Efficiency Centric Management (ECM) in Agriculture

Proceedings of National Symposium (October, 2014)

Editors:
Sunita T. Pandey, M.S. Negi, Rajeew Kumar, Amit Bhatnagar and Sumit Chaturvedi

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Dr. Mangla Rai
Vice-Chancellor

Foreword

Increasing agriculture productivity from the ever shrinking natural resources has become the focal point of agriculture development. Efforts are being made for optimum utilization of resources in agriculture sector but ways and means for increasing the efficiency of these resources are of paramount importance. The overall productivity of a farm depends on optimum, proper and timely utilization of natural as well as other external resources. The non judicious use of external inputs in agriculture is not only affecting the productivity of crops but also causing environmental pollution. The ever increasing population and allocation of land for non agricultural purposes has led to a situation where the only option left for safe, secure and profitable food production is to utilize the resources with utmost efficiency. The farmers of the country are desperately looking towards scientists to come out with prudent technologies that can increase the efficiency of inputs in agriculture.

The Agronomy Department of the G. B. Pant University of Agriculture & Technology, Pantnagar has been doing yeoman's service in the field of developing efficiency centric management technologies for the benefits of farmers. In this pursuit, the department organized a National Symposium on **Efficiency Centric Management (ECM) Technology for Safe, Secure and Profitable Food Production** from October 10^{th}-11^{th}, 2014 to give a common platform to all stakeholders, concerned with the cause of development of agriculture sector in the country. In the present scenario, every resource of agriculture production, requires maximum use efficiency. Hence, at this juncture, the book **"Efficiency Centric Management (ECM) in Agriculture"** edited by Dr. Sunita T. Pandey, Professor Agronomy, Dr. M. S. Negi, Associate Professor Agronomy, and Drs. Rajeew Kumar, Amit Bhatnagar, Sumit Chaturvedi, Assistant Professors, Agronomy would be a valuable contribution to understand the long term consequences of efficiency centric management of resources in agriculture. Different topics have been adequately covered by the experts in their field. It is noticeable that the implications of ECM of various production resources on environment and soil health have been discussed at length. The editors had an opportunity to compile the outcome of deliberations on efficiency centric management technologies for safe, secure and profitable food production in the form of an excellent book for the benefits of all stakeholders. I hope that this book will be a valuable base in the scaling up of the efficiency centric management of resources.

I congratulate the editors for their efforts in making such valuable information available for all those concerned for ensuring food security in the country.

(Mangla Rai)
Vice-Chancellor

Preface

Indian agriculture is facing many new challenges with the passage of time. The increasing population pressure is demanding more resources to meet out needs of people. The trade off for recourses between agriculture and non agricultural development has created an ironic situation. The land available for agricultural use is shrinking day by day, compelling to increase farm productivity. The resources are becoming costlier and limited. In this scenario providing safe, secure and profitable food production in the country is a challenging task. The only way out is to utilize the available resources efficiently to cope up with this situation. Minimizing the yield gaps, increasing profits and product quality are not possible by using single technology centric approach. The integration of component technologies in proper manner targeting towards increasing efficiency with time space and economy is considered to be effective way out in achieving descried levels of satisfaction in agricultural production. In agricultural production undesirable variables are to be managed in such as way that their ill affects could be minimized to the considerable extent. The over and non judicious use of inputs in agriculture has led to multifarious undesirable results like polluted environment, degraded soils, nutrient deficiency and sickening of soil health. The efficiency centric management technologies could provide the solution to all these undesirable changes that are being faced in recent years. The technologies that are efficiency centric could be utilized holistically in achieving higher and sustained productivity of crops and other components of farming system.

Thus, there is strong need to have a publication which contains information on various aspects of enhancing input use efficiency. This prompted the editors to bring out an edited book on **"Efficiency Centric Management (ECM) in Agriculture"** which is a collection & collation of latest knowledge for its wider dissemination & use for betterment of mankind. In this edited book efforts are made to compile all such efficiency centric management technologies which may lead to increasing productivity of agricultural production systems. It is our belief that this book will prove worthy to policy makers, planners, researchers, teachers, students, development agencies, NGO's, entrepreneurs and other stakeholders as a resource treasurer. We are sincerely grateful to the contributors of this book, who have made all possible efforts & extended all cooperation is bringing out this publication. The book comprises a wide spectrum of topics related to efficiency centric management covering Input Management, Integrated Forming System, Maximizing Fertilizer Use Efficiency. Precision Resource Management, Metaphysical Energy for Seed Invigoration, HOMA Therapy, HOMA Organic

Farming, Innovations in Tillage, Nanotechnology and other important aspects related to soil and environmental quality. On the one hand, given efficiency centric management technologies could be applied as such by the farmers and on the other hand, the book is helpful for scientist and policy makers in designing and planning agricultural developmental activities.

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Contents

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Efficiency Centric Management: An Overview

ARVIND KUMAR

Even passing decades of industrial development, India remains an agrarian country. At a time of decline in many countries, the agricultural population in India rose a whopping 50% between 1980 and 2011. Although agriculture's contribution to GDP has been falling, it has a far more important role in the Indian economy than its share of GDP suggests. Farming employs about half of the nation's workforce and provides a livelihood to about two-thirds of the population. Moreover, almost half of the average Indian household's expenditure goes towards food, which is an important factor in inflation and thus the nation's chronic poverty. Although a net exporter of agricultural products, India still depends on imports for essential items like pulses and cooking oil. Food self-sufficiency is not out of the question, yet food security at the micro level remains elusive. The agricultural sector's ongoing performance struggles are cause for concern in terms of food and income security as well as rural poverty eradication. We all know the 20th century was marked by unprecedented human achievements in a range of endeavors. Yet, at the beginning of this century, widespread poverty, chronic hunger, malnutrition, disease, conflict and severe environmental degradation made the goal of sustainable development appear elusive. The human family has been facing formidable challenges. The most important challenge is the world's ability to feed its inhabitants. Efficiency centric agriculture is the sector that provides solution to this challenge. In my Opinion**,** it is also the sector that is affected most by climate change. In the circumstances, transforming agriculture through efficiency centric management technology is essential for increasing and sustaining agricultural productivity, protecting the environment and meeting the challenges of reducing hunger and poverty. Agriculture is still the engine of growth for many countries in the world and India is no exception. Unfortunately, agriculture is one of the important economic sectors that is most affected by natural disasters. I would say, estimates about India indicate that around 60% of the country's land mass is vulnerable to earthquakes of various intensities; over 40 million hectares is prone to floods; 68% to droughts; and, 8% to cyclones. Often, agricultural activity is adversely affected by any unforeseen weather changes or variations in physical conditions that influences plant growth, health and productivity. The adverse impact of a disaster on agriculture get accentuated in case of cyclones, floods, and droughts, not only resulting in disruption of people's livelihood, but also adding to the risk, damage and stress associated with the disaster. Susceptibility of agriculture to these disasters is compounded by the outbreak of epidemics and man-made disasters such as fire, incidence of spurious seeds, fertilizers and pesticides, price fluctuations, etc., which severely affect farmers through loss in production and farm income. Disaster management is therefore extremely important in agriculture sector.

As a climate change hotspot, emergent climate phenomena seem to be aggravating the agrarian distress in India. An estimated 70% of the country's arable land is being prone to drought, 12% to floods, and 8% to cyclones. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change predicts that a temperature rise would result in a significant drop in Indian agricultural yield. Given that about 250 million Indians lack food security, the challenge is to produce enough food "sustainably" to meet the increasing demand, despite shrinking resource availability. While the sector is highly vulnerable to climate change, agricultural production is a major contributor to the problem, accounting for 17.6% of gross emissions in India. Add emissions related to consumption and that figure rises to 27%. Thus, as an economic activity, agriculture emerges as not only less productive but also highly carbon intensive – hardly the ingredients of a sustainable scenario. In keeping with its global position and trends in the developed world, India seems to be prioritizing the energy, industry and transport sectors for low-carbon development. However, there seems to be growing recognition of agricultural mitigation opportunities in developing countries, as evident in the recent Nationally Appropriate Mitigation Actions. As part of its climate action plan, India has already set up a dedicated Mission, the National Mission for Sustainable Agriculture (NMSA), to promote "sustainable agriculture," seeking to "transform Indian agriculture into a climate resilient production system through suitable adaptation and mitigation measures in the domain of crops and animal husbandry." NMSA has been partly successful in identifying the challenges faced by agriculture and how they will be exacerbated in a changing climate. Yet it has failed to find innovative solutions. While aiming to promote resource-efficient technologies, it has not addressed unhealthy agricultural practices. Moreover, it seems to be targeting the big farmers, who can afford the new technologies, leaving the small and marginal farmers vulnerable for which efficiency centric management technology is the need of the time. Already, somewhere between 900 million and a billion people are chronically hungry, and by 2050 agriculture will have to cope with these threats while feeding a growing population with changing dietary demands. This will require doubling food production, especially if we are to build up reserves for extremes. To do this requires sustainable intensification getting more from less on a durable basis. Farmers must work to increase productivity of their lands in a sustained manner using efficiency centric management technology thus bringing about an 'evergreen' revolution. The revolution must result in a doubling or tripling of productivity and not merely an annual 'evolving' single-digit increase. Even while applying their traditional wisdom that "the maiden Earth will laugh at the sight of those who plead poverty and lead an idle life". Farmers' enthusiasm too is important. They must be guided not to go for genetic homogeneity in crop selection, since their crops would become vulnerable to particular diseases. Variety of crops is thus very important.

Let me say, the critical nature of agriculture with respect to rural transformation and the national economy requires substantial governmental and financial sector interventions in order to not only ensure the food and nutritional security of households in the farming community but also generate savings and investments in this grossly under-funded sector.

Food Security

Food Security in short-term to long-term remains India's major priority and this requires efficiency centric agriculture production systems to change in the direction of climate-smart agriculture that will be centered around the small-scale farmer and enhance sustainable productivity of land, water, energy and other resources. Local-level economic, environmental and social sustainability concerns must be embedded into agricultural policies, practices and efficiency centric technologies through innovations. With world population growing by leaps and bounds (6.91 billion) rapid urbanization, agricultural lands becoming industrial parks and satellite towns, changing weather patterns, and environmental pollution, food security has become a growing challenge today. Governments around the world, Environmentalists, NGOs, researchers and world organizations are taking all-out efforts to ensure sustainable food production and food security. Food security is not just a problem of increasing production. It is a problem of improving access. It is a problem of equitable distribution, and it is also a problem of enhancing effective demand of the poorest of the poor for food.

Climate Change

Participants from central, state and local government organizations, international and regional organizations and institutions, academic and research institutions, nongovernmental organizations, as well as farmers, met throughout 2010 under a series of consultation workshops (Bundelkhand, April 2010; Maharashtra, July 2010; and Tamil Nadu, November, 2010) organized by - MS Swaminathan Research Foundation, Development Alternatives, Watershed Organization Trust (WOTR), National Bank for Agriculture and Rural Development (NABARD), International Union for Conservation of Nature (IUCN), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and Swiss Agency for Development and Cooperation (SDC) under the aegis of National Policy Dialogue on Climate Change Actions - linking voices of communities and their call for policy action and develop a roadmap for action, In pursuit of the ultimate goal of finding solutions to climate change, in accordance with National Action Plan on Climate

Change and by linking voices and lessons of grass root communities to policy dialogue, science and knowledge sharing, Have agreed on this Action Plan for policy makers as an expression of commitments to take forward, enhance and enrich the implementation of the National and State Action Plans on Climate Change, which will be People-centric and result in People led actions by internalizing this as part of policy making process. Maintaining Ecosystem Resilience is essential for an inclusive growth. So actions to combat climate change must focus on efficiency centric ecosystem based approach to augment human security and to manage natural resources sustainably, consistent with traditional knowledge and science.

Traditional Practices

The modernization is crucial for development, yet some traditional practices are more efficient. Land leveling, mulching, and crop diversification are all traditional practices that reduce the need for input resources like water and fertilizer. Farmers often neglect them, partly to avoid the extra labor and partly because they don't understand the benefits. Yet these inexpensive practices reduce the need for inputs, and also help prevent erosion, preserve soil nutrients, suppress weeds, and increase fertility. Crop residues that are mostly burnt in the field, contributing to emissions and local air pollution, can be used productively as mulch. Similarly, agroforestry as a farming practice has tremendous benefits for productivity, resource efficiency, adaptation, and carbon sequestration. More modern practices like soil fertigation and systemic rice intensification can further improve resource use efficiency and productivity.

