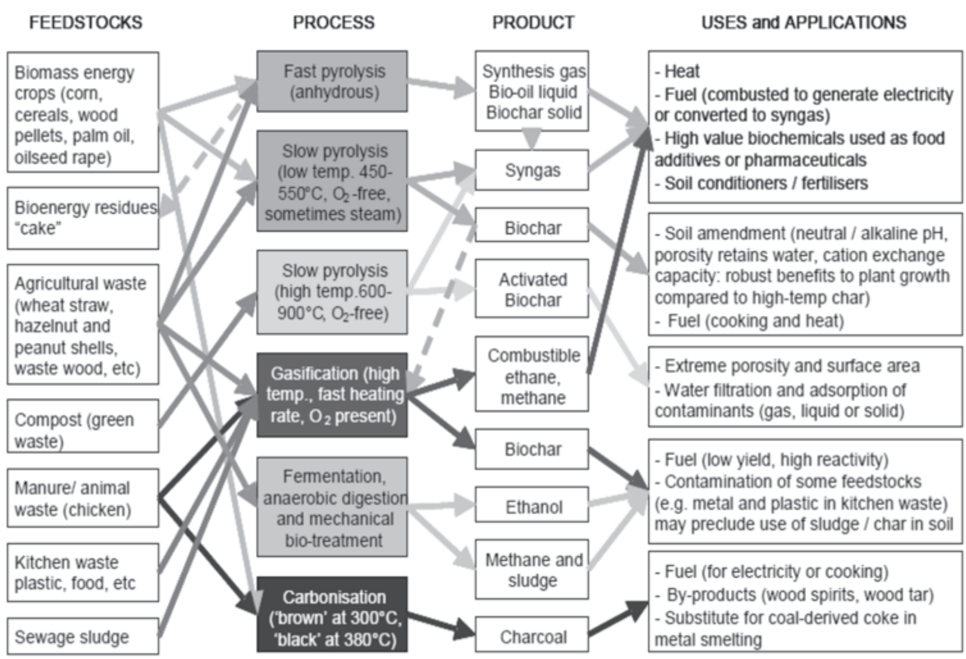

Fig. 1. Summary of pyrolysis processes in relation to their common feed stocks, typical products and the applications and uses of these products (Adapted from Venkatesh *et al.*, 2011)

A Brief Description of the ICAR-CRIDA Biochar Kiln

In designing the kiln, both the requirements of controlling the loading rate and rate of partial pyrolysis periods to stop the process when all of the crop residues have been converted to biochar have been addressed. Biochar kiln functions on direct up-draft principle with bottom ignition. The biochar kiln consists of a metal cylinder modified from a ready-made oil drum of about 0.21 m^3 capacity is based on a single barrel design of vertical structure with perforated base. At one end of the cylinder, a square shaped hole of 16 x 16 cm is formed for loading the crop residue, which can be closed at the end of conversion by a metal lid (about 26 cm in length and 26 cm in width) with a handle (110 cm). The other end of the cylinder is marked with alternating and staggered vents of 16, 16 and 8 numbers in first, second and third equidistant concentric circles from rim for uniform heat transfer through the crop residue by primary air movement (Fig 2.). This perforated portion of the cylinder has a central vent of about 2.5 cm radius to hold wooden pole or metal rod, to create a central vent. A strip of metal is welded with handles at around three-fourth height of kiln, to serve as lifting jack (Venkatesh *et al.,* 2013c, 2015)

Key Features of the CRIDA Biochar Kiln (adapted from Venkatesh *et al.,* 2015)

1. *Portability*: Easy mobility of the kiln to the source of crop residue and with access to most remote places helps to reduce collection, handling and transporting expenses
2. *Simplicity*: Farmer-friendly, easy-to-understand, convenient-to-use, minimize operational labour costs
3. *Adaptability*: Designed for non-competitive and surplus crop residue
4. *Affordability and Durability*: Least expensive kiln (approx. cost: Rs. 1200/-) to match the needs of the small and marginal tree cultivators and kiln can be operated for multiple batch process

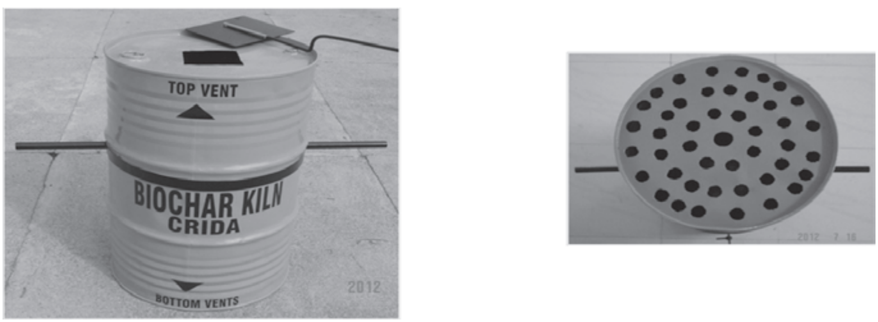

Fig. 2. Low cost portable biochar kiln (whole and bottom view) to produce biochar from crop residue
Source: Venkatesh *et al.,* 2013c

Biochar Application Method

Biochar is more susceptible to wind and water erosion. During transportation, measuring and soil incorporation of fine biochar, drifting losses can be significant; precautions must be taken to minimize the losses by mixing thoroughly the measured quantity of biochar with some amount of carrier like native soil. Incorporating biochar well into soil will minimize surface runoff with water after heavy rainfall events, and/or wind erosion (Venkatesh *et al.*, 2015). Biochar application methods have a substantial impact on soil processes and functioning. Biochar application methods must be based on extensive field testing. Various methods of biochar application in soil were mixing the biochar with fertilizer and seed, applying through no till systems, uniform soil mixing, deep banding with plow, top-dressed, hoeing into the ground, applying compost and char on raised beds, broadcast and incorporation, mixing biochar with liquid manures and slurries (Hussein *et al.*, 2015).

Biochar Application Rates

Availability and type of crop residue, nature of biochar, application rate, soil type, perennial crops to be applied, labour, time, climatic and topographic factors of the land, and the preference of the tree farmer may determine to employ one-time application of large quantity or frequent application of smaller quantity biochar. Biochar is not substitute for fertilizer. Adding biochar with necessary amount of inorganic nutrient can enhance the crop yield. Biochar is stable in nature compared to manures, compost and other soil amendments; therefore, biochar does not need to be applied with each crop. Beneficial effects of biochar can improve with time over several growing seasons in the field (Venkatesh *et al.,* 2015). Past studies have found that rates between 5 to 50 t per ha have often been used successfully (Lehmann and Rondon, 2006).

Cost of Biochar Production

Biochar production process should be economically viable and sustainable. The total cost of the CRIDA biochar kiln comes is Rs. 1200/- per unit (Venkatesh *et al.*, 2013c). An expenditure of Rs. 100/- per unit is required for maintenance during lean season. The cost of production of biochar per kg of crop biomass should be worked out on the basis of crop residue load per kiln and its conversion efficiency into biochar. All aspects from on-field crop residue preparation, handling and operation of the kiln, pounding, sieving and packing of biochar were to be considered for cost estimation. For example, on an average, the production cost of one kg of biochar from maize, castor, cotton and pigeonpea crop residue was 17.0, 14.0, 17.0 and 10.0, respectively. The cost estimates for biochar production is affected by several factors *viz*. availability of family labour, quantity of on-field availability of surplus unutilized crop biomass, demand for biochar and weather conditions to run biochar kiln (Venkatesh *et al.*, 2015).

Benefits of Biochar Incorporation in Soil

Transforming a low-value crop residue into a potentially high-value carbon source and its soil application has several important benefits (Venkatesh *et al.*, 2015) (Table 2).

Table 2. Benefits of Biochar incorporation in soil

Physical properties	Chemical properties	Biological properties
• Decreases bulk density, improves soil workability, reduces labour and tractor tillage and minimizing fuel emissions • High negative charge of biochar promotes soil aggregation and structure • Positive effect on crop productivity by retaining plant available soil moisture due to its high surface area and porosity	• Liming effect provides net carbon benefit compared to standard liming • Enhance the fertilizer use efficiency, reduce the need for more expensive fertilizers and improves the bioavailability of phosphorus and sulphur to crops • Reduce leaching of nutrients and prevents groundwater contamination • Carbon negative process, stable carbon, longer residence period and reduces Green House Gas emissions from soil	• Enhances the abundance, activity and diversity of beneficial soil bacteria, actinomycete and arbuscular mycorrhiza fungi • High surface area, porous structure and nutrient retentive capacity of biochar provides favourable microhabitats by protecting them from drought, competition and predation

Biochar and Nutritional Quality of Food Crops

There were very few studies have been done all over world on the effects of biochar on improvement of food crop nutritional quality. The availability of nutrients in biochars from various feedstocks and produced under different pyrolysis conditions is relatively unknown. In pot studies, Chan *et al.*, (2008) reported poultry litter biochar increased N, P, S, Na, Ca, and Mg concentrations of the radish plants (*Raphanus sativus* variety Long Scarlet) indicating these nutrients are plant available; however, only concentrations of P, K, and Ca increased in radishes with the addition of greenwaste biochar (Chan *et al.*, 2007). Wilujeng *et al.*, (2015) reported that application of 75% *Phaseolus lunatus* L. +25%B treatment produced the highest carbohydrate content (33.37%) in sweet potato. Those carbohydrate content values were higher than previous studies of 26.99% reported by Ginter *et al.*, (2011). Agegnehu *et al.*, 2015 reported significant improvement in N content in peanut seed when biochar was applied @ 10 t ha^{-1} and in co-composted biochar and compost mix.

Biochar for Ameliorating Soil Health and Grain Quality Improvement

Numerous studies have reported on the beneficial impacts of biochar addition on soil health and grain quality improvement and GHG emissions reduction which are of critical importance in tropical environments in combating climate change induced drought and to improve soil and crop health. Biochar additions have positive effects on the soil and crop health directly and indirectly. The incorporation of biochar into soil alters soil physical properties like bulk density, penetration resistance, structure, macro-aggregation, soil stability, pore size distribution and density with logical implications in soil aeration, wettability of soil, water infiltration, water holding capacity, plant growth and soil workability; positive gains in soil chemical properties include: retention of nutrients, enhances cation exchange capacity and nutrient use efficiency (Venkatesh *et al.,* 2012), decreases soil acidity, decreases uptake of soil toxins and increases the number of beneficial soil microbes (Srinivasa Rao *et al.,* 2015) and thereby promotes improvement in grain nutritional quality in tropical areas.

Biochar to Counter Climate Change

Biochar has the potential to counter climate change because the inherent fixed carbon in raw biomass that would otherwise degrade to greenhouse gases is sequestered in soil for years. In recent years the use of surplus organic matter to create biochar has yielded promising results in sequestration of carbon. Lehmann *et al.,* (2006) estimated a potential global C-sequestration of 0.16 Gt per yr can be achieved from biochar production from agricultural wastes. In India, biochar from residues of maize, castor, cotton and pigeon pea can sequester about 4.6 Mt of total carbon annually in soil, making it a carbon sequestering process (Venkatesh *et al.,* 2015). A number of studies have reported on environmental benefits of biochar additions which will reduce emission of non-CO_2 greenhouse gases by soil (Zwieten *et al.,* 2010) that could be due to inhibition of either stage of nitrification and/or inhibition of denitrification, or promotion of the reduction of N_2O; increases CH_4 uptake from soil (Rondon *et al.,* 2006) and long-term carbon sequestration in soil (Srinivasa Rao *et al.,* 2013).

Constraints

With limited studies in effect of soil application of crop residue based biochar on different soil type, climatic zone and land use situations, it is difficult to predict its agronomic effects. Due to the heterogeneous nature of biochar, cost of production of biochar for research and field application is likely to remain a constraint until commercial-scale pyrolysis facilities are established (Sparkes and Stoutjesdijk, 2011). Some of the practical constraints on use of biochar in agricultural systems were ; once applied to soil, remains permanent, unavailability of enough biochar, dry biochar is liable to wind erosion, response of local communities to adopt (Adtiya *et al.,* 2014); unavailability of farm labour, higher wage rates for collection and processing of crop biomass, lack of appropriate machines for on-farm recycling of crop residue and inadequate policy support/incentives for crop residue recycling (Venkatesh *et al.,* 2015) . The production of biochar from crop residues and their injection into arable soils offers multiple environmental and financial benefits. Biochar production and application in soils has a very promising potential for the development of sustainable agricultural systems in India, and also for global climate change mitigation.

Conclusion

Efficient, sustainable disposal of surplus unutilized crop residues remains a key issue in plantation areas. Most wastes are either burnt which leads to significant emissions of greenhouse gases to the atmosphere causes adverse impact on environment as well as soil fertility or end up in landfill, which degrades the environment. Thus there is a need to discourage on-field burning of crop residues. There is significant availability of crop residue resources in India as potential feedstock for biochar production. However, to promote the application of biochar as a soil amendment for improving the nutritional quality of food crops, and also as a climate change abatement option, research, development and demonstration on biochar production and application mentioned below seem to be very vital. First, a baseline study comprising compilation of data on unutilized crop residues resources in India needs be conducted. Second, a review of current unutilized crop biomass utilization and thermo chemical conversion technologies, particularly slow pyrolysis also has to be carried out. It is also relevant to create awareness among the various biochar stakeholders such as farmers, agricultural extension officers, agriculture department and research scientists, and to build their capacities in biochar production and application technologies through the development and implementation of training programmes. Since there are both agronomic and environmental benefits that could be derived from the production and application of biochar in arable soil, implementation of farm schemes involving the application of biochar should first be critically evaluated in the form of a pilot or demonstration project. This could then be transformed into large-scale schemes throughout the country. Participatory approach could be adopted in conducting field trials using the biochar that would be produced. Finally, a business plan for national scale-up biochar production and application project could be prepared based on available carbon finance opportunities in the country.

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33 Genetic Enhancement of Nutritional Quality of Food Crops - Strategies and Challenges

M Maheswari

Introduction

Nutrient deficiency is an entrenched global socio-economic challenge that reflects the combined impact of poverty, poor access to food, inefficient food distribution and an over-reliance on subsistence mono-agriculture. Micronutrient deficiencies affect approximately 3 billion people worldwide. Further it also hinders the development of human potential and socio-economic development (Khush *et al*., 2012). Strategies to tackle nutrient deficiency fall into three major categories (Gómez-Galera *et al*., 2010). First one is, increasing the diversity of food intake, which is impractical in many developing-countries, particularly in case of low-income groups (Massot *et al*., 2013), second approach is artificial supplementation of nutrients to the diet, by means of providing supplements or by the fortification of basic food products such as salt and flour, but it is unsustainable over the longer term because it relies on a robust distribution infrastructure and on consumer compliance (Hotz and Brown, 2004). Third one is biofortification, in which crop plants are modified or treated to accumulate additional nutrients at source (Zhu *et al*., 2007). In this context, developing micronutrient-enriched staple plant foods, either through conventional crop improvement methods or via molecular biological techniques, is a powerful approach benefitting the most vulnerable people including resource-poor women, infants and children.