Farmers around the world will need to produce more food and other agricultural products on less land, with fewer pesticides and fertilizers, less water and lower outputs of greenhouse gases. This must be done on a large scale, more cheaply than current farming methods allow. And it will have to be sustainable that is, it must last. For this to happen, the intensification will have to be resilient. Developing resilient agriculture will require technologies and practices that build on agro-ecological knowledge and enable smallholder farmers to counter environmental degradation and climate change in ways that maintain sustainable agricultural growth. Examples include various forms of mixed cropping that enable more efficient use and cycling of soil nutrients, conservation farming, micro dosing of fertilizers and herbicides, and integrated pest management. These are proven technologies that draw on ecological principles. Some build on traditional practices, with numerous examples working on a small scale. In Zambia, conservation farming, a system of minimum or no-till agriculture with crop rotations, has reduced water requirements by up to 30 per cent and used new drought-tolerant hybrids to produce up to five tons of maize per hectare (five times the average yield for Sub-Saharan Africa). The imperative now is scaling up such systems to reach more farmers.

Soil and Nutrients

Soil erosion is a serious problem under rain-fed agriculture. In India, it has been estimated that more than 5 billion tons of soil is washed away every year taking away with it more than 6 million tons of nutrients. Hence, adoption of efficiency centric management technology for soil and moisture conservation practices which would restore and stabilize the productivity of agriculture is essential. In improving the food accessibility through increasing purchasing power and food utilization, I can say, the current programs of the Government of India such as the Public Distribution System reinforced by the National Food Security Act, National Rural Employment Guarantee Act and the Integrated Child Development Services are the largest safety net programs in the world. I would like to share with the audience here, following efficiency centric management techniques, developed through Research to retain the surface layers of lands in their respective places.

- **Cover crops:** Cover crops play a vital role in controlling erosion by shielding the soil surface from the impact of falling raindrops, holding soil particles in place, preventing crust formation, improving the soil's capacity to absorb water, slowing the velocity of runoff and removing subsurface water between storms through transpiration.
- **Green manure:** Crops grown as green manure add nitrogen to the soil, increase the general fertility level, reduce erosion, improve the physical condition of the soil, and reduce nutrient loss from leaching.
- **Precision farming or precision agriculture:** Precision agriculture management practices can significantly reduce the amount of nutrient and other crop inputs used while boosting yields. Farmers thus obtain a return on their investment by saving on fertilizer costs. Precision agriculture can be the cornerstone of sustainable agriculture, since it respects crops, soils and farmers
- **Zero Budget Natural Farming:** Quite interestingly, there is a new concept emerging in India called "Zero Budget Natural Farming (ZBNF). The fundamental principle underlying natural farming is that everything is connected to everything else on earth, as every function is served by many elements and every element has many functions. The relative placement of elements is thus an important key to the success of this method and requires a minutely detailed observation of nature in order to recreate in the fields the same kind of symbiosis, of interactivity between the plants. Natural Farming is based on the following four principles:

I. **Zero budget farming:** The production cost for the farmer is zero as no input needs to be purchased. The nutrients are taken from the soil air, water and solar energy by the plant, and there is no need to add fertilizers. These nutrients provided by nature (as in the forest) are totally free of cost. The farmer uses his own seeds and protects the crop with natural products that he collects himself so that he does not have to buy either chemicals or seeds.

II. **Natural inputs:** Natural farming does not require chemical inputs or organic compost like vermiculture but promotes a natural catalyst of biological activity in the soil and natural protection from diseases by application of local cow dung.

III. **Mulching:** It is necessary to create the micro-climate under which micro-organisms can best develop, Mulching indeed conserves humidity of the soil (therefore diminishing the need for (irrigation), cools it and protect its micro-organisms.

IV. **Multicropping:** Intercropping, multicropping or mixed cropping is the cultivation of two or more crops in proximity in the same field, based on the assertion that there is complementarity between plants. Natural farming enhances the efficiency of the soil and its nutrients utilization through this complementarity between the crops.

V. **Integrated Farming:** For a farmer who depends on rains, conserving every drop of water by increasing moisture retention in the soil is important. To achieve this he should integrate mixture cropping, tree growing and animal breeding. Thus, the by-product of one unit will serve as input for another leading to efficient Labor utilization.

- **Organic farming:** It is gaining prominence as sustainable alternative in reviving Indian agriculture and there is sufficient manpower and infrastructure to promote organic farming in the country.
- **Cultivation of nutri-cereals:** Ragi and bajra, which are nutritionally rich and could redress 'hidden hunger', should be propagated among farmers.

Water Use

Efficiency centric climate-resilient management requires Smart Water policies with equal emphasis on supply augmentation and demand management. In the case of supply, emphasis has to be placed on augmentation and conservation of water resources through indigenous community based management practices and policies involving rainwater harvesting and watershed management. Demand side management should focus on more efficient irrigation systems, institutional and management support in efficient application of water, crop-water budgeting and planning, alternative technologies, and economic instruments for improving water productivity, all the while respecting the need for domestic and livestock water use.

Water is critical for agricultural development. The availability of irrigation water is inadequate and susceptible to climatic change, while prevailing irrigation patterns are highly inefficient and energy intensive. Improving the management of irrigation water would help. Substantial cuts in water demand could be achieved by adopting efficient irrigation technologies such as the drip and sprinkler, and much of the remaining demand could be met by extending and enhancing the surface irrigation network. Sustained rainwater harvesting and groundwater recharge initiatives, combined with better irrigation pump efficiency, could also contribute. These initiatives will raise resilience to looming water scarcity without compromising productivity, with co-benefits that include reduced energy consumption and lower methane emissions from flood irrigation.

Optimizing the agronomic factors that may contribute to improved use of water (crop and variety selection, planting date, tillage, fertilizer application and harvest techniques) may conflict with minimising water losses. Maximizing rainfall effectiveness and optimizing the use of stored soil water may be as important as minimizing irrigation losses. Generally though, for a fixed production system, the system with the lowest losses will have the highest water use efficiency. When assessing efficiencies it is not only the physical aspects of the irrigation system that are of concern but also other emergent properties, such as the service industries that develop as a direct result of the presence of the irrigation scheme. Considering these factors adds to the complexity of an already complex problem but highlights the need for a multidisciplinary approach that considers the economic and social aspects as well as the physical. Adding further to the complexity of the problem is the farmer's view of the success of an irrigation scheme. This view will depend on where in the system they sit and may be very different to the views of the operators of the system. In turn these views may be diametrically opposed to the view of society in general. Therefore an approach is required that tries to avoid formulating a solution from one perspective while excluding all other perspectives.

Energy

Enhancing the use of clean and efficient energy services is critical for social and economic development and moving people out of poverty. Addressing the energy poverty in India is an opportunity for low-carbon development and in this context there is a need for strong emphasis on inclusion of decentralized generation and distribution of energy services, coupled with institutional frameworks that are coherent with the centralized production and distribution and promote stakeholder engagement and community participation to ensure that energy needs are fulfilled. The Agricultural Demand-Side Management program, another narrowly technology-centric approach, seeks to replace existing irrigation pumps with energy-efficient models, reducing electricity consumption by a fifth. The new pumps are apparently capable of drawing more water with the limited electricity supplied to Indian farmers. But water demand in India is much higher than what currently extractable, so improving pump efficiency is will increase water use and further deplete the groundwater table. That in turn will raise the horsepower of pumps needed to draw water from greater depths. More horsepower means more electricity consumption.

Risk Management

The major climate threat to agriculture is increased stress on already scarce resources, raising the vulnerability of agriculture dependent communities. An effective adaptation efficiency centric strategy would seek to boost resilience by preparing communities to deal with resource scarcity and extreme events through sustainable alternatives and resource use efficiency. Likewise, mitigation in agriculture would require improved efficiency in resource consumption so that induced stresses, extreme events, and their intensity can be attenuated. In that sense, both adaptation and mitigation have the same goal, seeking to achieve sustainability in agricultural consumption and production. Mainstreaming Climate and preparing vulnerability profiles will assist in developing appropriate efficiency centric strategies and in dealing with reducing risks from climate-induced disasters and extreme weather events. In this regard, following actions are proposed:

i. Communicating science of climate change and its impact on communities by systematically incorporating climate information and climate risk management in decision-making processes at panchayat, block, district and state level;

ii. Investing in building climate information infrastructure such as Agrometeorology services and early warning system and their dissemination;

iii. Setting up a cadre of climate managers at grass-root level as key operating institutional and human resource mechanism; and

iv. Building capacities of existing and new government institutions to support community actions.

Emission from Deforestation and Forest Degradation

Innovative efficiency centric initiatives are needed in critical ecosystems such as Eastern and Western Himalayas, Central India Landscape, Terai Arc Landscape and Western and Eastern Ghats to provide positive incentives for community participation in conservation of forest resources. For achieving these people-centric actions, following enabling and crosscutting measures need to be undertaken:

i. There is need for field-laboratory interactions, focused Research and Development on ecosystem vulnerability and various aspects of adaptation to climate smart agriculture, specifically the effects on Himalayan, Arid and Semi-arid and Coastal ecosystems. It is important to address knowledge gaps in many areas, e.g. efficiency centric sea water farming.

ii. Additional Education and Extension Services on the effects and risks of climate change as well as ways on how to adapt to it need to be created so that communities are kept informed and aware of all developments in this field in real time. One effective way for long term awareness would be to include the subject in school and college curricula

iii. Insurance needs of rural people need to be seen in a holistic manner, covering both livelihood and health risks. There are efficiency centric practices available, which need to be scaled up and replicated.

iv. Establishment of a National Eco-technology Mechanism to accelerate climate efficiency centric management technology development and transfer in support of action on adaptation and risk mitigation.

v. Scaled up, new and additional, and adequate national and international Financial Mechanism as well as improved access to financing through suitable institutional structure, and using a combination of public and private financial sources, needs to be established.

vi. It is important to set-up measurable targets and appropriate monitoring and reporting mechanisms

Livestock

It is a major contributor to India’s food basket and accounts for 40% of agricultural emissions. Yet it gets no mention in India’s low-carbon strategy. Productivity in the livestock subsector is highly vulnerable to temperature rises, let alone the impacts of extreme events. However, simple interventions like feed quality improvement and health and reproduction management, achievable through efficiency centric management and improved extension service, have the potential to increase productivity, improve resilience, and slash emissions. Dairy industry in India is undergoing a phase of metamorphosis, when age long back yard farming is rapidly vanishing and commercial dairies are replacing them. Efficiency centric nutrition based farming is making ways while medicine centric management is becoming oblivious. Cost optimization is thought out at every stage of dairy farming. Labor shortage is giving ways to farm mechanization. All of them have opened door for new technologies like efficiency centric management technology, which can reduce cost and increase farm productivity and profitability.

Subsidies

Agricultural electricity and fertilizer subsidies, though lower than global standards, have contributed to significant inefficiencies in India. Broader agricultural subsidy policies and food procurement policies must be realigned to value scarce resources, and should incentivize resource-use efficiency and conservation in agriculture. For example, better support prices for water-efficient crops and varieties could encourage their adoption, while substituting regressive energy and fertilizer subsidies with subsidies for efficiency centric irrigation technologies could help poorer farmers.

Human Resource

Economic, social and cultural development of any country mostly depends upon its human resource potential. Many of the countries are endowed with same level of natural resources, technology and international aid etc. Their productivity and development mostly depends upon the availability of efficiency centric human source and more importantly, the commitment of such resource. Another recent development that has taken place is shifting importance from manufacturing organizations to service-oriented organizations, which have resulted in growing importance of the human resource. The depreciation that results in all other factors of production in the long run doesn't result in case of human resource. Human resources with proper organization and motivation can grow and develop their potential in the long run. There is no depreciation value for human resource

Grading, Standardization and Storage

Spreading awareness about Grading and Standardization aspects of agricultural products is essential for promoting quality consciousness among the farming community, entrepreneurs and other market participants. This would enable them to compete in the domestic and world market for better price realization. Farmers must be extended help in marketing their produce and assured of good remuneration. There also has to be a sufficient number of godowns to store crops, to prevent wastage of food.

Opportunity for the New Government

The challenges are not insurmountable. Indeed, they are an opportunity for the new government to prove its commitment to faster, sustainable and inclusive growth. The National Democratic Alliance was roundly criticized for its underperformance in agriculture during its last stint in power (1998-2004). It now has a chance to do better. While the Congress-led United Progressive Alliance government did better in the past decade, it fell well short of achieving a sustainability agenda. Prime Minister Narendra Modi has an opportunity to better, giving agriculture its rightful place in India's development policy agenda. While it may be politically infeasible and socially unacceptable to take a mitigation-first approach, the new government can plan a development-first strategy for agriculture with clear adaptation and mitigation co-benefits.

Conclusion

In the coming decades, feeding a growing population will demand ingenuity and innovation, to produce more food with fewer resources in efficiency centric manner. India's obsession with grain production as a means of food security is flawed, and has led to crippling price inflation and nutrition deficiencies. For accelerated growth and food security, policymakers need to adopt a demand-driven approach, accounting for local political-economy and environmental contexts. Agriculture must transform to adapt an efficiency centric management for food demand and reduce emission intensities per output. An efficiency centric management strategy is needed to achieve the triple wins of development, adaptation and mitigation. We have seen some of those great human costs – people going hungry all over the world despite some of the richest farmlands. Some of the policies might have led to counterproductive consequences in various periods. Yet, we need to understand these issues and to do that we need to stop and think through certain issues. This forum is for understanding these issues. Here, several empirical questions need to be asked as we are truly interested in the well-being of others, rather than in excitement or a sense of moral superiority for ourselves. For those who are willing to stop and think, this conference has provided some tools for evaluating technologies, policies and proposals in terms of their logical implications and empirical consequences. If this paper has contributed to that end, then it has succeeded in its mission.

2

Efficiency Centric Management Technologies can Usher in Second Green Revolution in India

V.C. Dhyani and Sumit Chaturvedi

Even after several years of industrial development, India remains an agrarian country. At a time of decline in many countries, the agricultural population in India rose a whopping 50 per cent between 1980 and 2011. Although agriculture's contribution to GDP has been falling, it has a far more important role in the Indian economy than its share of GDP suggests. Farming employs about half of the nation's workforce and provides a livelihood to about two-thirds of the population. Moreover, almost half of the average Indian household's expenditure goes towards food, which is an important factor in inflation and thus the nation's chronic poverty (Swain, 2014). Silver-lining is that enough food now is produced in our country and we never experienced 'begging bowl' like situation after seventies. Much of the credit goes to widely talked about green revolution.

First Green Revolution in the sixties accelerated the yields of major food crops such as paddy, wheat, millets and oil seeds, particularly in irrigated areas of Northwest India. It was launched to ensure food security through mass agricultural production as there was severe scarcity of food in the country.

According to Swaminathan, 1968 intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened prior to the Irish potato famine of 1845 and the Bengal rice famine of 1942. Therefore, the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity." All these consequences predicted by Swaminathan in the sixties proving to be true fifty years after. Pingali (2012) enumerated several drawbacks which Dr. M S Swaminathan had predicted 50 years back. He observed that Green Revolution contributed to widespread poverty reduction, averted hunger for millions of people, and avoided the conversion of thousands of hectares of land into agricultural cultivation. He further stated in a series of his and others' publications that the negative consequences of green revolution were not merely because of technologies but also due to faulty policies accompanied them. Still in those areas where green revolution was successful, it was not able to get rid of problems of poverty, inequality etc. An interesting development to note that green revolution driven intensification saved new land from conversion to agriculture, a known source of greenhouse gas emissions and driver of climate change, and allowed for the release of marginal lands out of agricultural production into providing alternative ecosystem services, such as the regeneration of forest cover (Millennium Ecosystem Assessment, 2005). High yielding varieties more responsive to external inputs were central to the productivity achievements; however, in many cases, appropriate research and policies to incentivize judicious use of inputs were largely lacking (Pingali, 2007). Unintended consequences in water use, soil degradation, and chemical runoff have had serious environmental impacts beyond the areas cultivated (Burney, 2010). The slowdown in yield growth that has been observed since the mid-1980s can be attributed, in part, to the above degradation of the agricultural resource base. These environmental costs are widely recognized as a potential threat to the long-term sustainability and replication of the Green Revolution's success (Pingali and Rosegrant, 1994).

These problems are aggravated due to poor efficiency of doing agriculture by us. These inefficiencies are seen in every field like low energy efficiency, low labour productivity, low nutrient use efficiencies, low irrigation efficiencies, poor agricultural marketing efficiency, poor safety standards, disparity within states, lack of policy support to rainfed areas etc. Unless water-use efficiency is increased, greater agricultural production will require increased irrigation. However, the global rate of increase in irrigated area is declining, per capita irrigated area has declined by 5% since 1978, and new dam construction may allow only a 10% increase in water for irrigation over the next 30 years (Postal *et al.*, 1996). Solutions to problems stated earlier will require significant increases in nutrient-use efficiency too, that is, in cereal production per unit of added nutrients (Tilman *et al.*, 2002).

To achieve all these we need to create a second green revolution in the near future but with a focus on rainfed and marginal areas where farmers are resource poor. Emphasis also should be given to irrigated areas so that resources should be used with greatest efficiency. The second Green Revolution should aim at promoting sustainable livelihood, enabling the poor to come out of poverty by generating gainful self-employment, and above all making agriculture profitable and environmentally sound. Thus the second green revolution should focus on efficient production by masses rather inefficient mass production.

Decoupling Concept

The concept of resource decoupling given by OECD will be very important for agricultural development as we want to have higher production but with reduced environmental impacts. Above goals of second green revolution will be achieved only if we stick to concept of decoupling.

The Organization for Economic Co-operation and Development (OECD) appears to have been the first international body to have adopted the concept of resource decoupling, treating it as one of the main objectives in their policy paper 'Environmental Strategy for the First Decade of the 21st Century' (adopted by OECD Environment Ministers in 2001). The OECD defines decoupling simply as breaking the link between 'environmental bads' and 'economic goods'.

Resource decoupling could be referred to as increasing resource productivity, and impact decoupling as increasing eco-efficiency. Resource decoupling means reducing the rate or use of (primary) resources per unit of economic activity. This 'dematerialization' is based on using less material, energy, water and land resources for the same economic output. Resource decoupling leads to an increase in the efficiency with which resources are used. Such enhanced resource productivity can usually be measured unequivocally: it can be expressed for a national economy, an economic sector or a certain economic process or production chain, by dividing added value by resource use (e.g. GDP/ Domestic Material Consumption). If this quotient increases with time, resource productivity is rising. Another way to demonstrate resource decoupling is comparing the gradient of

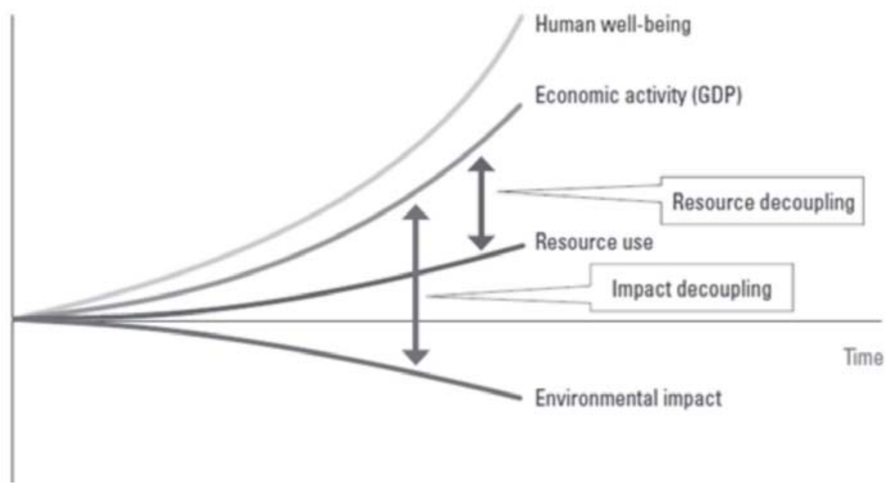

Fig. 1: Two aspects of 'decoupling

economic output over time with the gradient of resource input; when the latter is smaller, resource decoupling is occurring (Fig. 1). Impact decoupling, by contrast, requires increasing economic output while reducing negative environmental impacts. Such impacts arise from the extraction of required resources such as groundwater pollution due to mining or agriculture, UNEP, 2011.

Thus in view of decoupling concept it seems that the second green revolution would be made possible through combination of better agronomy, genetic yield enhancement through conventional breeding and biotechnology and very importantly through good policies.

Better Agronomy

Better agronomic management include, better nutrient management, better water management and better management of problem soils so that applied inputs can be utilized with full efficiency.

Nutrient Management

Despite several years of concerted efforts, our nutrient use efficiency particularly N use efficiency is very low, well below the standards of developed countries. Here attempt is made to let people understand that there is lot of disparity in input use in our country and increase in input use does not mean corresponding increase in crop yields, rather same or even higher yields can be achieved by (reducing input use also) improving use efficiencies of the different inputs. It is also worth noticing that irrigated areas consume significantly larger amount of fertilizers (Fig. 2) compared to what it contributes towards total food basket of the country compared to rain fed areas. Large amount of input saving in the irrigated areas can be diverted towards areas lacking in input use. These areas are mostly rainfed area of the country. There are several ways by which fertilizer use efficiency can be increase and fertilizers can be saved.

Since 1980-2010 in the USA, NUE (expressed as PFP for fertilizer-N applied to maize) has undergone steady improvement over the past three decades, driven

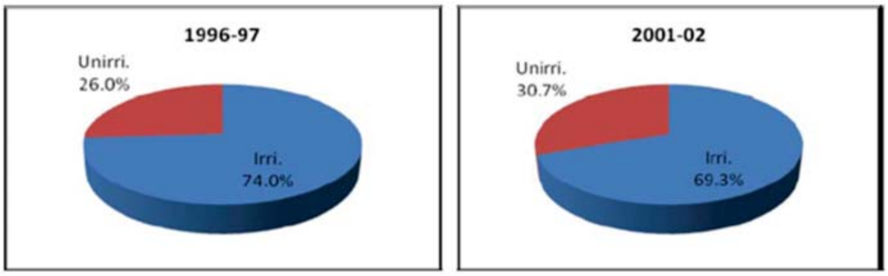

Fig. 2: Changes (%) in share of irrigated and unirrigated areas in consumption of fertilizer between 1996-97 and 2001-02 http://www.iimahd.ernet.in/ publications/data/2009-07-01Sharma.pdf www.fertilizer.org/en/images/Library.../2014_ifa_ff_october.pdf).

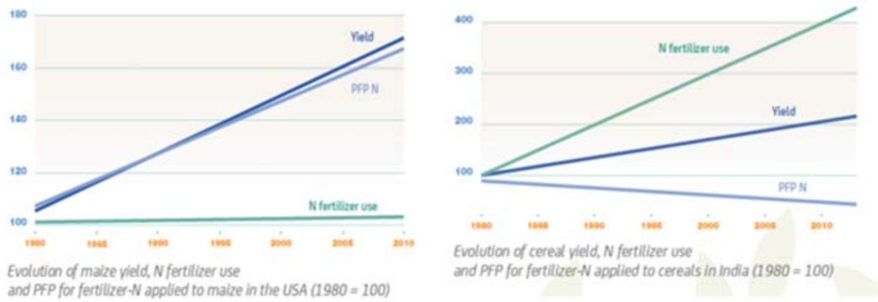

Fig. 3: Nitrogen fertilizer use crop yield and partial factor productivity of in the USA (maize) and India (cereal) from 1980-2010

by the adoption of fertilizer best management practices. Similar trends are observed in other developed countries, for instance for wheat in West Europe and rice in Japan. In India, N fertilizer applications to cereals are increasing faster than cereal yields, resulting in declining NUE (Figure 3). This trend can be explained by a fertilizer subsidy regime that has contributed to unbalanced and inefficient fertilizer use (www.fertilizer.org/en/images/Library.../2014_ifa_ff_october.pdf).

Nutrient-use efficiency is increased by better matching temporal and spatial nutrient supply with plant demand. Applying fertilizers during periods of greatest crop demand, at or near the plant roots, and in smaller and more frequent applications all have the potential to reduce losses while maintaining or improving yields and quality (Tilman *et al*., 2002). Such 'precision agriculture' has typically been used in large-scale intensive farming, but is possible at any scale and under any conditions given the use of appropriate diagnostic tools. Strategies that synchronize nutrient release from organic sources with plant demand are also needed (Neumann *et al*., 2010, Licker *et al.*, 2010).