Plants and plant based products are considered as the chief source of nutrition to most of the global population. However, the plant derived staple food *viz*., rice, wheat contain insufficient levels of several micronutrients that are essential to meet minimum daily requirements in edible tissues (Zhu *et al*., 2007). For example, iron content is high in rice leaves but low in the polished rice grain. Similarly, provitamin A carotenoids are only present in rice leaves. Hence, biofortification efforts are directed towards improving the levels of specific, limiting micronutrients in edible tissues of crops through crop nutrition management of fertilizer application, conventional breeding and molecular approaches. Nevertheless, usage of micronutrient fertilizers is expensive as well as potentially damaging to the environment and is applicable to specific crops and mineral scenarios but cannot be universally utilized as a strategy to boost the nutritional quality of foods (Hirschi *et al*., 2009).

There are several barriers to overcome in genetically modifying plants to accumulate more micronutrients viz. Fe and Zn in edible tissues (Welch, 1995). These barriers are the result of tightly controlled homoeostatic mechanisms that regulate metal absorption, translocation, and redistribution in plants allowing adequate, but non-toxic levels of these nutrients to accumulate in plant tissues. The physiological basis for micronutrient efficiency in crop plants and the processes controlling the accumulation of micronutrients in edible portions of seeds are not understood with any certainty (Welch and Graham, 2009).

The first and most important barrier to micronutrient absorption resides at the root- soil interface. To increase uptake by roots, the available levels of the micronutrient in the root-soil interface must be increased to allow for more absorption by root cells. This could be enhanced by changing root morphology and by stimulating certain root-cell processes that modify micronutrient solubility and movement to root surfaces and by increasing the root absorptive surface area such as the number and extent of fine roots and root hairs.

Absorption mechanisms, for e.g. transporters and ion channels located in the root-cell plasma membrane, must be sufficiently active and specific to allow for the accumulation of micronutrient. Subsequent to the uptake by root cells, the micronutrients must be efficiently translocated to and accumulated in edible plant organs. For grains, phloem sap loading, translocation and unloading rates within reproductive organs are important characteristics that must be considered in increasing micronutrient accumulation in edible portions of seeds and grains.

Therefore, biofortification efforts are usually directed toward increasing the levels of specific, limiting micronutrients in edible tissues of crops.

Biofortification Through Conventional and Molecular Breeding Approaches

Plants often show genetic variation in essential nutrient content, which allows conducting breeding programs for improving the levels of minerals and vitamins in crop plants (Gelin *et al*., 2007). For example, different rice genotypes exhibit a 4-fold variation in iron and zinc levels and beans and peas are known to exhibit variation up to a 6.6-fold (Gregorio *et al*., 200; Grusak & Cakmak, 2005). Maize mutants, such as *opaque-2*, produce enhanced levels of lysine and tryptophan, which are deficient in maize endosperm proteins. The *Opaque-2* gene in maize encodes a transcriptional activator that controls the expression of various genes during kernel development, particularly some of the most abundant endosperm storage protein genes. Pro-vitamin A enriched rice, Golden Rice, has been used to develop elite indica breeding lines, through marker assisted selection. The genotypes possessing valuable traits can be employed in breeding programmes to introgress potentially viable traits into well adapted varieties for imparting improved nutrient values.

Genetic Engineering Approaches

Although, biofortification through conventional breeding approaches allows improving the levels of minerals and vitamins in crops, lack of desired traits in the germplasm has heightened the interest to rely upon and adopt the transgenic technology.

Plant genetic engineering provided a path for increasing productivity and sustainability, offering efficient and cost-effective means to produce a diverse array of novel, value-added output traits such as improved nutrition and food functionality. Genetic engineering has enabled the incorporation of potential candidate genes for several beneficial traits thereby surpassing the limitations normally associated with the conventional methods of crop improvement. This technology allowed the precise transfer of alien genes into the plant genome for several quality traits such as alterations in amino acid composition (Yang *et al*., 2002), oils and fatty acids (Roesler *et al*., 1997), carbohydrates (Caimi *et al*., 1996) and vitamins (Ye *et al*., 2000).

Amino Acid Composition

The inability of humans and many farm animals to synthesize certain amino acids has long triggered tremendous interest in increasing the levels of these so-called essential amino acids in crop plants. Knowledge obtained from basic genetic and genetic engineering research has also been successfully used to enrich the content of some of these essential amino acids in crop plants. Enriching crop plants in essential amino acids has both economical and humanitarian interest. In developing countries, where plants directly account for the majority of the food, the interest is both humanitarian and economical. Recently, Liu *et al*., (2016) produced transgenic rice plants expressing a *LYSINE-RICH PROTEIN* gene (*LRP*) from *Psophocarpus tetragonolobus* (L.). The endosperm-specific expression of *LRP* significantly increased the Lysine level in the transgenic rice seeds to more than 30%, compared to wild-type. On the other hand Yang *et al*., (2016) engineered rice with increased lysine content by expressing bacterial aspartate kinase and dihydrodipicolinate synthase and inhibiting rice lysine ketoglutarate reductase/saccharopine dehydrogenase activity. In another study, overexpression of lysine (K)/threonine (T) motif (*TKTKK1) produced* transgenic rice plants expressing significantly increased levels of lysine, threonine, total amino acids and crude protein content by 33.87%, 21.21%, 19.43% and 20.45%, respectively in seeds, when compared with wild type control (Jiang *et al*., 2016)

Oils and Fatty Acids

The ability to genetically engineer plants has facilitated the generation of oilseeds synthesizing non-native fatty acids. One of the major goal of agricultural biotechnology is to increase the value of traditional crops by the addition of novel and desirable traits. An area in which significant progress has been made toward this goal is the modification of seed oils. Vegetable oils are important agricultural commodities, worldwide, they contribute significantly to human caloric intake and their composition can have a major effect on cardiovascular health. Anai *et al*., (2003), demonstrated increased á-linolenic acid content in transgenic rice seed oil exprtessing microsomal omega-3 fatty acid desaturase gene. Dehesh *et al*., (1996), reported that the expression of Ch FatB2 an acyl-ACP thioesterase from *Cuphea hookeriana*, in transgenic canola plants revealed the increased levels of caprylate and caprate accompained by the preferential decreases in linoleate and linolenate.

Carbohydrates

Transgenic rice seeds expressing a thermostable and bifunctional starch hydrolase, amylopullulanase (APU) from *Thermoanaerobacter ethanolicus* 39E, were generated by Chiang *et al*., (2005). APU was highly expressed in both mature and germinated transgenic rice seeds under the control of rice glutelin and a-amylase gene promoters and lead to autohydrolysis and altered composition of starch. Tissue-specific expression and targeting of the *Bacillus amyloliquefaciens* SacB (SacB) protein to endosperm vacuoles resulted in stable accumulation of fructan in mature maize seeds (Caimi *et al*., 1996).

Micronutrients and Functional Metabolites

Plants are a major source of vitamins in the human diet. Due to their significance for human health and development, research has been initiated to understand the biosynthesis of vitamins in plants. Ye *et al*., (2000), introduced the provitamin A (b-carotene) biosynthetic pathway into rice endosperm. Endosperm-specific co-expression of recombinant soybean ferritin and Aspergillus phytase in maize resulted in significant increases in the levels of bioavailable iron (Drakakali *et al*., 2003).

Conclusion and Perspectives

By the year 2050, the human population is expected to reach 9 billion and as such require sustainable agricultural production to meet the demands of food and nutrition. Crop plants being the major source of nutrition, play a significant role in meeting the future nutritional needs of an ever increasing population. To achieve biofortification of crop plants through breeding approaches, it is necessary to identify sufficient genetic variation, suitable selection methods and markers apart from workable heritabilities. Plant genetic engineering also offers potential scope to address the challenge of enhancing nutritional quality of food crops. Identification and isolation of new candidate genes, spatial and temporal regulation of transgenes are expected to contribute for nutrient enhancement of crop plants. It is also equally important to overcome the barriers associated with the accumulation of nutrients in food crops prior to genetically enhance plants in ways that will increase the density of micronutrients in edible tissues.

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34 Knowledge Sharing for Improved Food Security and Better Nutrition

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Introduction

The idea of creating a new generation of agricultural system data, models and knowledge products (NextGen) is motivated by the convergence of several powerful forces. First, there is an emerging consensus that a sustainable and more productive agriculture is needed that can meet the local, regional and global food security challenges of the 21st century. This consensus implies there would be value in new and improved tools that can be used to assess the sustainability of current and prospective systems, design more sustainable systems, and manage systems sustainably. These distinct but inter-related challenges in turn create a demand for advances in analytical capabilities and data. Second, there is a large and growing foundation of knowledge about the processes driving agricultural systems on which to build a new generation of models (Jones *et al.,* 2016b). Third, rapid advances in data acquisition and management, modeling, computation power, and information technology provide the opportunity to harness this knowledge in new and powerful ways to achieve more productive and sustainable agricultural systems (Janssen *et al.*, 2016a,). Our vision for the new generation of agricultural systems models is to accelerate progress towards the goal of meeting global nutrition and food security challenges sustainably. But to be a useful part of this process of agricultural innovation, our assessment is that the community of agricultural system modelers cannot continue with business as usual. In this paper we employ the use cases and our collective experiences with agricultural systems, data, and modeling and Information and communication Technology (ICT) to describe the features that we think the new generation of models, data and knowledge products need to improve food security and better nutrition. A key innovation of the new generation of models that we foresee is their linkage to a suite of knowledge products which could take the form of new, user-friendly analytical tools and mobile technology "apps" that would enable the use of the models and we organize this paper as follows. First, we discuss new approaches that could be used to improve food security by sharing the knowledge using improved ICT technologies. We also discuss strategies for model improvement for better Nutrition using improved ICT technologies.

Role of ICT in Improving Food Security

Access to desirable, sufficient, safe and nutritious food is a basic component of development and health of a society. Most observers of rural development believe that, currently, the necessary condition for obtaining food security is information. Knowledge and information are important factors to ensure food security, and ICTs have the ability to present the information required for improving food security. According to the definition determined by the World Food Summit (1996), Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Food security can be summarize according to three factors: food availability, food accessibility and food utilization. Food availability is achieved when a sufficient amount of food is constantly available for all members of society. This kind of food can be obtained through household production, local production, imports or food aids. Food accessibility is obtained when households and individuals have sufficient sources to consume a suitable diet. In other words, food accessibility is possible if the household income allows for the preparation and purchase of enough food (Bakhtiari and Haghi, 2003). Food utilization refers to suitable biological uses of food that depend on a household knowledge of techniques for storing and processing food and basic principles of nutrition and caring for children (Temu, 2004)

Different strategies exist for obtaining food security; the use of information and communications technology is one of these strategies. ICTs consist of various collections of resources and technical tools that are used for connecting, spreading, storing and managing information (Pigato, 2004). In other words, ICT represents the collection of hardware and software that is used for producing, preparing, transferring and storing data via devices such as computers, radios, televisions, etc., and it includes an extensive scope of traditional and modern media (Norad, 2002).

ICTs Can Be Classified Into Three Groups:

New ICTs: This group consists of computers, satellites, one-on-one connections, wireless phones (mobile), the internet, e-mail, the web, internet services, video conferences, CD-ROMs, personal computers (PC), distance control systems, informational-geographical systems, global positioning systems (GPS), electronic cameras, databases, etc.

Old ICTs: This group consists of radios, televisions, telephones, telegraphs, audio and video cassettes, films and slides. This group of technologies has been used for several decades.

Very Old ICTs: This group of technologies has been used for several centuries and includes newspapers, books, photo albums, posters, theater, human interactions, markets and plays (Obayelu *et al.,* 2006).

According to Chowdhury (2001), ICTs play an important role in food security through facilitating accessibility to related policies and information for market communication, improving market profitability, helping farmers to make decisions, increasing diversity in rural economies and reducing the cost of living. In general, some of the important capacities of ICTs in food security are related to improving communications between research systems, farmers and extension, improving accessibility to information regarding inputs, introducing technologies, providing more rapid accessibility to high quality information, ensuring information about the appropriate times and places for optimized sales of agricultural products, increasing agricultural products and decreasing agricultural waste products (Balakrishna, 2003; Temu *et al .,* 2004).

Case Studies for Effective Knowledge Sharing Technologies for Improving the Food Security/ Accessibility of Rural Households

The effective capabilities of information and communications technologies for improving the food accessibility of Iranian rural households the following objectives were compiled:

- The study of the personal and professional characteristics of extension experts.
- The study of the situation of food accessibility in rural Iranian households, from the extension experts' point of view.
- The examination of the role of information and communications technologies in improving the food accessibility of Iranian rural households.

According to Chowdhury (2001), ICTs play an important role in food security through facilitating accessibility to related policies and information for market communication, improving market profitability, helping farmers to make decisions, increasing diversity in rural economies and reducing the cost of living. In general, some of the important capacities of ICTs in food security are related to improving communications between research systems, farmers and extension, improving accessibility to information regarding inputs, introducing technologies, providing more rapid accessibility to high quality information, ensuring information about the appropriate times and places for optimized sales of agricultural products, increasing agricultural products and decreasing agricultural waste products (Balakrishna, 2003; Maoz, 2004; Temu *et al.,*2004).

Studies Carried out Improving Food Security

Many studies have been carried out in relation to the role of ICTs in improving the food security of rural households. The main result of the FAO research (1998) focused on creating an agricultural communication network project in Italy has helped to ensure agricultural inputs and product marketing. The results of Indonesia's participatory video project (1998) have been considered to help with clientele needs. The findings from the research of Fortier and Van Crowder (2000) about the electronic diffusion of agricultural information projects in rural communities of Kenya can improve the ability for individuals to acquire information, increase food production and develop the local capacity of rural community building. The research of Gerster and Zimmermann (2003)focused on a radio program project aimed at improving financial decisions and increasing food production.

The findings of Uganda's knowledge system and agricultural information project are related to improving the power of acquiring individual information and attending to clientele needs (2000).

The results of PCARRD (2003) research regarding the Philippines' information services and agricultural technology were used to improve the marketing of agricultural products and to increase production. The findings of Bangladesh's rural ICT project (2001) resulted in better marketing of agricultural products, decreased costs of accessing information and the creation of jobs. The main results of Malaysia's E-bario project pertained to the improvement of interactions and communications and responses to clientele needs.

To determine ICTs capabilities in improving food accessibility of Iran's rural households, total of 48 statements were used. The results shown in table 4 indicate that most respondents (36.5%) assigned an important role to ICT capabilities in improving food accessibility of Iran's rural households (Table 1).

Table 1. The role of ICT in improving food accessibility of Iran's rural households

Role	Frequency	Percent	Cumulative percent
Little	15	8.8	8.8
Medium	60	35.3	44.1
Much	62	36.5	80.6
Very Much	33	19.4	100

Source: (Farad, 2012)

Opportunities for Using ICT to Improve Food Security

ICT is a major driver of technological advancement in agriculture, as evidenced in such fields as bioinformatics, farm automation and precision farming. Other advanced studies, including explorations of genetic engineering and space seed processing, rely heavily on ICT. In the ESCAP region, developed countries, such as Australia, Japan, New Zealand and the Republic of Korea, as well as developing countries, such as China, India, Malaysia and some of the Central Asian countries, have been experimenting with these new technologies.