Use of chlorophyll meter or Soil Plant Analysis Determination (SPAD meter), leaf colour chart, optical sensor based N management can reduce the N application rates substantially. Applying 30 kg N ha^{-1} each time the SPAD value fell below the critical value of 37.5 resulted in application of 90 kg N ha^{-1}, which produced rice yields equivalent to those with 120 kg N ha^{-1} applied in three splits. Using a SPAD value of 35 was inadequate for the two rice cultivars because it resulted in application of only 60 kg N ha^{-1} and, thus, low yields. With high inherent soil fertility resulting in rice yield of >3 Mg ha^{-1} in zero-N plots, applying N basally or a week after rice transplanting did not further increase yield. Limited experimentation with leaf color chart (LCC) indicated that N management based on LCC shade 4 helped avoid over application of N to rice. Wheat responded to N application at maximum tillering (MT) when SPAD value fell below 44. Wheat yield increased by 20% when 30 kg N ha^{-1} was applied at SPAD value of 42 at MT. Results show that plant need–based N management through chlorophyll meter reduces N requirement of rice from 12.5 to 25%, with no loss in yield (Bijay Singh *et al*., 2002). The nutrient saved can be diverted to those areas where fertilizer use is less to enhance productivity. High yielding varieties too should be promoted to rainfed and dry areas so that they can exploit the fertilizer applied.

It is widely recognized that neither use of organic manures alone nor chemical fertilizers can achieve the sustainability of the yield under the modern intensive farming. Contrary to detrimental effects of inorganic fertilizers, organic manures are available indigenously which improve soil health resulting in enhanced crop yield. However, the use of organic manures alone might not meet the plant requirement due to presence of relatively low levels of nutrients. Therefore, in order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields. It not only improves soil quality yield but also increases nutrient use efficiency. The highest nitrogen use efficiency with application of 75 % chemical fertilizers + weed vermicompost @ 2.5 t ha^{-1}. The lowest production efficiency was recorded with 100 % chemical fertilizers alone. (Rama Lakshmi, 2012). More research on improving efficiency and minimizing loses from both inorganic and organic nutrient sources is needed to determine costs, benefits and optimal practices (Tilman *et al*., 2002).

Significant and positive interaction between applied N and water supply was observed on wheat yield and water and nutrient use efficiency by wheat (Bhale *et al*., 2009). With 80 kg N/ha, N use efficiency increased up to 300 mm water supply in sandy loam soil. Interestingly, with 120 kg/ha, it did not increase when water supply was increased from 50 mm to 125 mm, but increased markedly when water supply was further increased to 300 mm (Table 1). This implied that the balance between these two inputs influenced input use efficiency.

Table 1: Water and nitrogen use efficiency in wheat.

Irrigation (mm)	WUE N rate (kg/ha)				NUE N rate (kg/ha)		
	0	40	80	120	40	80	120
0	5.3	7.6	8.1	6.0	8.5	5.5	1.5
50	6.3	9.5	11.3	13.2	20.2	18.4	17.8
125	5.7	10.3	11.9	11.8	33.2	25.5	17.0
300	4.6	7.4	9.5	10.2	30.2	30.3	23.7

Bhale *et al*. (2009)

Water Management

Water is regionally scarce. Many countries in a band from China through India and Pakistan, and the Middle East to North Africa either currently or will soon fail to have adequate water to maintain per capita food production from irrigated land (Seckler *et al.*, 1999). Thus emphasis should be given to both irrigated and rainfed areas to increase water use efficiency.

Irrigated Areas

Irrigated agriculture has been an extremely important source of food production over recent decades. As the graph below shows, the highest yields that can be obtained from irrigation are more than double the highest yields that can be obtained from rainfed agriculture. Even low-input irrigation is more productive than high-input rainfed agriculture. Such are the advantages of being able to control, quite precisely, water uptake by plant roots (www.fao.org).

There are other reasons why conventional irrigation cannot continue to grow as fast it has over the past few decades. Irrigation seems cheap but it is highly costly input because it is most subsidized input in the world. The environmental costs of conventional irrigation schemes are also high (and are not reflected in food prices) - high-intensity irrigation leads often to waterlogging and/or salinization. About 30 per cent of irrigated land is now severely or moderately affected. The salinization of irrigated areas is reducing the existing area under irrigation by 1-2 per cent a year (www.fao.org). Salinization is a worldwide problem, particularly acute in semi-arid areas which use lots of irrigation water, are poorly drained, and never get well flushed (http://people.oregonstate.edu/~muirp/saliniz.htm).

In spite of these reservations, of course, not only will irrigation continue to be used but the area under irrigation will also expand. What is also badly needed is improved efficiency in the use of irrigation water. There are ways to improve water use efficiency (www.fao.org)

1. Reduce seepage losses in channels by lining them or using closed conduits;
2. reduce evaporation by avoiding mid-day irrigation and using under-canopy rather than overhead sprinkling;
3. avoid over irrigation;
4. control weeds on inter-row strips and keep them dry;
5. plant and harvest at optimal times; and
6. Irrigate frequently with just the right amount of water to avoid crop distress.

Rainfed Areas

Globally, rainfed agriculture is practiced on 83 per cent of cultivated land, and supplies more than 60 per cent of the world's food. In water-scarce tropical regions such as the Sahelian countries, rainfed agriculture is practiced on more than 95 percent of cropland. One reason is that, in these areas, conventional irrigation development of food crops may be extremely costly and hardly justified in economic terms.

As indicated by Agarwal (2000), India should not have to suffer from droughts, if local water balances were managed better. Even during drought years watershed development efforts of improving rainfall management has benefited Indian farmers.

National network on Model Watersheds had convincingly established that runoff to a limited extent can be harvested and recycled to stabilize crop production across different climatic zones and production systems.

Increasing the productivity of rainfed agriculture, which still supplies some 60 per cent of the world's food, would make a significant impact on global food production. However, the potential to improve yields depends strongly on rainfall patterns. In dry areas, rainwater harvesting can both reduce risk and increase yields. There are various forms of rainwater harvesting: using microstructures in the field to direct water at specific plants or plant rows (*In situ* water conservation); capturing and directing external water from the catchment area to the field in which crops are grown (flood irrigation); and collecting external water from the catchment area and storing it in reservoirs, ponds and other structures for use during dry periods (storage for supplementary irrigation).

In Situ Water Conservation

In dry areas, poor land management can greatly reduce crop yields, even to below 1 tonne per hectare. One reason is that land degradation often affects the soil surface, leading to crust formation and other phenomena that prevent infiltration by rainwater. Most rainfall then simply runs off the land surface, collects in silt-laden torrents and produces severe gully erosion. Crops benefit little.

Conservation tillage instead of heave conventional tillage will be more helpful in conserving soil and moisture in the rainfed areas. Conservation tillage holds promise because it does not require elaborate tillage and may ultimately reduce animal draught in the hilly regions. Recycling available organic materials having no fodder value coupled with conservation tillage may help enrich the soil environment in the long-term (Acharya, 1998). Thus alternative forms of tillage - such as turning the soil only along plant lines, deep ploughing to break up soil crusts, building raised ridges that follow the contour, growing crops in pits, and building eyebrow terraces round trees and shrubs - can improve crop yields and reduce erosion. They lead to a much more efficient use of limited rainfall. Use of organic materials can also help conserve moisture. Incorporation of palmarosa spent material in soil greatly helps in *In situ* conservation of soil moisture and thereby improves the essential oil yields of palmarosa (Rao *et al*., 2001).

Flood Irrigation

More needs to be done to cope with the effects of the dry spells that occur every year in arid and semi-arid areas. Although these periods of drought often last less than three weeks, if they occur during sensitive growth stages - such as during flowering or grain filling - there is a high risk of serious yield reductions.

The best way of tackling the problem is to divert rainfall from the surrounding catchment area to the soil in which the crops are being grown. Providing the right infiltration conditions have been established, water can be stored in the soil around the crop roots for considerable periods certainly for long enough to be of considerable use during a three-week drought (www.fao.org).

Storage for Supplementary Irrigation

Finally, there are ways of storing the runoff from rainy periods for use during the dry spells: these include the tanks, ponds, cisterns and earth dams used for supplementary irrigation in China, India, sub-Saharan Africa and many other areas. Although they are more costly and require considerable know-how on the part of the farmers who have to build them, they have the advantage of greatly reducing the risk of small or non-existent harvests as a result of drought (www.fao.org).

Small-scale farming can be productive in marginal rainfed areas if supplementary irrigation is available to overcome short-term droughts which are critical to the crop and reduce yield considerably. If there are cost-effective ways to store water before critical crop stages and apply it when the rain fails in these critical stages, crop production can be considerably increased. Though this district level analysis shows modest impact of irrigation for some crops, experimental results/ demonstrations suggest that the impact of irrigation alongwith other management practices is considerably higher (Table 2). Non-availability of irrigation at critical stages of plant growth and low efficiency of the canal irrigation

Table 2: Effect of critical irrigation on yield rainfed crops at different locations in India

Location	Crop	Yield, t/ha		Per cent increase with critical irrigation (Ratio of irrigated versus rainfed yield)
		Without irrigation	With critical irrigation	
Ludhiana(4)*	Wheat	1.92	4.11	114.06(2.14)
Agra(2)	Wheat	2.19	2.74	24.15(1.25)
Dehradun(4)	Wheat	2.14	3.55	65.89(1.66)
Rewa(4)	Wheat	0.57	1.88	229.82(3.30)
Varanasi(2)	Barley	2.60	3.36	29.23(1.29)
Bijapur(5)	Sorghum	1.65	2.36	43.03(1.43)
Bellary(4)	Sorghum	0.43	1.37	218.60(3.19)
Sholapur(5)	Sorghum	0.98	1.82	85.71(1.86)
Rewa(4)	Upland rice	1.62	2.78	71.60(1.72)

systems may be the possible reasons for lower district level yields even under irrigated conditions. On a potential (excluding very arid and wet areas) rainfed cropped area of 25 m ha, a rainfall surplus of 9.97 m ha-m was available for harvesting. A part of this water was adequate to provide one critical irrigation to 18.75 m ha during drought year and 22.75 m ha during normal year. (http://nrlp.iwmi.org/PDocs/DReports/Phase_01/11.%20 Potential%20 of%20 Rained%20 Agriculture%20-%20 Sharma%20et%20al.pdf).

Management of Problem Soils

Acid Soils

In tropical acid soils, acidity is an important constraint for availability and uptake of nutrients by annual crops, and this leads to lower crop yields. Factors that contribute to low nutrient uptake efficiencies in these soils are low natural levels of most essential plant nutrients and unfavorable soil and plant environments. High P fixation capacity, Al, Mn and H toxicity, low activities of beneficial microorganisms, soil compaction, infestation of weeds, diseases and insects, drought and intensive monoculture are some of the major factors that contribute to the unfavorable soil and plant environments. Improving nutrient use efficiency in these soils, demand adoption of special management practices. These practices include timely application of adequate levels of lime, gypsum and fertilizers to meet crop demand, use of proper crop rotation, improvement of organic matter content, control of soil erosion and use of acid tolerant crop species and cultivars within species (Frageria and Baligar, 2001). About 12 m ha of arable acid soils with pH<5.5 have low nutrient use efficiency and crop productivity. Liming can enhance nutrient use efficiency and productivity of crops, especially of pulses and oilseeds. This practice saves 50% fertilizers. Nutrient availability to plants is often affected by soil pH, with the greatest availability generally occurring between pH 6.5 and 7.0. For example, on acid soils (below 5.5), soluble aluminum is toxic to many plants and reduces the availability of P fertilizers. On alkaline soils, P availability is also reduced, resulting in reduced fertilizer efficiency and crop yield. Liming acid soils will also improve nodulation of legumes and increase fixation of atmospheric nitrogen, thereby reducing added N fertilizer requirements (http://www.extension.org/pages/62014/energy-efficient-use-of-fertilizer-and-other-nutrients-in-agriculture).

Salt Affected Soils

Reclamation of 7 m ha of salt affected soils for increased nutrient use efficiency and productivity. Nitrogen use efficiency improved significantly with gypsum addition (https:// www.agronomy.org / files / publications / crops-and-soils/amending-soils-with-Gypsum.pdf). In saline alkali soils, wheat needs to be supplied with higher amounts of nutrients, particularly N, than in normal soils. Band placement of fertilizers, particularly phosphorus, leads to improved fertilizer use efficiency, but appropriate machinery is lacking (Jat *et al.*, 2014).

Genetic Engineering: The Next Green Revolution

Today scientists see a critical need for a 'second green revolution' to enhance crop yield and improve crop quality, in a sustainable manner, with a minimum input of water, fertilizers, and agrochemicals. Many plant scientists believe that the use of modern biotechnology, molecular breeding techniques, and genetic engineering of crop species can contribute significantly to achieving these goals. Currently, the major commercialized genetically modified (GM) crops are engineered for herbicide resistance and/or insect resistance. GM technologies offer a very wide spectrum of possibilities for crop genetic improvement; in the short term – in other words, a period of five to ten years – it will be possible to improve resistance to fungal and viral pathogens in different species. Within the next 10 to 20 years, increased tolerance to drought, salinity and high temperature can be expected, and improvements of nitrogen fixation and photosynthetic efficiency are achievable in the long term. Water scarcity represents a major threat to agriculture and is the single most common cause of food shortages in developing countries. Breeders use conventional methods to develop plants that are better able to cope with stress situations; they cross varieties and select the progeny based on their ability to deal with stress. This approach on its own is not enough, however. Plant biotechnology has by far the greatest potential for future improvements. It makes it possible to identify the key genes involved in water use and drought tolerance and then modify one or more of these genes to obtain the desired traits. (http://www.research.bayer.com/en/22-essay.pdfx). Biotechnology helps farmers produce higher yields on less land. In the last 40 years the amount of synthetic nitrogen (N) applied to crops has risen drastically, resulting in significant increases in yield but with considerable impacts on the environment. In addition, it is becoming increasingly apparent that the environmental benefits of transgenic crops outweigh any potential environmental risks. What's more, the use of biotechnology to develop more disease-resistant crop varieties can have an even greater impact on the development of sustainable agriculture. Namely, the use of transgenic crops that are genetically modified to resist disease can significantly lower the raw material and energy demands of agriculture A requirement for crops that require decreased N fertilizer levels has been recognized in the call for a 'Second Green Revolution' and research in the field of nitrogen use efficiency (NUE) has continued to grow (McAllister *et al.*, 2012). Success in fine mapping of SUBMERGENCE 1 (SUB1), a robust quantitative trait locus from the submergence tolerant FR13A landrace, has enabled marker-assisted breeding of high-yielding rice capable of enduring transient complete submergence (Bailey-Serres *et al.*, 2010).

Technology allows us to have less impact on soil erosion, biodiversity, wildlife, forests, and grasslands With this in mind, many researchers have become of the opinion that there must, and will be a second green revolution and that the medium in this situation will be genetic engineering of cereal crops (reviewed by

Sakamoto and Matsuoka, 2004). Plant breeders generally select varieties in highly fertile, weed-free, densely seeded environments. However, alleles needed for achieving maximum yield in low-input environments often differ from those required in high input conditions. Thus, when effective selection can be undertaken under low-input conditions, breeding programs specifically targeted at low-input environments should produce the best varieties for those environments (Atlin and Frey, 1989).

Policy Support

1. The country must move from consumption subsidies to capital subsidies to encourage farmers to invest in new technologies and equipment. Subsidies on water, electricity and fertilizer were crucial to the Green Revolution, but led to severe environmental consequences. These subsidies must be phased out, and replaced with targeted subsidies to encourage the adoption of new technologies that use resources more efficiently (http://www.icarda.org/second-green-revolution).
2. Linking MANREGA to watershed development programme
3. Interlinking Himalayan rivers to peninsular rivers.
4. Heavy subsidy to drip and sprinkler system in rainfed areas.
5. Legislation to stop burning crop residues.
6. Binding rules for dealing with genetically modified plants must be created and politicians must help to raise acceptance for biotechnology in the population. After all, without green genetic engineering, we are unlikely to be able to secure the supply of food for a growing world population.

Policy Support by Present Government

1. Presenting the 2014-15 Budget, Union Finance Minister Arun Jaitley, however, announced the Setting up of a Price Stabilisation Fund with a corpus of Rs. 500 crore to help farmers deal with volatility.
2. Lowering of interest rate by 3 per cent on short-term crop loans for timely payment
3. Finance to five lakh *Bhoomi Heen Kisan* Joint Farming Groups
4. Soil health cards for farmers
5. Mobile soil-testing laboratories and
6. An Agri-Tech Infrastructure Fund. The agri-tech fund will be used to make farming competitive and profitable, step up public and private investment, develop agro-technology and modernize existing agri-business infrastructure.
7. *Swachh Bharat* mission of Prime minister: This should also be linked to recycling.

Conclusion

- Technologies for second green revolution need to be more sustainable and should address rainfed areas.
- First green revolution in irrigated areas will not be deemed achieved until we accomplish efficiency.
- Development of problematic soils and genetic enhancement of crop productivity could be answer to India's low productivity.
- India does not need to be bothered about the food grains because productivity of rain fed area is miniscule and can be increased tremendously with existing technologies.
- Heavy investment in irrigation and policy support in rainfed areas is required to exploit full potential of crops.

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3

High Tech Intervention in Input Use Technology for Efficiency Centric Management

S.K. Tripathi

India is an agrarian country as the livelihood of more than 65 percent of the population depends on agriculture. The year 1966 was a turning point in the history of modern Indian Agriculture as it marked the release of dwarf varieties of rice (Tichung Native 1) and wheat (Larma Rojo) by CGIAR institutes. They were cross bred with many indigenous varieties and indigenized high yielding varieties (HYVs) were developed. These HYVs were dwarf and responsive to fertilizer and water. They were adopted in multiple (200-300% cropping intensity) cropping systems. Rice-Wheat- Urd/Moong crop rotation in irrigated areas became very popular and age old myths were dissolved. Success of this rotation was observed due to the quality of their longer sowing span, synchronous growth stages and responsiveness to intensive cultivation practice (water and fertilizer application). However, continued cultivation raised environment, land, soil and health related problems. In order to overcome the problems, modern cultivation technology with a view to safe, secure, sustainable and efficient use of inputs has been strongly recommended in the 12th plan. Modern technologies also had to keep in view the shortage of farm labour, shrinkage of land base, increasing cost of cultivation, adverse impact of climate change and dwindling water resources. In order to give a thrust to 2nd green revolution, high tech interventions with other disciplines viz biotechnology and nanotechnology, precision & conservation agriculture etc. that can give efficiency centric management of crops are also recommended.

India is an agrarian country as the livelihood of >65% of its population depended on agriculture. The country adopted a mixed economy system for agriculture and industrial after independence in 1947. The year 1966 was a turning point in the history of modern Indian Agriculture. This was the year when country witnessed widespread drought and faced a serious problem of food shortage. Due to the poor economic condition of the country and international political pressure, many developed nations refused to sell food grain to India. The then political leadership of the country took a bold decision of making this country self reliant in food production at any cost. This was also the time when dwarf varieties of rice (*Tichung Native 1*) and wheat (*Larma Rojo)* were released. Their yield potential under laboratory condition was known but their field performances under diverse soil climatic condition was to be established. Indian Agricultural Universities conducted field experiments and developed package of practices to grow these HYV varieties on the farmer's field. The packages of practices developed were different from the traditional practices. Traditional farmers were prejudiced with their own inhibitions. Major problem was their non-palatable quality.

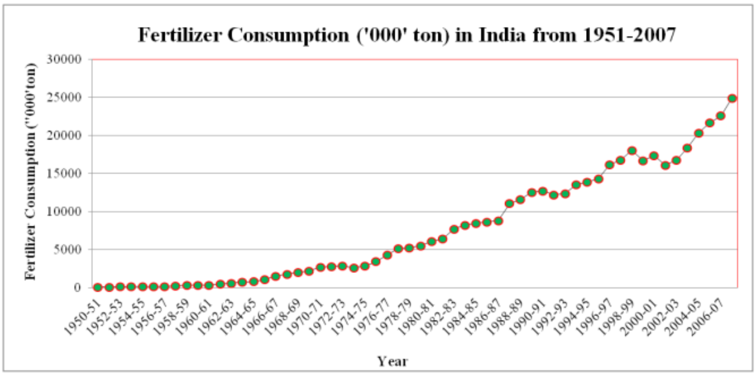

Fig.1: Fertilizer consumption in India

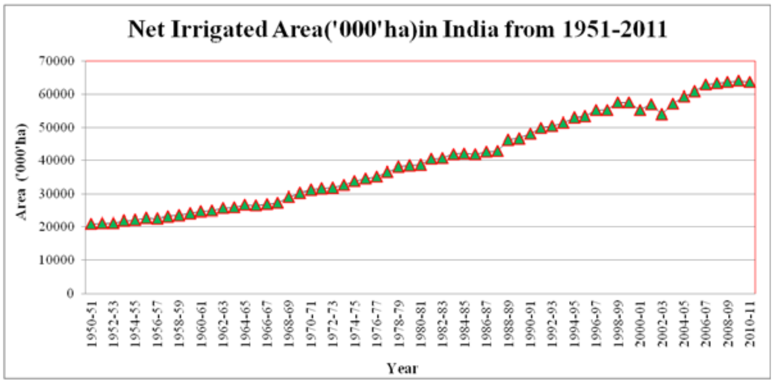

Fig.1a: Irrigation Development in India

We must congratulate our agricultural scientists from different Universities and research centres particularly the GB Pant University of Agriculture and Technology Pantnagar for undertaking research to develop improved HYV. Our agronomists demonstrated successfully.

Growing three crops i.e. Rice-Wheat- Urd/Moong in multiple cropping systems. Now old myths of traditional cropping system and traditional farmers were removed. Farmers came forward in a big way for adopting intensive and high tech cultivation practices and the country entered into the era of green revolution in 1971.

In this process the use of fertilizers, pesticides and irrigation water increased tremendously (Fig 1& 1a) but their efficiency was very low. This inefficiency also added to their increasing cost of their cultivation. The inefficient use of inputs in cultivation practice, affected adversely the ecology, environment and health. This also challenged the safety, security and sustainability of our natural resources. A second green revolution is required to give a further boost to production. There are many new areas of technology (biotechnology& nanotechnology) that have emerged and could be very useful in redesigning the package of practices for obtaining safe and secure production with higher input use efficiency. In this background the objective of this presentation on **"High tech intervention in input use technology of efficiency centric management for safe, secure and profitable food production"** is to share my views with such an august gathering at this great agricultural university.

National Concern in Future Agriculture

The planning commission is the highest national body for preparing growth oriented five year plan taking lesson(s) from the past. In view of the space restrictions tables are not elaborated. But the points remarkably seen from the tables are: increasing population @+1.9% per annum and reducing operation holding of big farmers, loosing productivity of agricultural land, reducing availability of water for agriculture, using nitrogen disproportionate to other nutrients, recording agricultural growth rate of 4% per annum to produce 450 m t food grain by 2050 and harnessing limited available of water resource etc. Data given in Table1 presents the present and future scenario of population growth, productivity status of staple food crops (rice and wheat), land availability, water resource use, fertilizer use and production status throw light on the national concerns as the country is to mach fast to fulfil the needs of 2050.

Table 1: Drivers of Indian Agriculture and its Supporting Resources.

S.No.	Particulars	Units
	POPULATION	
1a	Population Growth Rate	1.9% per annum
1b	Population in 2011	121 crores
1c	Population by 2050	150 Crores
	PRODUCTIVITY	
2a	Rice Yield	2.8 t/ha
2b	Wheat Yield	2.3 t/ha
	LAND	
3a	Geographical Area	329 m ha
3b	Operational Size of Holding (1951)	4.57 ha
3c	Operational Size of Holding (2011)	1.16 ha
3d	Marginal Farmers % and Size of their holding	80%, 0.38 ha
	WATER	
4a	Average Rainfall	1100 mm
4b	Net Irrigated Area	62 m. ha
4c	Gross Irrigated Area	89 m. ha
4d	Irrigation Efficiency	30-40%

4e	Cost of Creating Irrigation Potential	Rs 1.2 L/ha
4f	Share of water in Agriculture during 2000	85%
4g	Share of water in Agriculture during 2050	74%
4h	Total Live Storages created up to 2011	359 Km^3
4i	Loss of Live storage due to sedimentation	53 Km^3
4j	New live storage to be created by 2050	150 Km^3
4k	Ultimate Potential to be Created	450 Km^3
	FERTILIZER	
5a	Nutrient (N:P:K) Use in India (2011)	144 kgs/ha
5b	Chemical Fertilizer Use in India	188 Kgs/ha
5c	Nitrogen Use Efficiency	30-60%
	FOOD GRAIN PRODUCTION	
6a	Production in 2011	232 (m t.)
b	Production required by 2050	450 (m t.)