Bioinformatics is the field of science that combines information technology and computer science with biology. The initial focus of bioinformatics was the creation and maintenance of a database to store biological information. The field has since evolved to encompass other key areas, such as the analysis and interpretation of various types of biological data, including genome sequencing.

Precision farming, or precision agriculture, is a technique that uses technology to collect and analyse data for the assessment of variations in soil or climate conditions, in order to guide the application of the right agricultural practices, in the right place, in the right way, at the right time. It relies greatly on new technologies, including the Global Positioning System, sensors, satellite or aerial images, and information management tools, to collect information on such variables as optimum sowing density, fertilizers and other input needs. This information is then used to apply flexible practices to a crop.

Farm automation involves the use of control systems, such as computers, to derive higher yields with more predictable results through farming processes that are more efficient, less labour intensive and less time-consuming.

Biotechnology offers considerable potential as an instrument for achieving food security and sustainable agriculture. It uses advanced plant breeding techniques, including genetic modification and manipulation, to directly modify the structure and characteristics of genes, with a view to introducing beneficial traits to crops grown for food and fibre. The application of biotechnology in developing countries of the Asia-Pacific region could reduce the need for inputs and increase efficiency of input use. This could lead to the development of crops that use water more efficiently, fix nitrogen from the air, extract phosphate from the soil more effectively, and resist pests without the use of synthetic pesticides.

Conventional Applications of ICT in Agriculture

In most countries of the ESCAP region, due to various limitations, ICT applications in agriculture are confined to the more conventional uses. However, with agriculture rapidly moving away from artisanal, labour-intensive, traditional practices and towards information-intensive models, access to ICT and other technologies has become a necessity for farmers, including those in developing countries of the Asia-Pacific region. ICT can play a key role in achieving much-needed improvements in regional agriculture productivity, agriculture planning and practices and food distribution, as well as in the area of information on weather impacts and disasters empirical evidence suggests that, in the area of agricultural production, prices of inputs such as seeds, fertilizers and pesticides are the most frequently telecommunicated information. The telephone (mobile or fixed-line) is the communications technology most commonly used by farmers in the Asia-Pacific region. The use of other ICTs could also contribute significantly to agricultural productivity.

a. Marketing and Distribution of Agricultural Produce

The link between food security, markets and ICT are obvious when it comes to integrating farmers into national, regional and international trade systems. ICT improves the ability to search for information and increase the quantity and quality of information available, ultimately reducing uncertainty and enhancing market participation. One of the application using ICT for agricultural marketing is Agmarknet which is discussed below:

Agmarknet: an agricultural marketing information system

In India, almost all the states and union territories provide producers, traders, consumers and other market users with some form of market information. However, the information is collected and disseminated through conventional methods which can cause inordinate communications delays, thus adversely affecting the economic interests of affected target groups. In order to provide an effective information exchange on market price, the Directorate of Marketing and Inspection, Department of Agriculture & Cooperation, Ministry of Agriculture, and the Agricultural Informatics Division, National Informatics Centre, Ministry of Communications & Information Technology, collaborated to create the Agricultural Marketing Information Network. The project aims at establishing an efficient nationwide system for the collection and dissemination of market information, and computerizing data on market fees, market charges, storage and modes of transportation (www.agmarknet.nic.in).

To make ICT available to farmers have sought to improve the availability and quality of information either indirectly through producer associations, extension workers, among others, or directly through broadcast radio information, mobile phone messaging and community e-centers. For the most part, small farmers do not use ICT to market products beyond local and regional markets. Instead, there are nationally and globally active organizations that aim at mobilizing small-holders to join a programme and market their produce. Such programmes use ICT to provide overall coordination, transfer knowledge, arrange transportation and exchange market information.

b. Community e-centres to Improve Agricultural Productivity

Rural access to ICT through community e-centres can be used to improve agricultural productivity by connecting the rural poor to direct markets, and by giving them ready access to information on the prices of inputs and products. Better information would also give farmers a sense of market demand and seasonal variations in produce and prices, which would enable them to adjust their production.

A wide variety of information is available on the web, which can be accessed through telecentres. This includes information that enables farmers and farmers' cooperatives to determine current and forecast prices for agricultural produce, and to market directly to a broader choice of wholesalers or retailers. Information also includes global-to-local monitoring and analyses of crop conditions and yield forecasts, so that farmers (and farmers' cooperatives) can strategize steps to optimize the quantity, quality, and security of their crops, both prior to and after planting.

In villages around Pondicherry, villagers operate local "knowledge centres", which are part of a network of telecentres established by the Swaminathan Foundation. These operators adapt data and information from public sources for their own weather bulletins, which they post on notice boards for the local fishermen. The telecentre also broadcasts appropriate information over loudspeakers, to benefit those who are illiterate, and publishes a local newsletter.

Another example is the e-Choupal model, established by a private Indian tobacco company. These telecentres are operated by ITC-trained local farmers, and provide the agricultural community with access to good practices in agriculture and market prices for commodities. Better market information helps farmers to decide when and where to sell. By purchasing directly from the farmers, the tobacco company made the channel more efficient and created value for both itself and the farmers, who benefit from more accurate weighing, faster processing and prompt payment. By 2007, more than 6,400 e-Choupals were operating in about 31,000 villages (http://telecentresap.org/meeting/cmap2007/India_Presentation_eChoupal.pdf).

Stronger e-government for Improved Intra Governmental Coordination

Poor policy decisions are one major factor contributing to food insecurity. Food insecurity sometimes happens because the food is not where it is needed, not because the global supply of food is insufficient. Food security depends on the availability of food, physical and economic access to it, and the physiological utilization of nutrients. Ensuring food security is a complex task involving agricultural, nutritional, gender and technological issues. Thus it requires the intervention of various ministries within a country and a streamlined and well-coordinated flow of information between them. In addition, timely and accurate information regarding food supply and demand needs to be delivered to the right decision maker.

Monitoring and Forecasting of Climate, Weather and Crops

Since the green revolution, arguably the greatest contributor to increased farm yields has been information technology, delivered to decision makers via innovative communication technology. This includes (a) monitoring and forecasting of climate, weather and crops, (b) the integration of forecasts with strategic preparation and response, from the ministerial to the farm level, (c) international social and corporate responses, and (d) precision farming which was described previously. The successful integration of such processes should lead to improved agriculture and to food security, as all stakeholders would be better able to forecast supplies and prices of agricultural products, as well as improve the reliability of results through better management of resources.

Public-Private Partnerships in e-agriculture: Stakeholder Roles and Incentives

A public-private partnership is an initiative formed and operated jointly by a Government or a public sector entity and one or more private sector companies, non-governmental organizations or civil society organizations. Fundamental to this partnership is an understanding of why the partnership is required, the respective mandates, and the incentives and roles of the partners in the initiative. Some examples of public-private partnerships in Asia include the e-Choupal centres, Life Lines-India, Krishi Vigyan Kendra, and the Kisan Call Centres in India; the Commonwealth of Learning supported Lifelong Learning for Farmers Project in various countries; the Grameenphone Community Information Centers in Bangladesh; and the e-Haat Bazaar in Nepal, among others. The e-Choupal model shows how cooperation between a private company, rural entrepreneurs, state agricultural universities and extension machinery of the Government of India has served to bolster the farmers' expertise and day-to-day awareness of what needs to be done to cope with myriad agricultural needs.

Grameenphone, in collaboration with WIN Incorporate, an international development project, established community e-centres to disseminate agriculture-related information to farmers. The key role of the public sector in implementing e-agriculture is in the preparation and effective dissemination of relevant content (as public information) on such topics as crop cultivation techniques, inputs, disease, soil, and fertilizer dosage.

The e-Agriculture Community of Expertise Initiative

In 2007, FAO launched the first phase of the e-Agriculture Community of Expertise with the aim of facilitating information exchange and communication processes for the e-agriculture community by:

- Developing virtual communities and networks for information and knowledge exchange between rural stakeholders, as well as for their empowerment through participation.
- Building the capacity of rural stakeholders in the use and application of ICT.
- Enhancing farmers' and producers' access to information on the market and on farming techniques and practices.
- Improving dissemination of and access to scientific and technical information.
- Enhancing access to statistics and other types of information for policy- and decision making.

Use of Innovative ICT for Better Nutrition

India registered remarkable economic growth during the first decade of this millennium. Ironically, during this period, a vast section of population remained under nourished (Government of India, 2009) and highlights of study shown below:

Highlights from Report of National Family Health Survey (NFHS)-3

- Wasting is quite a serious problem in India, affecting 20% of children under 5 years of age
- 48% children under 5 years of age are stunted and 43% are underweight; 24% are severely stunted and 16% are severely underweight
- Almost 70% children of age group 6–59 months are anaemic, including 40% who are moderately anaemic and 3% who are severely anaemic. The prevalence of anaemia does not vary by sex of the child
- 55% of women and 24% of men are anaemic
- More than one-third of women (36%) and men (34%) of age group 15–49 years have a body mass index (BMI) below 18.5 indicating chronic Nutritional deficiency, including 16% of women and 9% of men who are moderately to severely undernourished
- In general, women's food consumption is less balanced than that of men. 55% of women, compared with 67% of men, consume milk or curd weekly. Only 40% of women, compared with 47 % of men, consume fruits weekly; 32% of women, compared with 41% of men, consume eggs weekly; and 35% of women, compared with 41% of men, consume fish or chicken/meat weekly

Levels of child underweight in India at 43 per cent are twice the average level of 21 per cent reported in sub-Saharan Africa; and stunting at 48 per cent is 8 per cent higher than that reported in sub-Saharan Africa (Prasum Kumar Das *et al*., 2014).Malnutrition in all its forms imposes unacceptably high burden on society and contributed one-third to one half of child deaths (Government of India, 2009); the annual economic losses associated with malnutrition have been estimated at 3 per cent of India's Gross domestic product (GDP) (Susan, H., 1999). Experience has, however shown that increasing food production alone cannot address the issue of malnutrition; unless there is a nutrition focus and the poorest have access to a source of diversified and nutritious foods. Food Security encompasses 'Availability', 'Accessibility' and 'Utilization' which includes 'absorption' and bio availability of food making it inclusive of 'Nutrition Security' (Susan, 1999). Beyond staple foods, a healthy diet means a diversified food basket containing balanced foods providing adequate amounts of energy, fat, protein and micronutrients. Agricultural interventions in the development paradigm need to be more nutrition-sensitive, with a greater focus on nutrient-dense foods with high levels of bioavailability, i.e. the proportion of micronutrients capable of being absorbed by the body. The thrust on increasing production and productivity enabled India to address calorie hunger, but hidden hunger caused by micronutrient deficiencies is widespread.

Given the large percentage of population dependent on agriculture, the problem of malnutrition can be better addressed through innovative ICT technologies.

In recent years there has been increasing interest in use of innovative ICTs in the delivery of health and nutrition programmes. Examples of this technology include mobile phones, tablets, internet, email, global positioning systems (GPS) etc., and their use has coined the terms electronic health (eHealth) and mobile health (mHealth).

eHealth is the use of ICT to provide health services and information, such as electronic health information systems or a digital map of all health facilities in a particular area. mHealth is a subset of this, which focuses on many of the same services, but accessed primarily on mobile devices, such as tablets, smartphones or basic mobile phones. The World Health Organisation (WHO) defines mHealth as *"medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices"*.**(** www.who.int/goe/publications/goe_mhealth_web.pdf).

Under nutrition remains a significant public health problem. Globally, it is estimated that over 52 million children suffer from acute malnutrition. (Hobbs, 2004). Community based management of acute malnutrition (CMAM) (http://www.d-tree.org/) has been rapidly scaled up since 2003. More recently CMAM practitioners have started to look at how ICT innovations can effectively provide solutions to address key gaps and weaknesses in the services delivered. There is a need to bring together this experience to highlight promising practices in the use of ehealth in CMAM and related health programming and common constraints, and to identify key areas for research and development. The brief will then explore some practical examples of how ICT is being used in health and nutrition programmes, followed by discussion of some of the opportunities and outstanding challenges encountered when introducing ICT into nutrition service provision.

Existing examples were Drawn Based on the Experience of Both CMAM and ICT practitioners

- Published articles and reviews: General internet searches were also carried out to access unlisted publications (e.g. Emergency Nutrition Network Field Exchange; agency case studies).
- Policy and practice documents from major implementers of nutrition-specific programmes (World Food Programme (WFP), United Nations Children's Fund (UNICEF), Non-Governmental Organisations (NGOs) as well as from major eHealth and mHealth implementers and organisations: Center for Health Market Innovations (CHMI), mHealth Alliance, Groupe Spéciale Mobile Association (GSMA)) were used to gather information on current projects.
- Programme reports (and other grey literature) were accessed through contacts at implementing agencies. These documents provided more information on current practices, experiences and lessons learned. In addition, this information was complemented with informant interviews with key people within these organisations

The Background and History of ICT in Improving Nutrition

eHealth goes back to the development of the first automated pathology reporting applications. A health management information system (HMIS) currently used globally is the District Health Information System (DHIS). The DHIS was first developed for use in three districts in South Africa in the late 1990s and is now used in 46 countries. Since mid-2000s mobile phones have increasingly been one of the main tools used to reach clients, support health workers and collect data. In the last few years there has been a proliferation of mobile applications developed for data collection, clinical decision support, eLearning and client self-management.

Common types of ICT interventions in the health sector fall roughly into the following groups, which tend to be implemented as stand-alone components, although there are some examples emerging of integrated solutions

- Electronic medical record systems
- Point of care diagnostics/sensors
- Client education and behaviour change messaging

- Supply chain management
- Provider training and education
- Data collection and reporting
- Electronic decision support
- Financial transaction

ICT Help to Address Challenges and Improve the Efficiency and Effectiveness of CMAM Programmes

CMAM programming has been rapidly scaled up since 2003 and has provided a model which has allowed children worldwide to have improved access to services to manage acute malnutrition in their local communities. In many of the countries where malnutrition is present, governments are supported by various NGOs in developing policy, financing and delivering services for health and nutrition. Nutrition services are often fragmented within governments, whether it be ministries of education for school feeding programmes, ministries of agriculture for farming programmes or ministries of health (MOH) (often divided by health and nutrition) for healthcare service delivery.

CMAM programmes share many of the same characteristics of other programmes in the health system in that they require a patient to be identified with a problem, seen by a health provider, diagnosed, treated with therapeutic or supplementary food and medicine and counselled. This movement of a client between community and facility and between the various intervention areas is shown in the Fig 1.