(Compiled from GOI and FAI publications)

However some of the concerns of agricultural development of the country in the 12th plan document are elaborated below:

Shortage of Farm Labour

The agriculture now accounts for only 14 per cent of Gross Domestic Product (GDP), it is still the main source of livelihood for the majority (65%) of the rural population. A poor seasonal and uncertain economic return from the small farms is very much disappointing to the agricultural labours. The National Sample Survey Organization (NSSO) reported that rural labourers are shifting to non-agricultural work, tightening the labour shortage in agriculture and putting pressure on regularly increasing the unaffordable farm wages. Astonishingly, the educated young members (male or female) of the rural society (land owners or landless) are less interested to stay in the farming.

Shrinking Land Base

The dependence on agriculture remains unchanged among the rural self employed whose average operational farm size continues to decline (4.56 ha in 1951 to 1.16 ha in 2011) with national population growth @+2%. Continuously reducing size of holding due to family fragmentation of agricultural holdings accompanied with the township (industrial and urban) development in the midst of fertile agricultural belts is reducing the availability of land for cultivation. Statistical records show that the net cultivated area in the country had risen to 142 mha (1990) but is now reduced to 140 mha (2011).

Increasing Cost of Cultivation

The viability of farm enterprise, mostly small farms with average size of holding <0.5 ha constituting the dependence of >80% farmers and average size of operational holding reduced to 1.16 ha, therefore is the focus in the Twelfth Plan. The Plan also focus on other priorities such as improving resource use efficiency and development of cost effective farm technology to ensure sustainability of natural resources, adaptation to climate change and improvements in total factor productivity.

High Inflation Rate

The average of annual growth rates of GDP in agriculture and allied sectors during the Eleventh Five Year Plan is now placed at 3.7 per cent against the target of 4 per cent. Failure to reach the target growth is one reason for the high inflation in prices of food and other primary commodities.

Climate and Water Challenge

The climate challenge (drought, flood and global warming) facing agriculture needs to be taken seriously. Rainfall in context of agriculture has traditionally been considered in terms of the monsoon (June- September) due to the runoff generated in the streams and dominance of *Kharif* crops. Total live storage created in the country so far is 360 m ha-m (360 km^3) and is planning to harness another 60 m ha-m (70 km^3) by 2020 but rainfall variability (flood and drought) are posing a challenge in harnessing the live storage created. Temperature regime prior to 1997 was considered normal, but warming has increased at an accelerating pace since then thereby increasing the water requirement of all the living plants and animals.

Planning and Governance

Nonetheless, growth of land productivity did increase significantly from about 1 per cent per annum before Green Revolution (1970) to over 3 per cent during 1991-97, but the growth had decelerated to below 2 per cent thereafter but rebounded to 3% during 11th plan period. In order to bring a second Green Revolution in the country in order to record the growth rate of 4% as envisaged in NAP2000 and sustain it sincere efforts in the 12th plan period is to be made with following challenges:

a. Improving the viability of farm enterprise and returns to investment;

b. Improving the availability and dissemination of appropriate technologies that depend on quality of research and extent of skill development;

c. Plan expenditure on agriculture and infrastructure which together must aim to improve functioning of markets and more efficient use of natural resources; and

d. Governance in terms of institutions that make possible better delivery of services like credit, animal health and of quality inputs like seeds, fertilizers, pesticides and farm machinery.

Health Hazard

The hygiene and health hazard of the agricultural workers in the era of chemical intensive cultivation technology is a serious concern requiring urgent attention of the government. Rural masses have to spent major chunk of their earning on heath due to the water resources (surface and ground water) pollution problem.

Input Use Inefficiency in crop production

Crop production technology is dynamic in nature. It is developed with the arising needs. In the initial stage when the country was in dire need of food grain, the technology development was focused on "maximizing production" at any cost taking all the inputs (monetary or non monetary) as unconstrained to make the country self reliant. Since the participation of farmers in adopting the intensive cultivation (increased use of fertilizer, water and pesticides) was gradual, its evil effect was not visible until 1970.

The command area development authority was created in 1971 to fill the gap between potential created and utilized. The irrigation (created @Rs 1.2 L/Ha) efficiency reported on command area basis was very low (30-35%) in the country. This meant that each unit area of cropland was using water three times of its net requirement. This was a big financial and physical loss to the nation on account of low irrigation efficiency.

Fertilizer and pesticide use were also inefficient but could not be realized by common man in early stage. The spread of area under HYV was very fast throughout the country during 1970-1990 covering about 80% of the gross sown area.

By 2000 the adverse impact of intensive cultivation technology became visible to general public. It was realized that the productivity of soil is reducing, water resources (surface and ground) were getting polluted, agricultural produce were laden with chemicals and insects pests and pathogens developed resistant strains difficult to control with the available pesticides in the country.

The increased use of costly fertilizers and pesticides also substantially increased the cost of cultivation reducing the margin of profit in crop cultivation.

The use of chemical laden farm produce and water became instrumental in creating very costly health hazard (heart, liver and kidney failures etc) problem.

Chronology of Technology Up gradation and intervention

Technology up gradation is linked to associate technological developments and emerging requirements. Chronology of technology up gradation at farmer's field level in case of wheat could be summarized as below in Table 2.

Table 2: Chronology of technology up gradation in wheat cultivation

Year	Technology in Wheat	Year	Technology in Wheat
1950	• Scientific preparation of FYM, • Compost & Green manure, • Rhizobium Culture Use	1960	• Nitrogen (Ammonium Sulphate) application • Sowing of wheat in October; • Irrigation1-3 in wheat, • Rhizobium, Azotobactor and Algae culture use.
1970	• N(80):P(40):K(40) application, • Split application of N; • Urea and DAP became the popular fertilizers. • Use of Herbicides, Pesticides, Fungicides and Antibiotics started; • Wheat sowing staggered from November to December; • Irrigation 4-5 in wheat,	1980	• N(120):P(60):K(60):ZnSo4(20) application, • Sowing staggered from last week November to first week January, • Irrigation scheduling as the growth stages (4-5 irrigations), • Split and foliar spray of N in wheat; • Use of Herbicides, Pesticides, Fungicides and Antibiotics became essential; • Rice-Wheat crop rotation became popular.
1990	• N(140):P(60):K(60):ZnSo4(20) application, • Sowing staggered from November last week to January first week, • Irrigation scheduling as the growth stages (4-5 irrigations), • Split application of N in wheat; • Essential use of Herbicides, Pesticides, Fungicides and Antibiotics; • Rice-Wheat-Black Gram or Green Gram crop rotation became popular.	2000	• N(140):P(60):K(60):ZnSo4(20) application, • Sowing staggered from November last week to January last week, • Irrigation scheduling as the growth stages (4-5 irrigations), • Split application of N in wheat; • Rampant use of Herbicides, Pesticides, Fungicides and Antibiotics; • Rice-Wheat-Black Gram or Green Gram crop rotation became popular, • Use bacterial and fungal culture got revived. • Concept of precision and conservation agriculture was introduced. • IPN and INM approach was introduced.
2010	• Stagnation of technology, • Reducing productivity and environmental and ecological degradation, • Very high cost of cultivation		

In order to achieve the targeted food grain production of the country by the end of 12th plan, the planning commission has set targets and their possible interventions and are presented in Table 3.

Table 3: Technology intervention in crops and expected outcome by the end of 12th plan.

Commodity	Production (mt)		Technological interventions	Contributions
	Current	Targeted		
Cereals	223.0	251	a. Expansion of hybrid area under paddy, b. increasing seed replacement rate, c. balanced nutrient, d. single cross hybrids of crop, e. conservation agriculture, f. input use efficiency	Rice:13 ml, Others: 15-20 mt
Pulses	18.1	22	a. Cultivation on rice fallows, b. development of pod borer resistancevarieties and hybrids, c. introduction of pulses in rice-wheat system	5-10 m t
Oilseeds	31.1	39	a. Higher yield of dryland agriculture, b. hybrids for mustard, c. seed replacement,	10 m t

Planning Commission, GOI (2011)

Knowledge pool from different areas of technology could help changing the present scenario of crop production technology. Integrating the productive out puts of biotechnology (varietal development), nanotechnology (fineness for increased efficiency), agro hydrology (rain and irrigation water use), weather forecasting (occurrences of rain, insect pest and disease), RS and GIS (land use, crop health and production), crop system modelling (use of decision support system) and diagnostic instrumentation (soil moisture, nitrogen, land level etc) in the crop production technology could bring a revolutionary change in the efficiency centric management.

Round the clock services of infrastructural support of ICT (Computer/ Internet, TV, Radio and Mobile etc) power supply, banking, sales & service centre, processing units, marketing, transport and social security to the rural areas can ease the percolation of high tech research investigations in crop production will also be helpful in efficiency centric management.

21st century package of practices for cultivation of different crops should be prepared incorporating flora and fauna for soil fertility & productivity management as well as the integrated pest and nutrient management in addition to other inputs to help farmers to manage their crops focusing on the safe, secure and efficient use of inputs. The budget 2014 interestingly has proposed the setting up community radio, round the clock dedicated channel on agriculture in the country and village resource centre. This will be a very good back up of high tech intervention.

Planning Commission working group on agricultural research & education

Some of the important recommendations pertinent to production technology to be implemented in XIIth plan (1912-17) are described below:

a. Natural resources play a vital role in harnessing the potential of improved varieties/hybrids of all the food, feed and horticultural crops. Therefore, *conservation and optimum utilization of natural resources should be the major focus*. In addition, *the problem of declining soil health and water quality should be addressed on priority.*

b. Development of *appropriate methodologies employing GIS and remote sensing for detailed soil resource mapping and land use planning at watershed level is needed*. ICAR and SAUs should help develop an *information system on natural resources, including soil, and water* and disseminate information on weather and pest forecasting, and crop management practices to manage risks

c. Abysmally low water and nutrient use efficiencies continue to multiply farmers' miseries and cause environmental degradation. Precision agriculture *optimizing the use of water and nutrients involving pressurized irrigation techniques, site-specific and integrated nutrient management strategies; smart nutrient delivery system developed through nano-technological interventions; and development of customized and designer fertilizers are researchable issues.* The *popularization of bio-fertilizers and bio-pesticides should be taken up* for their wider adoption.

d. Agro-forestry, green manuring, plant residues, composting and vermi-composting, biogas and liquid organic manuring to reduce the cost of production and build strong sustenance should be taken as an important and integral component of agriculture.

e. Risk assessment of metal contaminated soils through case studies and modelling integrating *metal levels in soils, transference to food chain and health hazards* to animals and human beings should be taken up by ICAR and SAUs with active involvement of ICMR.

f. There is a need to *identify alternative cropping systems with higher and stable yields and/or profit in different agro-ecological regions*. Integrated farming systems internalizing synergies of different components for enhanced resource utilization, income and livelihood generation and minimizing environmental loading need to be developed for different agro-ecologies.

g. Precision farming, conservation agriculture, protected cultivation, cold chains, pressurized irrigation and use of by products need specialized machines which should be developed, tested and commercialized. *Mechanization needs of small farmers* should be given due attention.

h. Crop protection (weed, pest and disease) have become a serious problem in the intensive cultivation of crops. Crop protection chemicals are very costly and are apparently responsible for very increased cost of cultivation. This is very much discouraging for small farmers to continue in cropping. In spite of the so much use of pesticides farmers are unable to save their crops due to vagaries of nature or immunity to pesticides. A farmer borrows money to purchase and apply pesticides in crop and in the event of failure commit suicide. This creating a serious social problem in the country. Assuming as the biotechnical approach could help solving this problem; more emphasis has been laid in 12th plan research strategies. Therefore as a high tech intervention, priority areas in crop protection research strategies as recommended by planning commission are presented in Table 3.

Table 3: Priority areas in crop protection research strategies

Priority Area: **Development of Diagnostics & Molecular Bar-coding of Pests/Pathogens/ Nematodes and preparing their National Database.**

Research strategies:

National Select Agent Database or registry: This will serve as a referral center for identification and authentication of Pests/Pathogens/ Nematodes. Couple with the database envisaged, the center would serve as a resource for information related to bio-security related issues.

Molecular Bar coding: Electronically portable genome based codes for invasive pest/ pathogen/nematode needs to developed with the help of genome databases

Priority Area: **Development of pest anddisease surveillancemethodology, forecasting & prediction modelsand crop lossAssessment system.**

Research strategies:

Race/biotype monitoring: Monitoring of exotic Pests/Pathogens/ Nematodes

Disease surveillance and prediction models: Development of robust and accurate prediction and forecasting models for economically important pest and diseases. Pest and disease advisory and model based spray schedules would ensure cost reduction for disease management besides protecting the environment

Priority Area: **Genomics and novelmolecules**

Research strategies:

Genomics of pest and pathogens: Pathogenomics and identification of new genome targets for development of ultra sensitive diagnostics tools & high throughput race monitoring mechanism. Genome analysis of pathogenic species by high throughput bioinformatics programme for identification of multi spacer regions which can act as a genome target for diagnostics. This would complement presently available single gene based diagnostics. This would ensure high level of sensitivity for detection and the eventual diagnostics

Interactomics: Interactive genomics and transcriptomic approaches to mine genome and transcriptome targets leading to development of resistant cultivars. Identification of Pathogen Associated Molecules and the virulence associated effect or molecules in pathogen and their targets in host plant in order to exploit the universally occurring natural defense in plants. This would yield an array of molecules for future disease management strategies through conventional and unconventional methods. This is possible through a focused approach on transcriptomics and interactomics

Metabolomics: Genome mining of beneficial microbes for natural products that are mutually complementing for sustainable disease management and productivity enhancement. Genome mining and genome wide identification of genes and their clusters in bacteria & fungi for natural products that is useful in productivity enhancement. This would yield novel molecules that can be exploited as new generation microbial origin biocides

***Priority Area:* Genetic improvement of crop plants through biotechnological approaches including molecular breeding for biotic stress management**

Research strategies:

Transgenic crop plants: Environmentally and socially acceptable transgenic crop plants can be developed to mitigate biotic stress. Ecologically safe transgenic plants which does not pollute the environment can be developed

Transgenic root stocks: Use of transgenic root stocks for mitigating biotic stress especially viruses and soil borne bacterial diseases in high value horticultural crops.

Non host resistances and Cisgenic plants: Non host resistance must be explored to develop Cisgenic plants against major pest and diseases. The unexplored non host resistance can be exploited for identification of candidate genes for development of transgenic plants against major biotic stress

Planning Commission, GOI (2011)

Technology Hybridization

Crop production technology in isolation unconcerned to its evil effect on soil, plant and animal health will have poor rating as far safety (causing no harm to others), security (risk free), sustainable (everlasting) and profitable (B:C >1) is concerned because of the antagonistic effect on the life of natural resources and stakeholders. Knowledge should be borrowed from different areas of science & technology that could add into the productivity should be assimilation and advance technology for second green revolution should be prepared. This can be possible only when different technologies compatible to each other are hybridized under field environment.

Nanotechnology is totally new to crop production in India. Personal communications with nanotechnology experts at IIT Roorkee have revealed that the efficiency of fertilizers and pesticides can be increased tremendously with the help of nanotechnology. This is hoped that the agriculture will have increased input of this technique and record a breakthrough in efficiency centric management of crops.

Conclusion

ECM of crop production is a very complex issue because everything in and out (soil, weather, associated technologies, crop varieties, national policies as well as the quality & quantity of food requirement) is dynamic. Inefficient use of inputs in the cultivation process done unknowingly has left many scars on our environment (soil, water & land pollution), ecology (flora and fauna extinction), climate (weather aberration and GHG), produce (fruits, vegetable and food grains containing higher doses of toxic chemicals) and health (animals and human).In this context high technology in crop production is to be redefined incorporating the knowledge from various disciplines (biotechnology, weather forecast with Decision Support System, nanotechnology as well as the water & land management etc) and practice with the input use efficiency >80%. As the task of feeding massively growing population of the country is very high (450 m t by 2050 to feed 150 Cr population), a technological breakthrough by amalgamating different technologies a fresh, to record a 2nd green revolution in the country with the objectives of safety, security and sustainability in production is urgently required.

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4

Innovations in Input Management for Enhancing Crop Productivity and Quality

ANCHAL DASS, A.K VYAS, PRAVEEN JAKHAR AND RISHI RAJAND JYOTSHNARANI

Agricultural production governs the food security and economy of developing countries. Continuous evolution and development of agricultural practices have raised and maintained the production of agricultural commodities in the countries which have been self-sufficient in food, and in the - South African countries, where agriculture did not improve and the challenges of food security still exist. For that matter, India in a span of 60 years made a tremendous progress and has increased its food grain production from 50 million tones in 1950-51 to 264.38 million tones in 2013-14. To achieve this, many innovative production technologies including development of input responsive crop varieties, nutrient management, irrigation and rain-water management, weed and disease and insect-pest management were developed, disseminated and adopted. The present articles focuses on the recent innovations in crop establishment, nutrient and water management, the three most important practices of crop production and natural resource management. FIRB, RCTs like laser leveling, site specific nutrient management, precision nutrient, microbial consortia for residue recycling and seed inoculations, liquid bio-fertilizers, micronutrients, particularly Zn coated on urea, micro-irrigation systems, system of crop intensification, Integrated Crop Management and aerobic rice.

Nutrient Management

Fertilizer Materials and their Methods of Application

Nitrogen fertilizers are highly soluble and this leads to considerable leaching losses under upland conditions and denitrification losses under low-land situations. Thus, development of slow-release nitrogen fertilizers becomes important. These are of two kinds: the coated conventional fertilizers such as sulphur coated urea, polymer coated urea, neem coated urea, and the inherently less soluble materials, which are mostly urea-aldehyde products, such as urea form (urea formaldehyde), isobutylidene diurea (IBDU) and crotonaldehyde diurea (CDU). However, the cost of N in these materials is twice or thrice or even more than the conventional fertilizers, making them beyond the reach of common farmers. Another approach has been to use nitrification inhibitors to retard nitrification of applied NH_3 or urea-N and to reduce leaching and dentirfication losses (Prasad, 2005). The most widely tested and used nitrification inhibitors are Nitrapyrin or N-Serve, AM (2-amino-4-chloro, 6-methyl pyridine), and dicyandiamide.

Some researchers have suggested the use of urease inhibitors for reducing NH_3 volatilization losses and the most widely tested urease inhibitor is NBTPT or NBPT (Hendrickson, 1992). In India, Prasad and Prasad (1980) developed the neem cake coated urea (NCCU), which was shown to have nitrification inhibiting properties (Thomas and Prasad, 1982). It increased yield in rice (Sudhakara and Prasad, 1986) and rice-wheat cropping systems. In rice-wheat cropping system, NCCU was as good as sulphur coated urea; the major factor responsible for N regulation was nitrification inhibition by the triterpenes in neem. Since coating of urea with neem cake was industrially not feasible due to the large volumes involved (e.g., 20% w/w of urea), a neem oil micro-emulsion technique was developed. This technique or its modification is currently being used by the National Fertilizes Ltd., Indo-Gulf Fertilizers, and Shriram Fertilizers and Chemical Ltd. and about 0.4 Tg of neem coated urea (NCU) are being manufactured in India.

In Delhi, Punjab, Haryana, and Uttar Pradesh NCU resulted in 6 to 11% increase in rice yield. *PFPn* for NCU ranged from 41 to 43% compared to 36 to 41% for prilled urea (Prasad, 2007). Another important product worth mentioning is the urea super granules (USG), which are ~1 cm diameter granules/pellets weighing ~1 g. Yield benefits with USG over prilled urea varied from 0.2 to 1.2 Mg·ha–1at the same level of N (Kumar *et al..,* 1989). Thomas and Prasad (1982) have reported that in addition to the advantage of N placement, which reduces volatilization losses, placement of such a high amount of urea at a micro-locus produced very high concentrations of NH_3, inhibiting nitrification.

Site Specific Nutrient Management

Balanced NPK fertilization has received considerable attention in India. Farmers, specially the marginal and dryland farmers, generally, tend to apply only N. About 45% of Indian soils are also deficient in S (Biswas *et al.*., 2004) and 48% in Zn (Gupta *et al.*., 2007). The soils in eastern India are particularly deficient in Boron. Adequate application of S and Zn in the soils deficient in these nutrients automatically increases the Agronomic Efficiency (NPK) (Sakal *et al.*. 1998; John *et al.*. 2006). Widespread deficiencies of S, Zn, and B have led to the evolution of site specific nutrient management (SSNM). Simply put, SSNM involves analyzing the soils for all essential plant nutrients and developing fertilizer recommendations based on soil analysis. SSNM increases the *AE* of all nutrients applied.

Integrated Plant Nutrient Supply System (IPNS)

IPNS is an approach, which adapts plant nutrition to specific farming systems and particular yield targets, with consideration of the resource base, available plant nutrient source, and the socioeconomic background. As plant nutrients are transferred in cyclical processes, IPNS involves monitoring all pathways of flow of plant nutrients in agricultural production systems to maximize profit so that farming as a profession can be sustained, which is the only way to produce food

(Ange, 1997). Thus IPNS demands a holistic approach to nutrient management for crop production and it involves judicious combined use of fertilizers, biofertilizers, organic manures (FYM, compost, vermicompost, biogas slurry, green manures, crop residues etc.) and growing of legumes in the cropping systems (Prasad, 2008). IPNS also encompasses balanced fertilization and SSNM. Long-term fertilizer experiments have shown that addition of organic manures in addition to NPK results in high yields over a long period of time as compared to a decline in yield over time when only inorganic fertilizers were applied (Swarup, 2002). At PDCSR in most cropping systems like rice-wheat and rice-rice, application of 50% N through green manure, FYM or crop residues, and 50% of the recommended dose of fertilizer (RDF) to *kharif* rice and 100% RDF to *rabi* crop (rice/wheat) gave the same yield as obtained with 100% RDF to both *kharif* and *rabi* crops (Hegde, 1998), and thus saved 25% NPK from fertilizers.

Green manure crops are very important in IPNS. *Sesbania* or cowpea (*Vigna unguiculata*) and mungbean (*Vigna radiata*) residue incorporation produced the same grain yield of rice + wheat without any N application to rice, as obtained with 120 kg N ha^{-1} applied to rice in the control plot. Further, productivity of rice-wheat cropping could be raised by 1.2 t ha^{-1} with 80 kg N ha^{-1} applied to rice over 120 kg N ha^{-1} applied in control plots. Legumes are the most important component of IPNS. They may be grown as a green manure, grain crop or as a dual purpose crop (grain as well as green manure) in cropping systems. Soil restoring capacity of legumes has been known in India since historic times (Nene, 2006) even when their capacity to fix N was not known. Legumes fix 50–500 kg N ha^{-1} depending upon the crop and its growth period, and leave a residual N varying from 30–70 kg N ha^{-1} to the succeeding crop (Venkatesh and Ali, 2007). Sharma *et al.*. (1996) reported a saving of 5.6 to 39.1 kg N ha^{-1} in wheat following mungbean or urdbean (*Vigna mungo*). It is estimated that in India legumes fix about 2.4 Tg of N annually (Ahlawat and Gangiah, 2004). Green manures contribute 60–120 kg N ha^{-1} to the succeeding crop (Palaniappan *et al.*., 1997). When mungbean is grown as summer catch crop in the rice-wheat cropping system and its residue is incorporated in the soil after one picking of pods (giving about 0.5 t ha^{-1} grain), it contributes N equivalent to 60–90 kg ha^{-1} to the cropping system.

Organic manures, besides supplying major nutrient, also supply small amounts of micronutrients (Mishra *et al.*, 2006) and when applied regularly over a long time can help to avoid micronutrient deficiencies. Application of organic manures also improves the soil physical, chemical, and biological properties. Biofertilizers [*Rhizobium, Azotobacter, Azosprillum*, blue green algae (BGA), azolla, phosphate solubilizing organisms (PSO, PSB, PSF), vescicular arbuscular mycorrhyza (VAM)] can become an important component of IPNS specially under low-land rice cultivation and dryland agriculture, where only low levels of fertilizers are applied. Organisms accelerating the decomposition of crop residues also have a role.

Integrated farming system

In India, more than 80% farmers are small and marginal and their problems are different from those of than large farmers. These farmers depend on farming for their household needs and majority of these farmers are resource constraint, economically poor and having low level of education. As they rely on agriculture for meeting multiple needs (food, feed, fodder, fibre, fuel, etc.,), only crop based interventions do not suit them. Hence, integrated farming system (IFS) approach assumes greater relevance for bettering the small and marginal holders. There have been sporadic success stories of improvement in farmers' life by the adoption of scientifically improved IFSs in different corners of the country but their large scale adoption is still to be realized (Behera, 2012).