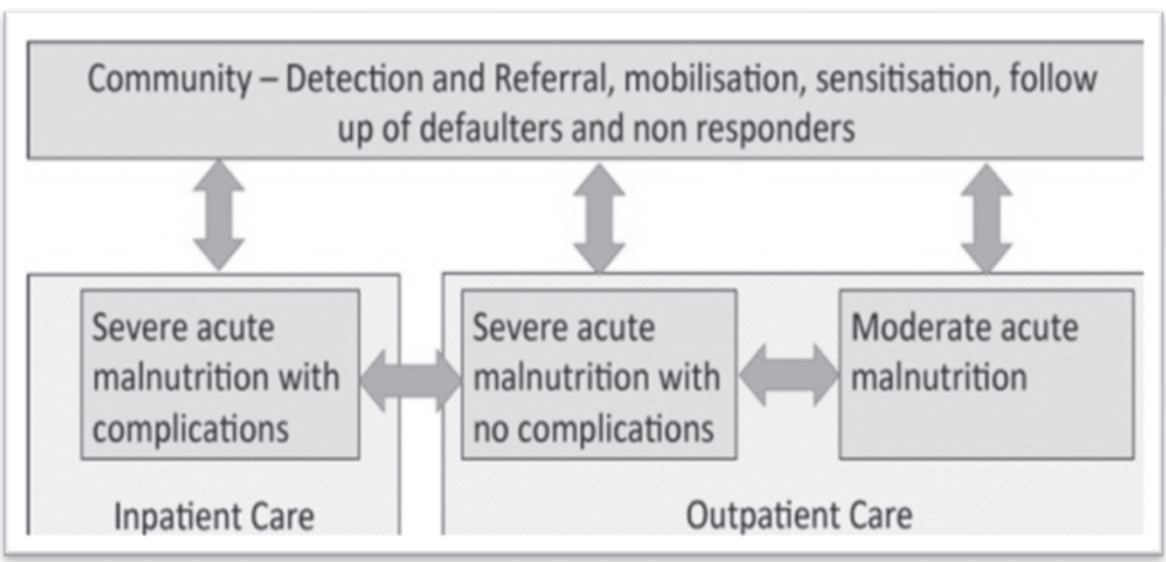

Fig. 1. Overview of movement within CMAM programme (Source : http://www.d-tree.org/)

An important element under pinning health and nutrition systems is the information systems used for monitoring and evaluating services. In many countries, the predominant form of recording patient information and reporting is in paper form. Multiple registers are kept, along with patient cards and the registers are manually tallied and sent up to the district and national level for aggregation and data entry. Along the way, new errors can be introduced with transcribing and data entry and the information that reaches the top of the system may be three to twelve months behind reality, rendering it difficult to use support services in a responsive way. Even in cases where there are electronic systems, these systems are often not interoperable and where they are tracking client level data, they are hampered by the lack of a unique identifier as many countries do not currently have a national identification system in place yet.

Impact of eHealth and mHealth

A recently published meta-analysis systematically reviewed 26,221 research articles documenting the effect of ICT use on health outcomes (Free, 2013). Out of this pool, 75 controlled trials were deemed eligible to compute pooled estimates of efficacy. CommCare, a platform currently used by 50 different organizations in 30 countries has identified significant contributions of mobile technology to maternal and child health (Chatfield A., 2014).

The review highlights preliminary evidence supporting the assertion that mHealth contributed to a range of outcomes: (Philbrick, 2013)

Improved compliance with scheduled follow-up appointments

- Improved service utilisation
- Consequent higher levels of trust
- Consequent greater user satisfaction with services
- Improved rates of delivery in the presence of skilled birth attendants

Current Use of Innovative Technology in Health and Nutrition Programmes

In this section we will explore the usage of innovative technologies, which have been deployed in both health and Nutrition programmes:

E-learning

Electronic learning (or e-learning) describes educational technology that electronically supports teaching or learning. E-learning encompasses a number of electronic formats, for example videos, CDs, and computer and web-based programmes used to facilitate learning. The University of Southampton offers a free e-learning course on malnutrition. The course is designed to take around 6-8 hours to complete and is aimed at doctors, nurses and public health professionals. The course is based on the WHO guidelines, and provides interactive learning in three modules which cover assessment and screening, visible and invisible changes caused by malnutrition. It is reported that around 300 people per month are enrolling for the course and the aim is to reach 100,000 health professionals; some are self-learners; others are teachers and trainers who use the e-learning course as part of their teaching.

(https://www.som.soton.ac.uk/learn/test/nutrition/courses/courselist/course3.asp?courseid=3).

Remote distance training, such as the USAID e-learning platform www.globalhealthlearning.org provides health professionals with short courses in a variety of health-related areas, as well as the ability to earn certificates. The platform is free and provides a course on childhood nutrition (which contains a brief overview of CMAM), in addition to other subject areas.

Health information systems and software

One of the major features of a health system is the collection of aggregate indicators to collect, track and report on core health indicators. The developed software's are discussed below:

The open source and free software District Health Information System (http://www.dhis2.org/), is a tool for collection, validation, analysis, and presentation of aggregate and transactional data, for integrated health information management activities. DHIS2 is today considered as an international standard, and is estimated to cover more than 1.3 billion people in 46 low-and middle-income countries.

World Vision has developed an online CMAM database, which not only allows district and regional staff to enter data from the facility level, but also incorporates the flow of information back to the health facility, so they can monitor their own programme's quality and take actions. This feedback loop is a critical component, which is often missing from the reporting processes of many systems. World Vision has realised many benefits including time savings in entering data and generating needed reports and in improved accuracy of data.

Coconut Surveillance is a system which builds on an earlier initiative in Zanzibar to report, track and alert the health system to new cases of malaria. This system allows the district malaria control officers to be informed of cases as they occur from the health facilities via SMS, and then collect additional geographically tagged information about the cases at both the facility and household level. This information is then all made available on a dashboard, which allows for real-time monitoring and response of outbreaks as they occur.

Twine is a United Nations High Commissioner for Refugees (UNHCR) project which aims to use data to improve humanitarian decision making. Twine is an online platform used to manage and analyse public health data collected in refugee operations. Data is collected using a number of different tools, which cover a range of sectors and operational settings . The tool also includes the capacity to support nutrition surveys.

Surveys and surveillance/Data Collection Tools

Effective nutrition monitoring systems are crucial for governments and other agencies to capture undernutrition, track trends and inform decision-making. Recently there has been increasing enthusiasm for the potential of ICT to facilitate faster and less work-intensive nutrition monitoring through quicker data collection and transfer and analysis, which can inform decision-making in a timely manner. Using tools such as Magpi (http://home.magpi.com/survey-app-messaging/) (formerly Episurveyor) and mFieldwork (http://mfieldwork.com/), organisations in Somalia, India, Nigeria and many other countries have automated paper checklists and other forms which had long been the main way to collect health programme data. The time saved on the data collection allowed the supervisors to spend more time on quality improvement activities, as well as providing more timely feedback to the health facilities on areas which required corrective action.

UNICEF Malawi deployed RapidSMS which instantly alerts field monitors of their patients' nutritional status. Automated basic diagnostic tests are now identifying more children with moderate acute malnutrition who were previously falling through the cracks as health surveillance assistants were only trained in identifying signs of severe acute malnutrition.

Mobile applications for nutrition improvement

The rapid expansion of mobile phones and networks in low and middle income countries (LMIC) and lower prices for handsets, airtime and data packages have made it possible for many organisations to consider using these as tools to strengthen delivery of their health programmes. Mobile applications are amongst the most rapidly expanding form of ICT in practice, and can be used at a number of levels.

mHealth applications have been built around a number of platforms and make use of different aspects of mobile technology such as text messaging i.e. short message service (SMS), voice and video services and the use of internet connectivity. Depending on the technology, mobile phones may be simple or may be smart phones providing more sophisticated solutions.

There are numerous components in the delivery of CMAM services that have utilised ICT as a means to strengthen their interventions. Some of the challenges addressed include those of low quality of services provided by health workers, improved access to services through the use of community health workers and the use of mobile messaging to improve awareness of nutrition services and drive demand.Several other initiatives have developed mobile education tools specifically for use on phones.

Digital Campus (https://digital-campus.org/) provides standalone health applications that contain mobile-adapted content from the Health Education and Training (HEAT) network. They have currently developed seven modules including maternal health, nutrition and immunization with plans to develop additional modules in the future. The Manthan Project's mSakhi *tool* also provides health education content within an application, but what is innovative about their approach is that this content is integrated within the mobile application that health workers use in their daily work. mSakhi was developed to be used by Accredited Social Health Activists (ASHAs) in India, whose role is to provide Maternal Child Health (MCH) services to their community. It combines registration, danger sign screening and counseling (FANTA 2008) with voice, image and video training content on the same subject matter (Manthan, 2013). Another innovative training programme in India is Mobile academy (http://www.rethink1000days.org/programme-outputs/mobile-academy) developed by BBC

Media Action. Mobile Academy is designed to expand and refresh CHWs' knowledge of life-saving health behaviours and to enhance their communication skills. The audio course is delivered via Interactive Voice Response (IVR) a technology that can be accessed from any mobile handset.

Pros and Cons of Various Interventions

The table 2 below attempts to list some of the major types of interventions and the advantages and constraints that may be faced in the use of each ICT interventions.

Table 2. Interventions, advantages and constrainds in use of ICT

Intervention	Advantages	Constraint	Evidence
Text messages to beneficiaries	Wide reach; can be accessed on any device	Cost of SMS; lower phone ownership among target groups (poor, women); restricted to shorter messages	Can improve clinic attendance and adherence to prescribed care (Lester RT, 2010)
Text messages to health care providers	Wide reach; can be accessed on any device	Cost of SMS; may be difficult to retrieve if provider receiving many messages a day	Modest benefits, may need more evidence
Structured SMS for data collection	Wide reach; can be accessed on any mobile device	Training needs for structured SMS; incorrectly formatted messages may be rejected	Clearly more efficient and faster than paper methods and can improve data quality (Habiba et al., 2012)
Use of PDAs/ Smartphones for data collection	Can have validation built in, run offline/online, transmit data	Cost of devices, power	Trails using mobile phone technology-tools reported reduction in correct diagnoses when compared to the standard (Free, C., 2013)
Use of smart phones by health workers	Can run many applications; greater storage space; increasing smartphone ownership	Greater power needs; may require longer training	Trails using mobile phone technology-tools reported reductions in correct diagnoses when compared to the standard (Free, C., 2013)
Use of mobile money	Easily send micro payments to many beneficiaries	Requires agent network to convert to cash (may be limited to urban); high fees; cash could be used for other purposes	Feasible to implement, clearly has ability to reach out into rural areas
Use of e-Vouchers	Avoid handling cash; easy to distribute	Need system to validate and redeem	Feasible to implement, clearly has ability to reach out into rural areas
Videoconferencing/ telemedicine	Can access expert opinion from anywhere	Requires connectivity; may have greater bandwidth	Feasible to implement, clearly has ability to reach out into rural areas. More evidence needed to show effectiveness

Source: Source : (CMAM, 2014)

Challenges

Despite the promise of ICT to address many of the issues in health and nutrition programmes, there are constraints which may restrict the ability of these solutions to go to scale as widely as necessary to achieve maximum impact. So we have to addressed to ensure optimal impact.

Sustainability: Efforts should be made to ensure that there is a path for incorporation into a larger programme for support, funding and scale up, if the results of the programme are promising, for instance, assuring an organised approach to the implementation of ICT interventions that includes a pilot phase, implementation, impact research and then evaluation which includes a cost-benefit analysis, and makes recommendations on the scale up and institutionalisation of the innovation by governments.

Weak health systems: Despite many of the interventions listed above having a significant impact on the success of a nutrition programme, none exist in a vacuum. That is, much of their success or failure depends on the health system within which they are being deployed. If there are no CHWs screening children or no mass communications about the nutrition services at the clinics, then few children will come for care. If the children come for care only to find that there are no staff members, or that they are poorly trained, or that there are not the necessary commodities to provide care, then they will not return. It is essential that any innovations are also introduced with health system strengthening being addressed, either directly or through other partners in the sector.

Ongoing operational costs to maintain the use of the ICT solution (airtime, hardware maintenance, etc.) need to be considered. Many pilot projects involving the use of mobile technology for health/nutrition programming have not been sustained beyond initial grant funding due to lack of foresight and planning for financial sustainability. At the same time, lack of national level ownership by MOH in many projects has also made the initiatives hard to sustain in the long run.

Lack of infrastructure: This can affect deployment of some of the initiatives described. This can be in terms of proper facilities to store commodities such as RUTF or vaccines, as well as lack of power to charge mobile phones or laptops. Although great strides have been made to improve mobile network coverage, it is not uncommon to find villages and primary health facilities where one cannot get a signal sufficient to consistently transfer data via General Packet Radio Service (GPRS). This will limit the ability to reach many communities, as although they may be able to use voice calls and messages and SMS, accessing data via the internet, applications, and video will have to wait. Many isolated communities are still years away from having a reliable power source.

Conclusion

Policymakers and other stakeholders need to be aware of how appropriate ICT-based instruments can help to influence agricultural practice as well as support efforts and initiatives to promote food security and sustainable agriculture. With agriculture rapidly moving away from artisanal, labour-intensive, traditional practices towards information-intensive models dialed into the global economy, access to information and modern communication technologies has become a necessity for farmers, especially in developing countries of the Asia-Pacific region.

The agriculture of the future will entail more efficient and sustainable production systems, making optimal use of land, water and other natural resources. Sustainable food production will rely more on agricultural information management and communication technologies. The increased knowledge of food production systems for improving food security and nutrition through learning applications and access to best-practice data will enable international, regional and national expertise to trickle down to local levels.

In this context, information exchange aimed at enhancing food security will be essential to the Government, the private sector, the academic community, farmer organizations and civil society. However, to realize the full potential of ICT-enabled agriculture, Governments need to provide the following things:

(a) A sound, market-oriented ICT regulatory framework.

(b) Universal access regulations and mechanisms that motivate operators to serve regions where it is economically unfeasible but socially desirable for them to do so.

(c) Incentives such as a sound business and taxation environment to encourage investor and donor involvement in ICT infrastructure development in Asia and the Pacific.

(d) The preconditions for interregional collaboration in Asia and the Pacific through, for example, the introduction of common standards and ICT-based monitoring and forecasts.

(e) Support to research institutions and other nonprofit organizations that use ICT tools to assess and transmit commodity prices, thereby allowing markets to emerge.

(f) Support for ICT use to increase the efficiency of knowledge systems in the context of agricultural production, and support for intermediate organizations in terms of transferring knowledge from global or regional levels to local levels, which in most countries will begin with the integration of agricultural extension services into knowledge systems.

(g) Initiatives that combine existing media channels, such as rural radio stations, with ICT to match potential local demand with global content and to distribute the information widely in the relevant languages.

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35 Nutrition Security Through Livelihoods Improvement in Rainfed areas: Experiences from DFID Project

K Nagasree, DBV Ramana, V Maruthi and N S Raju

Introduction

According to the FAO there are almost 870 million people chronically undernourished today, representing 12.5 per cent of the world's population, or one in eight people, of which nearly 850 million live in developing countries. Food security is a special concern and in rural areas may require physical infrastructure such as road and power infrastructures, property security, and access to systems of market-based exchange, in addition to public investment in research and extension and related communication system (FAO, 1990). National Rainfed Area authority (2012) in its report stated that rainfed areas currently constitute 55 per cent of the net sown area of the country and are home to two-thirds of livestock and 40 per cent of human population. Hence there is an immediate need to improve livelihoods of farming communities by improving their agricultural productivity and thereby contributing to their food security and also by income generation through agricultural and related enterprises. In most of the action research projects like DFID, NAIP etc., implemented by ICAR - CRIDA efforts were made taken to minimize the food insecurity through need based participatory technology dissemination.

Field Experiences from DFID Project:

Sheep rearing:

In order to promote sheep rearing as a source of income generation and self employment for the poor and landless households, including widows, two models of sheep rearing, (i) lamb fattening (ii) breed multiplication, were tried to evolve a practical model for replication elsewhere and to identify the potentials and constraints of wider uptake of sheep as a livelihood enterprise.

The project staff approached the poor and landless people and asked them to choose different alternatives for uplifting their standard of living during *Salaha Samithi* meetings and group discussions. The options offered to them were: sheep rearing, goat rearing, poultry farming and nursery raising depending upon caste and social customs. The majority of the poor people selected sheep rearing for improving their livelihood mainly because of easy maintenance and availability of ready-made market round the year.

A focused PRA was conducted and survey was made in order to have an idea about the sheep production system prevalent in the cluster villages. Based on a decision taken in the *Salaha Samithi* meeting, sheep units of 4-5 sheep for breed improvement and multiplication purpose and units of 3 (later reduced to 2) sheep for fattening purpose were given to improve the livelihoods.

The conditions for provision of sheep agreed with the S*alaha Samithi* and intending sheep owners was as under.

- The animals should be bought from the local market.
- The owners should rear them with care and responsibility.
- The owners should supply feed using local feed resources as advised by the project staff during lean period.
- The animals should not be sold or slaughtered before lambing in case of multiplication or before attaining the body weight of 25 kg in case of fattening.
- The owners should inform the project staff before sale or slaughter of the animals and in case of any illness or theft.
- The field staff would supervises the activity and arrange insurance of animals and should collaborate with the owners.

The *Salaha Samithi* proposed 10 - 40% contribution of total cost from the participating farmers, on a sliding scale based on the owner's capacity to pay. In Mahabubnagar and Tumkur the contribution was 10% whereas in Anantapur it was 40%. The contribution became a part of the revolving fund managed by the *Salaha Samithi*.

Backyard Poultry Unit

Backyard poultry was promoted through the project as a livelihood option for the landless poor in all the clusters. Improved strains of birds, Giriraja and Vanraja, were provided to landless poor people @ 5 birds/unit to rear in the back yard. The purpose behind this intervention was that the poultry would be a laying unit that could be managed by the landless and poor, and would produce eggs that are sold at three times the price of local eggs and hence generate income besides enhancing nutritional security.

The success rate of poultry was very low (10-30%) in most of the clusters. Farmers reported the following reasons for failure of poultry:

- The birds died in summer due to high temperature. The chicks were very vulnerable to the heat.
- The birds are not able to move quickly or fly due to their heavy weight. Because of this, the dogs and wild cats caught the birds and ate them.
- Because of their heavy weight, when birds fell from some height, their legs broke. This might be due to less bone strength.
- The birds were cut for meat during festivals or also offered when some guests arrived as a part of meals.
- Few people realized how much they could earn from the five birds

Experience shows that the poultry unit as livelihood intervention improved nutrition to the poor families, as in most of the cases, people just preferred to have them in their plate and palate than in their backyards. Increased attention had been given to planning with the recipients how to manage the birds and protect them from heat, predators, etc. A technical factor, which needs re-examination, is the vulnerability of small chicks during summer. This intervention is an example of where there is a gap between an improved technology and the resources of the (poor) farmers to manage it.

Nursery Raising

Nursery raising and maintenance in the cluster villages is a new intervention being carried out for the first time in the villages. In the clusters most of the people are small, marginal farmers and landless people. To improve the livelihoods of the landless poor, landless poor persons including women were identified for nursery training. Five men in Anantapur, two women per village in Mahabubnagar and 10 women in Tumkur were trained. During the training at Lakkihalli farm in Tumkur, the participants were taught grafting techniques, propagation methods and the techniques of nursery raising. After training, 4 nursery units (one per village) started in Mahabubnagar cluster, 3 men started in Anantapur cluster, and the ten women in Tumkur, raising a nursery in their backyards to supply seedlings to project supported tree interventions related and earning income.

Inputs like seeds, polythene bags, were supplied with a buy back system, from the project @ Rs. 2/- per live seedling. The cost and returns from nursery raising were presented in above table. From this it can be seen that the women could obtain around more than Rs.10,000/- profit by utilizing their free (and uncosted) labour. This has also enabled some of the women to obtain some capital assets and investment. One landless woman who has raised nursery informed that she has purchased some gold ornaments and also invested in starting a small grocery shop. This shows that this activity can be a sustainable activity for developing women entrepreneurship. The women are willing to continue this nursery activity but are now uncertain of where to market their produce. Facilitating linkages with State departments like Forestry and also local big nurseries in the nearby district headquarters could be a solution; or diversifying their nursery production to meet local needs for example vegetable seedlings (Table 1).

Table 1. Cost and Returns of Nursery Raising

Total No. of Plants: 7500	
A. COSTS :	Rs.
i) Labour for filling the polythene bags with soil 20 women labour @ Rs. 30/day	600.00
ii) Cost of material (FYM, soil & sand) **	2400.00
iii) Cost of polythene bags (7500) @ 0.25/bag **	1875.00
iv) Cost of seed **	500.00
Total cost	5375.00
B. GROSS RETURNS: 7500 plants @ Rs.2/plant	15000.00
C. RETURNS for family labour*	9625.00

Source : Case study from DFID research project, Mahabubnagar cluster, 2003-2006

* Watering was done by the landless women who have raised the nursery
** Supplied by the project

For two women of Chowderpalli village of Mahabubnagar cluster, water availability was a problem. But with the intervention of *Salaha Samithi* members, water at the site was arranged from nearby farmers having water sources.

One farmer was motivated to start a commercial nursery with 10,000 seedlings with varieties of forestry and horticultural seedlings that were in great demand at Shankarnhalli. Through this enterprise, the gender issue was taken into consideration.

The participants can utilize the profit obtained from nursery as “Seed Money” for further development of nursery in the coming years and to try for loan from banks for nursery development with the support of *Salaha Samithi*, Bank, Forestry Dept., VSS and others.

The project experience reveals that nursery raising, as a group activity is not recommended, as the returns are unlikely to be sufficient to maintain interest of group members. It is an activity that is best to be promoted at the individual level; which also caters the nutritional security at the household level .

Conclusion

Nearly 40% of the rural work force in the rural areas depend on Agriculture and allied sectors for their livelihoods in Rainfed areas and 55% of the net sown area is from Rainfed agriculture. Hence it is essential to empower the farmers and farm women in terms of capacity and skills for livelihood improvement which would also tackle food insecurity. In most of the action research projects like DFID, NAIP implemented by CRIDA efforts were made taken to minimize the food insecurity through need based participatory technology dissemination. Some projects interventions specifically supported the women farmer’s to address the root causes of nutritional insecurity. Participatory rural appraisal tools and techniques are used to analysis the local situation a gender inequalities. Appropriate extension strategies were used for promoting sustainable rural livelihood for food security in project areas.

People contribution is more important for sustainability of the livelihood interventions. Livelihood interventions planning should be based on the analysis of village situation (through PRA) and people priorities. Capacity development of target groups in terms of knowledge and skills is to be done before the implementation of the intervention to understand potential of intervention goals. Livelihood intervention should be designed based on local resources availability, investment choices, access to natural resource base in addition to human capabilities. The DFID project interventions specifically supported the women farmer’s to address the root causes of nutritional insecurity. Appropriate use of extension strategies for promoting sustainable rural livelihood is a key for enhancing food security in project areas.

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36 Effective Storage Structures for Food Grains, Fruits and Vegetables

I Srinivas, N S Raju and Ashish S Dhemate

Introduction

India blessed with its ecological advantage for the production major crops which are much useful for feeding the current population without any hitches. However, the poor infrastructure facilities are restricting their produce potential use in the consumer market there by effecting the needy persons. Apart from this we are unable to cater our domestic needs because poor storage resources at primary level in particular. Similar is the case with horticultural products like perishable fruits and vegetables. Food grains undergo a series of operations such as harvesting, threshing, winnowing, bagging, transportation, storage, and processing before they reach the consumer, and there are appreciable losses in crop output at all these stages. The post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank stipulates could feed one-third of India's poor. The monetary value of these losses amounts to more than Rs. 50,000 crores per year (Singh, 2010). Ramesh (1999) reported that high wastage and value loss are due to lack of storage infrastructure at the farm level. The losses during storage are quantity losses and quality losses. Quantity losses occur when insects, rodents, mites, birds and microorganisms, consume the grain. Infestation causes reduced seed germination, increase in moisture, free fatty acid levels, and decrease in pH and protein contents etc. resulting in total quality loss. Quality losses affect the economic value of the food grains fetching low prices to farmers (Ipsitaet al., 2013). The estimated postharvest losses at the farm level are 3.82 kg/q for rice and 3.28 kg/q for wheat in 2003-2004 (Basavaraja *et al.,* 2007). Post-harvest losses account for 9.5% of total pulses production. Among postharvest operations, storage is responsible for the maximum loss (7.5%). Processing, threshing and transport cause 1%, 0.5% and 0.5% losses, respectively (Birewar, 1984). Among storage losses, pulses are most susceptible to damage due to insects (5%) compared to wheat (2.5%), paddy (2%) and maize (3.5%) (Deshpande and Singh, 2001). Storage losses also vary geographically depending on the type of storage structures used. A study by Usha and Mohan (2007) indicated that in Coimbatore the storage loss estimated at the farm level indicated highest loss in black gram (40%) followed by green gram (30%), cowpea (30%), bengal gram (20%), mochai (20%) and red gram (10%). The predominant reason for this is the storage of pulses in gunny bags or baskets or other steel containers. Hence it is suggested to increase the utility of these produce by minimizing the magnitude of post-harvest losses in order to cope with current and future demand and attain a state of food security. All these facts are discouraging the potential utility of the produce at secondary processing level at industries which normally accounts for 30% value addition.

Total vegetable and fruit production in the world has been estimated 486 million and 392 million tons, respectively and 30-40% of total production in developed country is spoiled due to lack of postharvest handling up to consumption. India is second largest producer of fruits and vegetables with first rank in production of ginger and okra, second in bananas, papayas, mangoes etc. (Anonymous, 2013). But in the case of developing country like India, the postharvest losses noticed close to 50% of the total fruits and vegetables production which badly affects the availability of fruits and vegetables to the consumers (Sudheer *et al.,* 2007). Perishable fruits and vegetables facilitate the easy attack of the micro-organism due to high water activity and spoiled rapidly. Improper handling, storage, preservation techniques and microorganism spoilage increase the postharvest losses in fruits and vegetables up to 40%. The microbial effect plays a vital role in spoilage of fruits and vegetables due to some extensive heat or cold resistance micro-organism the processed or canned product also can be damage (Sharma *et al.,* 2013). Ironically, the small and marginal farmers who contribute 85% of the produce lack the proper storage facilities at field level. Due to this, the profitability at farm reduces considerably. Practices of postharvest technologies can reduce the quantitative and qualitative losses of fresh fruits and vegetables and also maintained the product quality up to final consumption. Attaining the hygienic agricultural produce should be focused on the varieties of higher postharvest longevity (Wasala *et al.,* 2014). Several studies concluded that postharvest losses are still a challenge and no significant declination has been observed within past two decades according to the resources utilized. Intensive study reveals that total postharvest losses (during harvesting, handling, packaging and transporting) lies between 30 to 40% of the total production. Review of many literatures also concluded the several hygienic and disinfected postharvest technologies are developed but evaluation of feasibility and financial benefits of the mentioned postharvest technologies to the producers has not been documented properly (Kitinoja *et al.*, 2011). Postharvest quality and shelf life of the fruits and vegetables related with the cultivation practices, varieties of the cultivar and environmental aspects. The soil and climatic characteristics and integrated management practices also affect the postharvest losses and postharvest storage duration (Bachmann *et al.*, 2000). Due to high water activity, fruits and vegetables are considered more perishable and nearly 33% of total produced fruits and vegetables have been spoiled during harvesting to marketing (Kader, 2005). Salami *et al.*, (2010) stated that total 30-40% fruits and vegetables wastage occurred within harvesting to consumption. In the case of developed and developing countries, the losses of fruits and vegetables estimated around 5-30% and 20-50% respectively (Kader, 2002). Reduction in the quality, storage duration and shelf life can be minimized with the help of adequate storage, transportation and environment conditions. Several environment factors like temperature, humidity and gaseous atmosphere are responsible for postharvest losses. Different fruits and vegetables treated as an important source of vitamins, minerals and fibre due to the several nutritional benefits the consumption of fruits and vegetables increased which also improve the commercialization of fruits and vegetables.

Inadequate Post-harvest Infrastructures for Fruits and Vegetables

Lack of sorting facilities, inappropriate packaging, and slow transport systems and inadequate storage facilities add to the deterioration of these perishables. Grading is generally not followed at the producer's level. As a whole, grading facilities of the desired level have not been created. Such facilities have to be developed at packing houses/grading and packing-centers for farmers. It is tabulated below(Table 1):

Table 1. Commodity-wise distribution of cold storage in the country (as on 31 Dec 2003)

Commodity	Number	Capacity ('000 tonnes)	Percentage
Potato	2618	14,792.3	81.23
Multipurpose	1045	3108.3	17.06
Fruits and Vegetables	121	38.9	0.21
Meat and fish	464	174.7	0.96
Milk and milk products	202	79.1	0.43
Others	91	15.7	0.08
Total	4541	18,209.0	100.0

Source: GOI (2007)

Grains in India, is stored at farmers, traders and industrial levels. Appropriate technology for handling and storage of pulses are been developed in all parts of the globe. Grain storage structure are a collection of devices for grains used after harvesting to store grains safely until their consumption or transport elsewhere (Tiwari *et al.*, 2012). Traditional storage practices do not guarantee protection against major storage pests of staple food crops, leading to higher percentage of grain losses, particularly due to post-harvest insect pests and grain pathogens (Tefera *et al.,* 2011). Diffrent grain storage structures are given below:

Conventional Structures

In India, around 60-70% of food grains produced is stored at home level in indigenous storage structures (Kanwar *et al.*, 2003). The percentage of overall food crop production retained at the farm level and the period of storage is largely a function of farm-size and yield per acre, different storage structures are in use are discussed below:

Straw storage structures are made of straw with 100-500 kg capacity. Bamboo/Read storage structures are more prominent in tribal habitats. Cement concrete structures has capacity to store between 500-10000 kg. Mud bins has capacity with 100-1000 kg and are well built structures for thermal safety (Figs 1 to 5).

Fig. 1. Straw storage sturctures

Fig. 2. Bamboo/Read storage structures

Fig. 3. Masonary storage structures

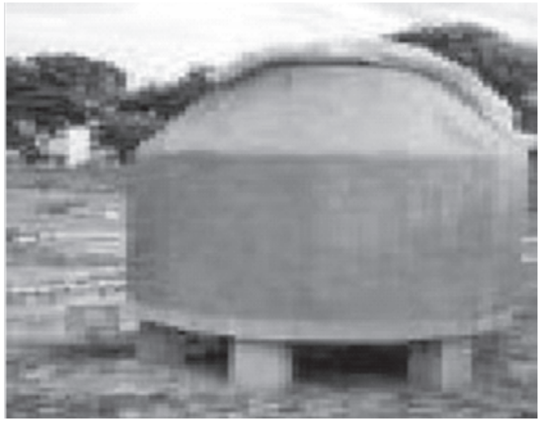

Fig. 4. Earthen storage structures

Fig. 5. Underground storage structures

Improved Grain Storage Structures

Pusa bin is one of the important improved methods of storage developed by IGSMRI (Indian Grain Storage Management and Research Institute) (Fig 6). One design consist of the floor and lower part of the walls burnt with a layer of plastic sheeting inserted between two bricklayers. This protects the grain from moisture and prevents air from top provides protection from sun and rain (Proctor, 1994). The other design of Pusa bin is made of double walls of masonary each 4.5 inch thick with polythene sheeting in between. The outer layers have steel reinforcement and the sides are plastered with cement (Jelle, 2003).

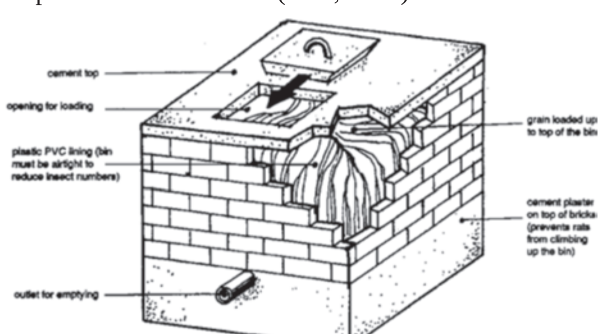

Fig. 6. Schematic view of Pusa bin

Bulk Storage Structures: Bulk storage structures are recommended for the ware housing facilities as per the community requirement. It is very important that the shelf life of the grain should be considerably increased for long term storage for public requirement. Hence , the temperature, and humidity control as per the grain requirement will be maintained apart from safety control measures from the pests, insects and rodents (Fig 7).

Fig. 7. Typical view of the grain storage structure

Storage and Preservations Structures for Fruits and Vegetables:

As the fruits and vegetables are highly perishable and high value products they need precision structures for increasing their shelf life. Commercially all these products are stored at - 5 C to 5 C temperatures with 65 to 85% humidity levels (Fig 8).

Fig. 8. Typical Bulk Cold storage structure for fruits

CRIDA Vegetable Preservator: This is highly useful for small and marginal farmers for on farm storage purpose. It is made up of fibre reinforced plastic (FRP) for its longer durability. It consists of two cylindrical baskets with circular holes all around their periphery (Fig 9). Smaller basket is inserted in larger one with one-inch gap between them (Srinivas *et al.,* 2004). Pine grass mats are placed all around in the gap between baskets. A tubular water tank is placed on top. Low discharge drippers are fixed at a bottom surface of tank so that the water is continuously dipped on to the mats. The mats absorb the water and are continuously wetted. Excess water drains out through circular path at bottom of outer basket and outlet tube. The drained water is collected in a bottle. The whole structure is placed on a steel tripod stand to enable the drain water collection. The button type low discharge irrigation drippers commonly available in the market were selected and fixed to bottom surface of circular tank. Tank design is wider on top and tapered towards bottom to enable free movement of water into drip inlet. Inlet of dripper is embedded to tank bottom surface during molding. The dripper outlet is threaded to inlet by rotating in clockwise direction. The dripper discharge can be controlled within some limit by rotating dripper outlet clockwise or anticlockwise. Discharge is minimum when dripper is fully tightened position. The water in the tank enters into inlet of dripper and moves through a designed micro size path to outlet. Since this path is very small it allows a controlled water drops out on pine grass chamber. About 4-6 drippers depend on size and tank are sufficient to keep pine grass wet. However, if water in the tank contains a suspended particles or dissolved salts, the dripper path may get clogged and water stops dripping out. Therefore, it is desirable to use clear water. In case of clogging of drippers, the water drops will stop. All drippers are visible and can be accessed through rectangular aperture from inside basket chamber. Clogged drippers outlets can be unscrewed and taken out from cleaning inside disc path for salt accumulation or clogging by suspended particles and refitted after cleaning. It is advisable to observe all drippers daily once while filling the water tank in the morning. The water can be filled in the tank through opening kept on top of tank. The opening can be closed with lid similar to water bottle.

Water tank has a capacity of 4.5-7 litres depend on size of preservator. The filling of water tank daily morning is advantageous, as during day time there will be higher evapotransmission losses from pine grass compare to night time. The full tank in the morning provides a higher gravitational pressure for normal discharge of water through dripper. As the water level goes down lowering gravity pressure also affect the dripper discharge. Therefore, low evapotranspiration in the night also synchronizes the low water level in tank and low dripper discharge without affecting the wetting of pine grass. The grass mats generally will last for one year depending on quality used, hence should be replaced once in a year or earlier as per grass condition and quality.

The lid with holder at centre and circular holes for aeration is placed on top of the cooling chamber resting on inside surface of the water tank. The outer basket is also provided with two holders in opposite direction for lifting and moving the preservator units. Inside the cooling chamber, fruits or vegetables of different types can be staked in plastic removable trays to avoid mechanical damage, friction and to enhance aeration inside the cool chamber (Fig 10).

Fig. 9. Vegetable preservator (5 kg capacit)

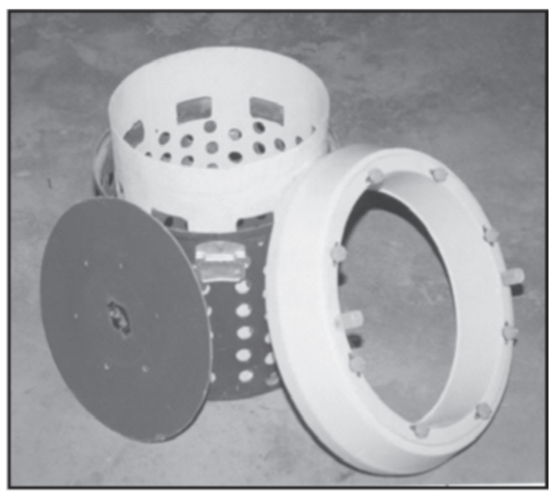

Fig. 10. Components of the Preservator

1. Outer body 2. Inner body 3. Water tank
4. Lid 5. Dripper 6. Aeration holes

Performance

The performance of a preservator device was evaluated to study the enhancement of shelf life of different type of vegetables/fruits, to study the impact of storage tank levels on discharge of drippers, correlation between ambient temperature and inside temperature during different seasons.

Shelf life of Vegetables and Fruits

The perishable products like tomatoes, brinjal, ladies finger, leafy vegetables, mangoes, grapes, guava, custard apple was studied under normal room temperature (Table 2).

Table 2. Shelf life of selected vegetables and fruits.

Vegetables/fruits	Shelf life (days)	
	Normal conditions	CRIDA Preservator
Tomato	4	10
Brinjal	4	9
Ladies finger	3	8
Leafy vegetables	2	7
Mango	4	10
Grapes	4	8
Guava	4	10
Custard apple	2	8

Leafy vegetables can be stored for about 7 days while tomatoes and some fruits can be stored safely for 10 days after harvest as compared to storage under normal room conditions. Thus, this device has opened a new vistas for small scale vegetable and fruit growers. The losses during handling, storage and transport can be saved to large extent and higher returns are imminent by enhancing marketability of product for longer period of time. However, it should be kept in mind that the product remains in good condition as long as it is inside the preservator for above period of time. It may start fast deteriorating once taken out from chamber after storage. Therefore, it is advisable that the product stored in preservator for few days should be immediately used or consumed after taking out from chamber.

Conclusion

Overall, it is concluded that the on farm storage facilities to be increased at small and marginal farmer's level for better value addition to their produce for self sustainability at village level.

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37 Biofortification: Improvement Zinc Contents in Rice Grains through Conventional and Molecular Approaches

V Ravindra Babu

Introduction

Rice plays a pivotal role in Indian economy being the staple food for two thirds of the population. With 44.62 million hectares, India ranks first in area, second in production with 31% of calories to Indian diet supplied through rice. Research efforts focused on development of high yielding varieties and adoption of modern production technologies witnessed impressive production leading to self sufficiency in the country. Next to yield, grain and nutritional quality has become the primary consideration in rice breeding programmes not only in India but also in various rice growing countries across the world. Rice bio-fortification programme aims at biological and genetic enrichment of food stuffs with vital nutrients (vitamins, minerals and proteins). Ideally, once rice is bio-fortified with vital nutrients, the farmer can grow the variety indefinitely without any additional input to produce nutrient packed rice grains in a sustainable way. This is also the only feasible way of reaching the malnourished population in rural India.

Using a plant breeding approach to address micronutrient malnutrition would provide a new 'tool' in combating the problem. The micronutrient-density traits are stable across environments. It will be possible to improve the content of several limiting micronutrients together. High nutrient density not only can benefit the consumer but also produce more vigorous seedlings in the next generation. Because of staple foods are eaten in large quantities everyday by malnourished poor adding of even small quantities of micronutrients makes the difference. Malnutrition is the most common cause of zinc deficiency and 25% of the world's population is at risk of zinc deficiency (Maret and Sandstead, 2006). In Asia and Africa, it is estimated that 500-600 million people are at risk for low zinc intake (HarvestPlus, 2010). Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system skin lesions, hypogonadism, and diarrhea (McClain *et al*., 1985). Males aged between 15-74 need about 12-15 mg of zinc daily while females aged between 12-74 need about 68 mg of zinc daily (Sandstead, 1985).

In this context, breeders are now focusing on breeding for nutritional enhancement to overcome the problem of malnutrition. Efforts are made at Directorate of Rice Research (DRR) to evaluate land races, basmati, non-basmati and high yielding rice cultivars collected from different parts of the country to study the iron and zinc in the grains and various varieties with relatively high iron and zinc in grains were identified and used in the breeding programme as donors and some fixed lines with high iron (>10 ppm) and zinc (>20 ppm) in the 10% polished rice were identified and are at testing stage in AICRIP system. The data on iron and zinc in brown, 5% and 10% polished rice of the popular varieties of India estimated on Varian Techtron AAS is furnished for the benefit of plant breeders.

Rice Grain

The structure of the rice grain is separated into three parts. The germ is the heart of the grain, which sprouts when the seed is planted. It is rich in B vitamins, vitamin E, protein, unsaturated fat, minerals, carbohydrates and dietary fiber. The endosperm constitutes the largest part of the grain. It is composed chiefly of carbohydrates in the form of starch, with some incomplete protein and traces of vitamins and minerals. The bran portion is the covering and is composed primarily of carbohydrate cellulose with traces of B vitamins (including thiamin, niacin and B-6), minerals (including iron, phosphorus, magnesium and potassium) and incomplete proteins (Table 1). The outer husk or hull is inedible but is often used for fuel or fertilizer (Trinkley and Fick). Rice grain average content is 80% starch, 7.5% protein, 0.5% ash and 12% water. The proportion of amylose and amylopectin in starch determines the cooking and eating qualities of the rice. In spite of the fact that rice is a primary source of carbohydrate, it is also a good source of protein, but it is not a complete protein, which means that it does not contain all of the essential amino acids in sufficient amounts for good health, and should be combined with other sources of protein, such as nuts, seeds, beans, fish, or meat (Wu *et al.*, 2003) in order to provide a balanced nutrient intake. As compared to the other cereals, rice contains low nutritional value. The nutritional status of the different cereals are presented in Table 2.

Table 1. Nutritional value of edible portion of rice per 100 gram.

Type of Rice	Energy (cal.)	Protein (g)	Fat (g)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Raw (milled	345	6.8	0.5	10	3.1	0.06	0.06	1.9
Parboiled (milled)	346	6.4	0.4	9	4.0	0.21	0.05	3.8
Flakes	346	6.6	1.2	20	20.0	0.21	0.05	4.0
Puffed	325	7.5	0.1	20	6.6	0.21	0.01	4.1

[Source: Nutritive value of Indian Foods, by Gopalan, C. et al., (1971), Indian Council of Medical Research Publication, pp.60-114].

Table 2. Micronutrient status of rice and other cereals

Crops	Protein	Iron (ppm)	Zinc (ppm)
Rice	6 - 7%	2 - 34	10 - 33
Wheat	13 -14%	25 - 55	25 - 65
Maize	8 -11%	10 - 63	13 - 58
Sorghum	10 -15%	10 - 65	14 - 55
Pearl Millet	6 - 21%	30 -146	25 - 85
Small millets: (Finger Millet, Foxtail Millet)	8 - 20%	37-142	5 - 60

Why Fortification?

- Healthy and productive populations require adequate amounts of essential vitamins and minerals. Food fortification leads to stronger, healthier people by providing appropriate amounts of vitamins and minerals. Global Impact of Malnutrition (Micronutrient Initiative and UNICEF).
- Malnutrition impairs millions of growing minds, lowers national IQ by 15%, causes damage to immune systems and deaths of more than a million children a year. The orange ribbon is designated as an awareness ribbon for malnutrition.
- Causes 200,000 serious birth defects annually.
- Contributes to the death of approximately 60,000 young women a year during pregnancy and childbirth.
- Burden of iron deficiency is the leading cause of anemia which reduces work capacity, impairs a child's physical and intellectual development and contributes to 20% of all maternal deaths.
- Iron deficiency is best known for causing fatigue and lethargy which would show adverse effects on the work force.
- Iron is also essential for a child's physical and mental development. Any cognitive skills a child loses early in life due to iron deficiency cannot be regained.
- Women are more likely than men to suffer from iron deficiency and women who are iron deficient are at greater risk of dying in childbirth.

- Fortification offers a number of strategic advantages like cost-effective, builds on existing technology, supports other public health strategies and finally enhances sustainability.

Biofortification:

The creation of plants that make or accumulate micronutrients is termed as Biofortification. Bioavailability is deûned as the amount of a nutrient that is potentially available for absorption from a meal and once absorbed, utilizable for metabolic processes in the body. Biofortiûcation, the delivery of micronutrients *via* micronutrient-dense crops, offers a cost-effective and sustainable approach, complementing these efforts by reaching rural populations. Being a genetic solution, growing biofortified crops does not require any additional expenditure for the farmers who grow them and hence the approach is highly sustainable. Biofortification could be effective in reducing the problem of malnutrition as part of a strategy that includes dietary diversification, supplementation, and commercial fortification among others.

Biofortification is the development of micronutrient-dense staple crops using traditional breeding practices and modern biotechnology. This approach has multiple advantages, including the fact that it capitalizes on the regular daily intake of a consistent amount of food staple by all family members. Staple foods predominate in the diets of all sections of people particularly the poor, hence biofortification strategy implicitly targets low income households. Thus biofortification can deliver naturally fortified foods to people with limited access to commercially marketed fortified foods that are more readily available in urban areas. In all crops studied, it is possible to combine the high micronutrient density trait with high yield economically. Predictive cost-benefit analyses show biofortification to be important for controlling micronutrient deficiencies. Getting consumers to accept biofortified crops will be a challenge, but with the advent of good seed systems, the development of markets and products, and demand creation, this can become a reality (Nestel *et al.,* 2006).

The Advantages of Biofortification Approach for Nutritional Improvement

Biofortification is Sustainable: By improving the nutritional content of the staple foods that poor people already eat, biofortification can be a sustainable method to deliver micronutrients to reduce malnutrition using familiar foods.

Biofortification is Targeted: Biofortification is an especially effective means of reducing malnutrition in rural areas, where about 75% of the poor live, and where they have limited access to supplements, commercially marketed fortified foods, or other urban-based interventions.

Biofortification is Cost-Effective: Unlike the recurring costs of traditional supplementation and fortification programs, a one-time investment in a biofortified crop can generate new varieties for farmers to grow for years to come, in many different countries. It is this multiplier aspect of biofortification, across time and distance that makes it so cost-effective an investment. There will be some recurrent expenditures for monitoring and maintaining high-micronutrient traits in crops, but these costs will be relatively low.

Need for Biofortification Especially in Rice:

- Global staple food, cultivated for over 10,000 years.
- Rice provides as much as 70 - 80 percent or more of the daily caloric intake of 3 billion people, which is half the world's population.
- The availability of large genetic variability in micronutrient concentration in grains of rice and its huge preference as a staple food by large population (Fig 1) particularly resource poor people in the world made it the candidate for biofortification purposes to enrich with crucial micronutrients (Graham *et al.*, 1999).

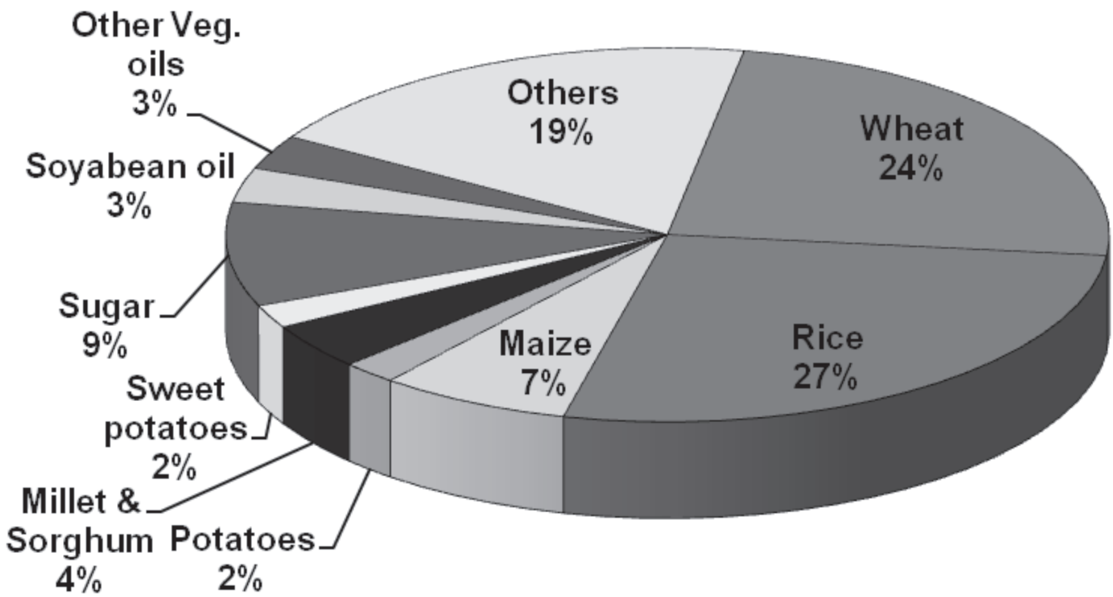

Fig. 1. Global Share of Dietary Energy Supply from Different Plant Sources
Source: FAO, 1996

Rice is a predominant staple food and a major source of dietary carbohydrate for more than half of the world's population (Zimmermann *et al.,* 2002). Unfortunately, it is a poor source of essential micronutrients such as iron, zinc and vitamin A. Modern agriculture had reasonable success in meeting the energy needs of developing countries. In the past 40 years, agricultural research in developing countries has met Malthus' challenge by placing increased cereal production at its center. However, agriculture must focus on a new paradigm that will not only produce more food, but bring us better quality food as well. Biofortification of staple food crops for enhanced micronutrient content through genetic manipulation is the best option available to alleviate hidden hunger with little recurring costs (Welch and Graham 2004; Monasterio *et al.,* 2007).

Even though the levels of carbohydrates are adequate in rice, parallel analysis of the levels and bioavailability of the other micronutrients in rice revealed that the levels are very low and consumption of rice alone cannot meet the Recommended Daily Allowance (RDA) for a range of vitamins, minerals and proteins. To overcome this, a genetic approach called Biofortification (Bouis, 2002) has been developed, which aims at biological and genetic enrichment of food stuffs with vital nutrients. Ideally, once rice is biofortified with vital nutrients, the farmer can grow the variety indefinitely without any additional input to produce nutrient packed rice grains in a sustainable way. This is also the only feasible way of reaching the malnourished population in rural India.

Using the plant breeding approach to address micronutrient malnutrition would provide a new tool in combating the problem. The micronutrient-dense traits are stable across environments. It will be possible to improve the content of several limiting micronutrients together. High nutrient density not only can benefit the consumer but also produce more vigorous seedlings in the next generation. As the staple are foods eaten in large quantities everyday by malnourished poor adding of even small quantities of micronutrients makes the difference. With the help of molecular markers, the loci associated with nutrient content in grains can be identified and used for Marker Assisted Selection in regular breeding programs.

The edible part of rice grain, the endosperm is filled with starch granules and protein bodies but lack several essential nutrients for the maintenance of health, such as carotenoids and other micronutrients. Rice breeders are expected to concentrate on increasing the total nutrient content in the endosperm of the grain, the part that remains after milling.

Malnutrition is the most common cause of zinc deficiency (Ronaghy, 1987). 25% of the world's population is at risk of zinc deficiency (Maret and Sandstead *et al.,* 2006). In Asia and Africa, it is estimated that 500-600 million people are at risk for low zinc intake (HarvestPlus, 2010). Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system (Solomons, 2003) skin lesions, hypogonadism and diarrhoea (McClain *et al.*, 1985). Males aged between 15-74 need about 12-15 mg of zinc daily while females aged between 12-74 need about 68 mg of zinc daily (Sandstead, 1985). Iron deficiency in humans adversely affects cognitive development, resistance to infection, work capacity, productivity, and pregnancy.In the last two decades, new research findings generated by the nutritionists have brought to light the importance of vitamins, minerals and proteins in maintaining good health, adequate growth and even acceptable levels of cognitive ability apart from the problem of protein energy malnutrition. In this context, breeders are now focusing on breeding for nutritional enhancement to overcome the problem of malnutrition. The range of iron and zinc concentrations in brown rice is 6.3 – 24.4 mg g^{-1} and 13.5 – 28.4 mg g^{-1} respectively. There was approximately a fourfold difference in iron and zinc concentrations, suggesting vast genetic potential to increase the concentration of these micronutrients in rice grains (Gregario, 2002). Major nutritional problems in rice consuming countries comprise malnutrition and deficiencies of iron, zinc and vitamin A. Targeting these traits, Directorate of Rice Research in collaboration with National Institute of Nutrition, Hyderabad started a bio-fortification programme and identified genetic variability for iron and zinc content in grains of rice germplasm and possibility of breeding to enhance iron and zinc contents in rice grains.

Several rice varieties and land races collected from different parts of the country and grown at RC Puram Farm, DRR and evaluated for their Iron & Zinc contents and samples were analysed at NIN, Hyderabad, whose iron content ranged from 6.9 ppm (DL 163) to 37.5 ppm (Varsha) and zinc content varied from 11.3 ppm (Karjat 3, IR 64) to 37.2 ppm (Phou Dum) in brown rice. Among them, about 10 varieties each with high iron and zinc content (Table 3 and Table 4) were identified and some of these lines were used in the breeding programme to develop high nutritional genotypes. Same samples were polished (5% and 10%) and loss due to polishing are also given. The percent loss due to polishing are presented in Table 6. In general, Basmati genotypes, deep water rices and land races were found to have high Iron and Zinc content in the grains (Table 5).

Table 3. Rice varieties with high iron content in grain

S.No.	Name	Grain Type	Fe (ppm) content in Polished Rice		
			0%	5%	10%
1	MSE-9	LB	34.4	12.4	10.8
2	Kalanamak	SB	34	12.1	10.9
3	Kanchana	MS	20.4	12.8	6.6
4	Karjat 4	MS	25.6	20.6	19
5	Chittimutyalu	SB	24.9	14	9.8
6	Udayagiri	SB	30.1	9.5	9
7	Jyothi	LB	19.8	14.9	4
8	VRM 7	SB	22.8	7.9	7.8
9	Metta Triveni	SB	26.1	7	7
10	Varsha	SB	37.5	11.2	8.1

Table 4. Rice varieties with high zinc content in grain

S.No.	Name	Grain Type	Fe (ppm) content in Polished Rice		
			0%	5%	10%
1	Chittimutyalu	SB	30.5	25.7	24.4
2	Poornima	SS	31.3	27.8	27
3	ADT-43	MS	30.9	26.6	20.9
4	Ranbir Basmati	LS	30.9	28.3	27.4
5	Type-3	LS	30.3	28.3	26.5
6	Udayagiri	SB	30.1	19.5	11.3
7	Ratna	LS	32.7	25.2	23
8	Jyothi	LB	31.3	22.4	20.6
9	Pant Sugandh 17	LS	32.5	24.7	20.6
10.	Kesari	MS	31.5	19.9	19.3

Table 5. Iron and zinc content in rice grains (brown rice)

Name	Grain Type	Fe (ppm)			Zn (ppm)		
		0%	5%	10%	0%	5%	10%
BASMATI TYPES							
Basmati 386	LS	14.8	13.1	9.5	30.3	27.7	25.9
Ranbir Basmati(R3)	LS	14.2	10.4	7.8	33.8	30.9	30.0
Type-3(R3)	LS	15.3	9.7	7.1	33.7	31.4	29.4
Kasturi	LS	11.3	8.3	5.8	34.3	25.4	24.9
PUSA BASMATI	LS	12.1	6.4	6.5	31.2	17.8	15.6
LANDRACES							
Chittimutyalu	SB	24.9	14.0	9.8	30.5	25.7	24.4
Nahazing	SB	16.8	9.0	5.3	33.6	26.1	23.4
Moirang Phou	SB	17.0	6.9	3.5	37.0	28.5	32.1
Phou Dum	LS	17.2	10.8	5.5	37.2	30.2	23.8
Munga	SB	25.4	15.8	8.0	35.0	28.7	19.6
DEEP WATER RICES							
Jalamanga	SB	25.8	7.0	5.3	28.2	17.5	16.3
Jagabandu	SB	10.1	6.9	5.7	26.6	23.1	21.9
Madhukar	LB	28.6	11.2	7.6	31.2	24.2	22.0
Jalapriya	LB	24.5	8.1	6.6	25.0	21.2	18.4
Dinesh	SB	11.9	7.8	4.7	28.1	25.7	20.0

Table 6. Percent loss of Fe and Zn after 5% and 10% polishing

	Fe content (ppm)	Zn content (ppm)
Brown rice:	4.9 to 22.5	17.4 to 33.1
5% polished rice: Loss: %	2.4 to 17.2 10.9 to 82.2	11.0 to 28.3 4.1 to 40.8
10% polished: Loss: %	1.1 to 11.2 26.9 to 90.7	11.6 to 28.4 14.2 to 44.4

The iron and zinc contents in brown rice as well as polished rice (5% and 10%) were varied in different varieties are presented in Fig 2 and 3 respectively. Some varieties showed very less loss even after polishing needs further study for their grain type etc.

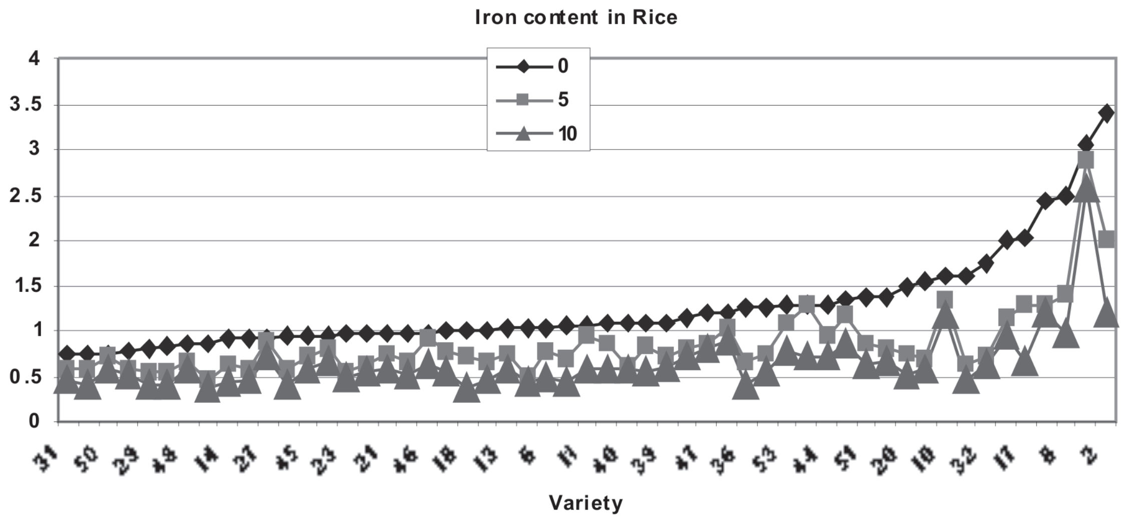

Fig. 2. Percent loss of iron in different rice genotypes after 5% and 10% polishing
Mean 12.9 ± 6.24; Range 7.5 – 34.4 ppm\

Compared to general availability there are varieties with good Fe content (ppm) in grains. Top 5 entries: Kalanamak (34.4), Karjat 4 (30.6), Chittimuthyalu (24.9), MSE 9 (24.4), Kanchan (20.4); Top 5 entries with less loss on polishing: ADT 43, Manoharshali, Karjat 4, Swarna, Seshadri

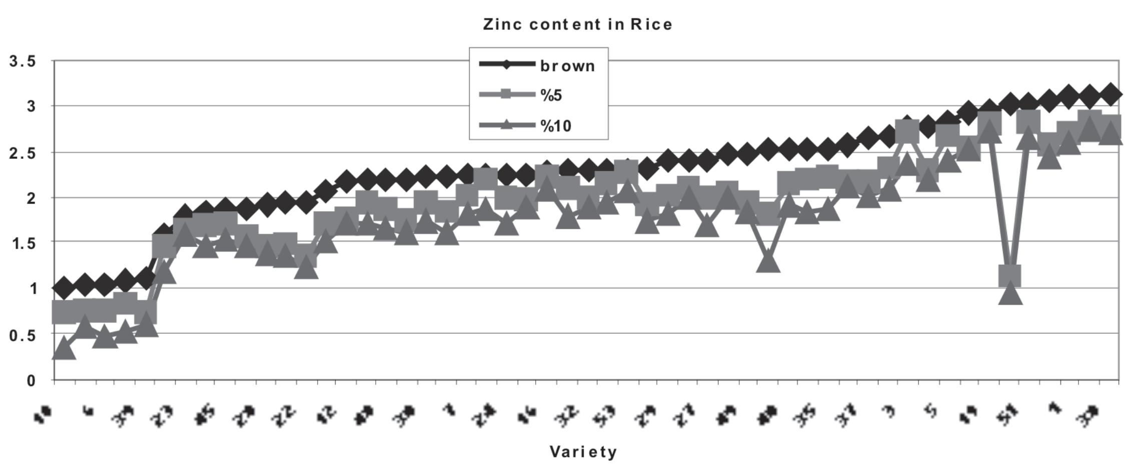

Fig. 3. Percent loss of iron in different rice genotypes after 5% and 10% polishing
Mean 22.7 ± 2.95; Range 10.1 – 31.3 ppm

Compared to general availability there are varities with good Zn content (ppm) in grains. Top 5 entries: Poornima(31.3), Ranbir Bas(30.9), ADT 43(30.9), Chittimuthyalu (30.5), Type 3 (30.3); Top 5 entries with less loss on polishing: White Ponni, Bas 386, Kanishk, Giri, Karjat 4.

XRF – the Magical Catalyst for Biofortification Work at DRR

Energy dispersive X ray fluorescence spectrometry (XRF) was gifted by Harvest plus programme to Directorate of Rice Research. It's principle involves, the expulsion of electron from innermost orbit followed by the transfer of one of the electron's from the outer most orbit to innermost orbit leading to release of specific energy which is simultaneously identified and quantified by the detector. This instrument is quite useful in non-destructive determination of relative iron and zinc concentrations in rice samples with more ease in comparison with atomic absorption spectrometry (AAS) and inductively coupled plasma mass spectrometry (ICP-MS). As AAS and ICP-MS, XRF involves certain maintenance guidelines like, dust free, air conditioned room, etc.

It was installed on 21-05-2012 and so far, ten thousand rice samples have been analyzed till 11-03-13. Since installation of this instrument has been serving the needs of scientists of the directorate and other Institutes/ Universities. Maximum Iron and Zinc values of rice samples used for standardization are comparatively less than some of our samples under trials. Due to this, there is variation in the values determined by this instrument in comparison with ICP-MS and AAS.

Correlation Between Yield and Iron/Zinc (Brown Rice)

Statistical Analysis (SAS) of 168 genotypes grown at four different locations revealed that there is no significant correlation between yield and iron content; yield and zinc content in brown rice

Achievement at DRR Through Conventional Breeding Approach:

Selections were made in the segregating populations and stabilized lines with high iron and zinc content with good quality and yield were identified. A line derived from the cross between BPT 5204 X Chittimuthyalu with short bold grains, semi dwarf with high yield potential (> 4.5t/ha) and medium duration with high iron (31.2 ppm) and zinc (40.0 ppm) in brown rice was identified (Fig.4) possessing good quality characters *viz.* good head rice recovery (67.5%), intermediate alkali spreading value (5.01), amylose content (24.05%) and mild aroma which was nominated to the AICRIP during kharif 2012 and some more fixed lines with high zinc are in the pipeline with different grain types to be nominated to the AICRIP for further testing (Fig 4).

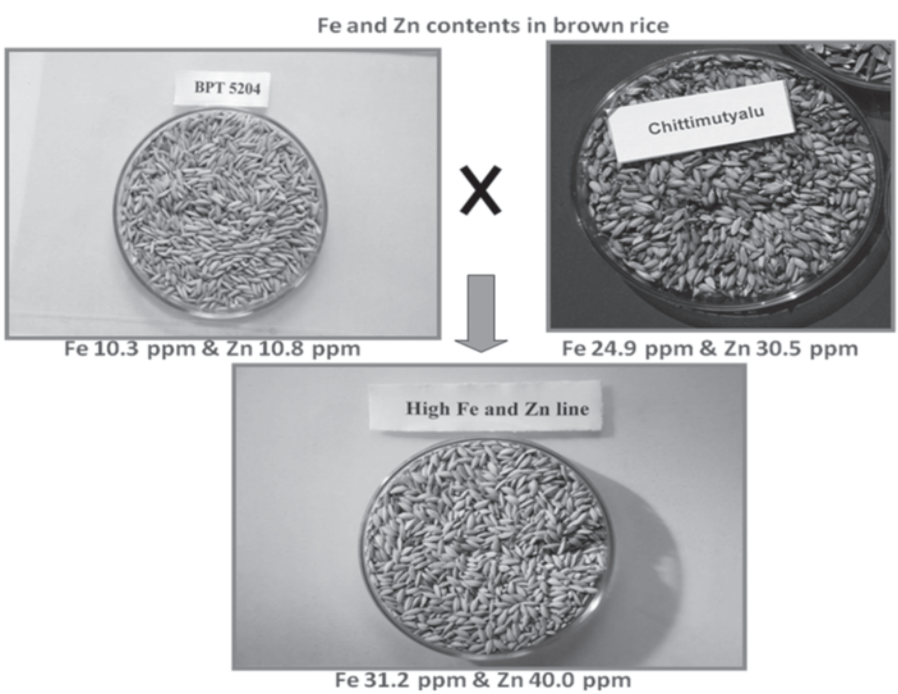

Fig. 4. Improved Chittimuthyalu with high iron and zinc content.

Conclusion

- The final permanent solution to micronutrient malnutrition is breeding staple foods that are dense in minerals and vitamins provides a low-cost , sustainable strategy for reducing levels of micronutrient malnutrition.
- Molecular marker technology expedites the development of rice varieties with improved iron and zinc content through identified genomic regions
- Information on iron and zinc content in brown and milled rice of national and international germplasm and identification of donors for their future deployment in the nutritional breeding programme and also to get mapping information on association of iron and zinc contents in grains.
- Rice lines in the genetic background of elite rice varieties possessing optimum concentration of zinc in the endosperm will be developed and released for cultivation.

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38 Food Chemical Risk Assessment

V Sudershan Rao

Introduction

Food safety issues could arise from chemical or biological hazards. Since biological hazards like food pathogens cause acute food borne illness like vomiting, pain abdomen, diarrhoea etc., they can be monitored by an effective food borne disease surveillance. In case of chemical contamination, it is very difficult to establish the cause- and-effect relationship as these contaminants are ingested in smaller concentrations over a period of time and do not usually cause any immediate effect. Globally consumers are usually concerned about chemical contaminants (like pesticide residues, toxic metals, bio-toxins and veterinary drug residues) as they are known to or suspected to be involved in causing cancers, reproductive disorders, birth defects, premature births, impeded nervous, sensory system development etc. Hence, the protection of diet from these hazards must be considered one of the essential public health functions.

World Health Organization (WHO) recommends carrying out Total diet studies for assessment of risk through chemical contaminants (Betsy *et.al.*, 2012). Risk assessment has four components - Hazard Identification, Hazard Characterization, Exposure Assessment and Risk Characterization. The information on the chemical hazards and their hazard characterization is mostly available. The most critical component is exposure assessment ie; to know how much of chemical contaminant is ingested through diet. In Total diet studies, chemical contaminants are estimated in foods in "table ready form", household processing is also taken into consideration. As the diets for different physiological groups like children, adults, pregnant women etc vary, so also the type and extent of contaminants' intakes. The contaminants intakes per kg of body weight is calculated and compared with Acceptable Daily Intakes/Tolerable Daily intakes.

Typical Indian Diet

On average, Indians gets 90% of their calories from basic commodities like rice, wheat, pulses etc and only 10% from secondary and tertiary processed foods. Therefore a major part of the diet is home-cooked food, prepared from raw and semi-processed foods. Typical food habits of Indians do not provide much scope for consumption of a large variety of foods thereby limiting the number of foods for consideration in a total diet study.

Another essential requirement for conducting the total diet study is the availability of food consumption data. In India the National Sample Survey Organization undertakes periodical surveys across the country of food consumption. The data is expressed in terms of per capita consumption, which does not provide information on different age and gender cohorts. The National Nutrition Monitoring Bureau (NNMB) is another agency, which performs diet surveys and reports food consumption data in selected states and has information on food consumption among different age groups and physiological strata. But the limitation of NNMB food consumption data is that it is carried out only in rural areas. There is no authentic data of food consumption from urban India.

Food Safety Issues in India

The food safety concerns in India are different from other countries due to the fact that dietary habits are so different. The foremost food safety concern among Indians is food adulteration (Sudershan *et al.*,2008). The concern for contaminants like pesticide residues and toxic metals in food and additives in processed foods is a more recent phenomenon.

A Pilot Total Diet Study in Andhra Pradesh

In order to standardize protocols for carrying out total diet study in India, Andhra Prdesh (combined state) was selected. Andhra Pradesh is the fifth largest State of India, and is often referred to as *"The Rice Bowl* *of India"*. Rice is the staple food, which is consumed in a wide variety of ways. A typical meal consists of cooked rice, vegetable curry, dhal and curd or buttermilk. Although more than 90% of population is non-vegetarian (Polasa *et al.,* 2006), rural areas are essentially vegetarian except in some coastal districts (Polasa *et al.,* 2009)

TDS sampling followed a stratified random sampling design to cover the entire state of Andhra Pradesh. The state was divided into three natural regions, i.e., Telengana, Andhra and Rayalaseema. From each of the regions, 2 districts were randomly selected and from each of the two districts, 2 mandals, i.e., districts, were randomly chosen. From each mandal, two market samples of each of the selected foods were collected along with 2 water samples. These samples belong to one of the TDS food groups. Four samples of each food from each district were collected. However, depending on the availability, the number varied. Thus a total of 503 samples were taken for analysis of contaminants. Since water is a component of food, water samples were also collected. The contaminants, namely heavy metals (lead, cadmium), fluoride, mycotoxins (aflatoxins B_1, fumonisin B_1, aflatoxin M_1 and T2 toxin) and pesticides were analyzed in food samples that were highly likely to contain the particular contaminant. From the above food lists, specific food-contaminant combinations that might result in high exposure were identified for analysis

Twenty-two types of foods belonging to eleven food categories were selected for the study. The choice was made on the basis of most commonly consumed foods in Andhra Pradesh as indicated by National Nutrition Monitoring Bureau 2006 (NNMB 2006) The food samples were prepared as they are normally consumed, that is "ready-to-eat", before they were analyzed. Standard methods were used for the analysis of the all the selected pesticide residues, heavy metals and mycotoxins.

Exposure Assessment of Contaminants

To assess the actual exposure of the contaminant, amounts ingested by all physiological groups were calculated. The mean concentrations of contaminants are expressed as µg per kg of food for all contaminants. The concentrations of contaminants in each foodstuff were an average of values from all the twelve mandals. Contaminant exposures were further expressed for each of the physiological group by multiplying the concentration in each food with the amounts of each food consumed. The exposures were expressed as mg per kg of body weight per week for toxic metals and µg per kg body weight per day for other contaminants. The estimated dietary exposures were then compared with the corresponding with their reference values given by Joint (FAO/WHO) Expert Committee on Food Additives and Contaminants such as the Acceptable Daily Intake (ADI), and Provisional Tolerable Weekly Intakes (PTWI). Mean contaminants concentrations were used in the exposure calculations as it provides an appropriate estimate of long-term exposure.

Exposure Assessment to Different Physiological Proups

Dietary exposure to a specific contaminant is dependent on the quantity of food consumed, which varies with age and gender. In order to assess the risk at different quantities of food consumed, dietary exposures were based on the following age and gender : 1-3 years, 4-6 years,7-9 years, 10-12 years, 13-15 years, 16-17 years, sedentary worker (Male), and pregnant women.

Food Composites and Dietary Exposure Assessment

The amount of foodstuff ingested directly determines the amount of contaminant exposure. Therefore, a percent contribution of all the foods to particular contaminants was assessed. The commonly consumed foods in Andhra Pradesh are very limited and if these foods are grouped as composites, they form 11 food composites. For accurate dietary exposure of the contaminants, the concentrations present in the cooked foods were added to the levels present in the amount of water needed for cooking the particular foodstuff**.** This gave the final exposure of the contaminants from the diet as a whole.

The exposure to select contaminants via the food composites has been assessed. The cereal and millet food composite was the major contributor of total DDT, aldrin, chlorpyriphos, cypermethrin, and cadmium in all cohorts. Milk and milk products were the major contributors of g-BHC in children 4-6 yrs, 7-9 yrs and also pregnant women. Milk and milk products, and cereals and millet made equal contributions (32% each) to the g-BHC exposure in 10-12 year children(Padmaja *et al.,* 2015). Groundnut oil and milk were the sole contributors of aflatoxin B_1 and aflatoxin M_1, respectively, to the diets of all cohorts. Most of the cadmium in pregnant women's diet comes from green leafy vegetables (Bhaskarachary *et al.*, 2014). Milk and milk products were chief contributors of lead to the diets of all cohorts(Polasa *et al.,* 2009) However, all the contaminants were well below their respective Acceptable Daily Intakes or Tolerable Weekly or daily intakes.

Exposure Assessment of Food Additives- A Case Study of Artificial Sweeteners.

There is a general perception among the consumers that consumption of artificial sweeteners is not safe. In recent years consumption of artificially sweetened foods and beverages became popular in India, with the regulatory formulations to use them in selected foods; their inclusion especially in sweets, biscuits and beverages has increased. So an exposure assessment has been carried to evaluate intake levels among high risk population for artificial sweeteners ie; Type II Diabetic, Overweight and Obese individuals. A cross-sectional study design was applied and a food frequency questionnaire was used to obtain the information on consumption of foods or beverages with artificial sweeteners. The quantity of sweetener and the amount of food or beverage consumed along with their body weight was collected. Range, Standard deviation and Mean daily intake levels were calculated. Results indicated that, the Mean daily intake levels of aspartame (0.85±0.75) were found to be high among type 2 diabetic individuals where as sucralose (0.41±0.41) and acesulfame k (0.07±0.02) were high among overweight group. There was a significant difference ($p<0.0001$) observed in intake levels among both groups. All the sweeteners were found to be well within their respective safe reference values ie Acceptable Daily Intakes (ADI) indicating there is no cause of concern with consumption of Artificial Sweeteners (Bhagyasri *et al.,* 2016).

Conclusion

The results of the total diet study reveal that the dietary exposures of contaminants investigated are generally much lower than the health references for all the age groups with average consumption. In specific cases, where the concentrations of contaminants were high or where the consumption of a particular food was high, the risk for toxicity may be higher. At maximum food consumption levels in certain physiological group, exposure to contaminants, like cadmium, significantly exceeded safe or tolerable limits. Similarly, in a case study of artificial sweeteners, even among the high risk population who regularly consume artificial sweeteners, there is no risk at the levels of their consumption. Initially, Total Diet studies were aimed at capturing the exposure assessment of food contaminants, but now it is realized that they are very useful even to understand exposures to nutrients and food additives (Betsy *et al.*, 2012). There is a need to carry out Total Diet studies in India at regular intervals to monitor the exposures to contaminants, nutrients and food additives to take appropriate steps to ensure food and nutrition safety.

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