Shifting from conventional farming to integrated farming systems requires a radical rethinking of agricultural education, research and extension. Agricultural professionals, including farmers, need a different type of orientation and training that emphasizes holistic concepts, institutional behavior, cooperation, and respect for nature, local farming systems and indigenous knowledge. Government and institutional supports for loaning on subsidized interest rate and developmental activities are critical factors for adopting IFS by resource constraint farmers. Training and update of knowledge to farming system agricultural professionals including farmers are key factors for adoption and continuous monitoring of IFS units. In this direction, India has already made headway and developing human resources in the field of farming systems through teaching and training programmes (Behera and Mahapatra, 1999)

Resource Conserving Techniques

FIRB System

Furrow-irrigated raised-bed planting system (FIRBS) was introduced in India in 1995 on the pattern of wheat grown in the Yaqui valley of Mexico. Generally, 2-3 rows of wheat are sown on the top of bed, 70 cm wide and irrigation is done through the furrows. The inter-row bed space is used to control weeds by mechanical weeding during the early vegetative growth of weeds. This technology is suitable for almost all types of soils, except black cotton soils. The FIRB system results in considerable saving of irrigation water compared with conventional sowing. Irrigation water saving exceeding 50% have been reported in certain cropping systems. However, 20-30 % water saving with bed planting is commonly demonstrated by different researchers (Hobbs, 2001).Reduction in irrigation time or amount by 35–50%, and slightly higher yields (mean 5%) with bed planting have been seen (Hobbs and Gupta, 2003; Kahlown *et al.*., 2006). Results of replicated experiments generally show similar or higher yields of wheat on permanent beds compared with conventional tillage, and reduced irrigation amounts (Bhushan *et al.*., 2007; Lauren *et al.*., 2008). In some situations, yields were lower on fresh and permanent beds than with conventional tillage—as a result of more rapid drying of the beds on coarse textured soils, accumulation of salt on the beds on a sodic soil, or inadequate tillering associated with late planting (Jehangir *et al.*., 2007; Yadvinder-Singh *et al.*., 2009).

Rotary Tillage Technology

Rotary tillage technology is a tractor-driven version of the rotavator attached to Chinese power tiller, which pulverizes the soil, places the seed and fertilizer at appropriate depth and does planking in a single operation. By using this machine, the soil can be pulverized to a depth up to 10 cm. The machine is capable of cutting and incorporating the weeds as well as residues left by the previous crop, which offer positive environmental effects. Behind the rotavator, a standard nine-row seed-cum-fertilizer drill is fitted to simultaneously place the seed and fertilizer at appropriate depths. Since the number of operations can be reduced from 6 or 8 to one, the total saving of energy and time can be 70-80% (Chhokar et al., 2008). Considerable benefits in terms of yield improvements and cost saving have been reported by various workers.

Laser Leveling

Despite the fact that fields for RW systems are puddled and leveled every year prior to rice transplanting, the soil surface is often very uneven, resulting in excessive water application to enable the highest portions of the field to be flooded for rice, or wetted during irrigation of wheat. Jat *et al.* (2006) reported leveling indices (LIs) of up to 13cm in farmers' fields in Ghaziabad, where LI is the mean deviation between the desired elevation and the actual elevation. LI increased rapidly with field area up to 1 ha. In 71 farmers' fields in Punjab, Pakistan, laser guided leveling gave an average reduction in irrigation amount of 76 mm (21%) and an average yield increase of 0.6 t/ha (15%) for wheat (Jat *et al.* (2006)). In 71 farmers' fields in western Uttar Pradesh, India, laser leveling gave reductions in irrigation amount of 50–100 mm in wheat and of 100–150 mm in rice. Assuming irrigation applications of 300 mm to wheat and 2000 mm to rice with conventional leveling, this represents irrigation reductions of17–30% for wheat, and 5–8% for rice. Mean WPI in both crops was increased by about 20% with laser leveling due to reduced irrigation amount and higher yield (by 9% in wheat, 6% in rice) Jat *et al.* (2006).

Aerobic Rice Cultivation

In Asia, 17 million ha of irrigated rice areas may experience "physical water scarcity'' (Tuong and Bouman, 2001), which points to the need of more efficient use of water in rice production. Several strategies are being pursued to reduce rice water requirements. The most prominent ones include SRI and AWD systems that lead to high water productivity with a water saving of about 20-30% without any yield penalty. However, water requirement of these production systems is also very high as land preparation consists of soaking, followed by wet ploughing or puddling of saturated soil. Further, when standing water is kept in the field (5–10 cm) during crop growth, large amount of water (about 10–15 per cent) is lost through seepage and percolation. Aerobic rice provides for effective use of rain that falls on the farmer's field, as there is no standing water and the farmer can skip irrigation if soil moisture status is sufficient for crop.

Zero Till Wheat

Sustainability of rice-wheat cropping had been mainly threatened by deterioration of soil structure due to repeated ploughing and puddling operations year-after-year. The problem can be reduced to some extent by adopting zero-tillage in at least wheat. The rapid expansion of the area under no-tillage / zero tillage from 45 million ha in 1999 to 105 million ha in 2008 shows the increasing interest that this technology is having among farmers. The concept of zero-tillage with residue retention/ application on soil surface is being extended in other crops like maize, soybean, etc. by pant zero-till machine, Turbo seeder/ Happy seeder, rotavator etc. The major driver for adoption of zero-tillage is the increased profitability as a result of lower establishment costs. In a detailed review of ZTW farmer participatory trials and research in RW systems of the IGP, Erenstein and Lakshmi (2008) found that zero till saved one irrigation, and gave average irrigation water savings of 10–30% or up to 100 mm, compared with conventional tillage. This was mainly due to lack of need for a pre-sowing irrigation due the ability to sow sooner after rice harvest while the soil was still moist, and due to the much shorter duration of the first irrigation because of the faster advance of the water over the non-tilled soil surface. Adoption studies in Haryana (Erenstein *et al*.., 2008) also showed that WP was significantly (17%) higher in ZTW than with conventional tillage, due to slightly higher yields (by 4%) and slightly lower irrigation amount (by 9%), although the average number of irrigations for both establishment methods was the same. The nature of the irrigation water savings for ZTW in comparison with conventionally tilled wheat need to be further investigated.

Seed Priming

Water deficit during initial stage of crop results in delayed and erratic seedling emergence and stand establishment and in severe cases, complete inhibition of seedling emergence may also result. The biggest challenge on this front is to improve the efficiency and productivity of water being used in existing systems. Simply soaking seeds in plain water before sowing could increase the speed and homogeneity of germination and emergence, leading to better crop stands, and stimulated seedlings to grow much more vigorously. Hydro priming, a simple hydration technique to a point of pre-germination metabolisms without actual germination (Farooq *et al*.., 2009), is one of the most pragmatic, simple, economic and short-term approaches to combat the effects of drought and other abiotic stresses on seedling emergence and crop establishment. Hydro primed seeds usually have early, higher and synchronized germination owing to reduction in the lag time of imbibition otherwise required much time (Brocklehurst and Dearman 2008) and build-up of germination enhancing metabolites (Farooq *et al.*., 2006). Preliminary research has also identified a number of opportunities for priming to be used as a vehicle to introduce biofertilizers, micronutrients and crop protection agents into seeds. Studies also suggested that it is possible to prime seeds with small amount of phosphate to good effect in the early root growth is stimulated allowing more effective uptake of available P in the soil good establishment increases competitiveness against weeds, increases tolerance to abiotic stress especially dry spells and ultimately maximizes the yields.

Aqua-Fertilization

Aqua-fertilization is a new technique in which some amount of water in the forms of nutrient solution can be applied in the crop root zone at the time of sowing. At IARI, aapplication of 15000 L of water through aqua-fertilization with 100% RDF gave significantly higher seed yield of mustard over control and 50% RDF under rainfed conditions. Wheat crop gave superior yield with the application of aqua-fertilizer with 20000 L water/ha over dry sowing. Lentil crop also gave higher yield with the application of 15000 L water/ha.

Soil Conditioners

Hydrogel is an indigenous product designed and developed to enhance the crop productivity per unit available water and nutrients, particularly in moisture stress agriculture. Hydrogel exhibits maximum absorption capacity at temperatures above 45^{o}C (characteristic of semi-arid and arid soils) and absorbs 350-500 times more water from its dry weight and gradually releases the same. It is stable in soil for a minimum period of one year and less affected by salts. Soil application @ 1-2 kg/ha for nursery of horticultural crops, 2.5-5 kg/ ha for field crops are sufficient. Jalshakti is another chemical which when applied (mixed) in soil, improves the aeration, infiltration and water holding capacity of the soil

Integrated Crop Management

ICM has been adopted recently in agriculture and is of much significance and relevance than the individual approach of soil, water, nutrients, crops, pests and energy management. It suggests using suitable agronomic management practices for raising a good crop including INM, IWM and IPM. It combines the best of traditional methods with appropriate modern technology for balancing economic production of crops with positive environmental management. Integrated Crop Management (ICM) is a pragmatic approach to the production of crops, unlike Integrated Pest Management (IPM) which focuses on crop protection, ICM includes more aspects. This can include such things as IPM, soil, social and environmental management. Over recent decades the focus on crop production has moved from yields to quality and safety, then more recently sustainability. This results in new challenges for farmers and growers each season.

Precision Farming

Precision farming is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. Crop variability typically has both a spatial and temporal component which makes statistical/computational treatments quite involved. Defining management zones (MZs) is important for improving efficiency in input application. Whelan and McBratney (2003) articulate a number of approaches that are currently being used to define management zones (mostly by the research community), these include hand drawn polygons on yield maps, supervised and unsupervised classification procedures on satellite or aerial imagery, identification of yield stability patterns across seasons, etc. Among these many approaches is a phyto-geo-morphological approach which ties multi-year crop growth stability/ characteristics to topological terrain attributes. The interest in the phyto-geo-morphological approach stems from the fact that the geomorphology component typically dictates the hydrology of the farm field. Multi-year datasets are now becoming available that show this stability and these effects, however, there is a lot of work remaining to create an actual DSS system that could universally help farmers.

The practice of precision agriculture has been made possible by the advent of GPS and GNSS. These tools help to locate the precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured. Further, these maps can be interpolated onto a common grid for comparison and the reference to the VESPER kriging system). Spatial and temporal variability of crop variables are at the heart of PA, while the spatial and temporal behaviors of that variability are key to defining amendment strategies, or 'recipe maps'. Recipe maps would be the output of any generalized decision support system that could be defined for farm use. Precision agriculture has also been enabled by technologies like crop yield monitors mounted on GPS equipped combines, the development of variable rate technology (VRT) like seeders, sprayers, etc., the development of an array of real-time vehicle mountable sensors that measure everything from chlorophyll levels to plant water status, multi- and hyper-spectral aerial and satellite imagery, from which products like NDVI maps can be made.

Adoption of precision farming practices in countries like India has been slow largely due high cost, small land holding and greater skill requirements. However, now certain low cost sensors are available which can help precise application of nutrients and water. Applying N when SPAD value of top-most fully expanded leaf approaches 37.5 saved 30 kg N /ha and increased yield by about 10 % (Dass *et al.* 2014). Applying water at crop water stress index (CWSI) value of H" 6 was found rewarding in-terms of water productivity in *kharif* maize (Dass *et al.* 2012). Water-use efficiency of 80-90% has been achieved with drip irrigation method with higher crop yields.

Summary

For enhancing crop productivity and quality such technologies have individually led to yield improvements as high as 50%. In precision nutrient application, applying N when SPAD value of top-most fully expanded leaf approaches 37.5 saved 30 kg N /ha and increased maize yield by about 10 %. In maize-wheat system, total N saving using chlorophyll meter is 50 kg/ha without yield loss. FIRB system has been shown to increase yields by over 20 %, save irrigation water on an average by 30 % and saves seed by 30-50 % (Pandey *et al.*., 2014) and enhances nutrient use efficiency by over 25 %. Laser leveling increases nutrient-use efficiency by 6–7% and saves water by 10-30 %. Site specific management of macro nutrients increased yield of rice and wheat by 12 and 17 % and profitability by 14 and 13 %, respectively in North-west India (Khurana *et al.*, 2008). A considerable amount of saving on nutrients like, N, P and K has been reported by various researchers. In precision nutrient application applying N when SPAD value of top-most fully expanded leaf approaches 37.5 saved 30 kg N /ha and increased yield by about 10 % (Dass *et al.* 2014). Applying water at crop water stress index (CWSI) value of H" 6 was found rewarding in-terms of water productivity in *kharif* maize (Dass *et al.* 2012). Water –use efficiency of 80-90 % have been achieved with drip irrigation method with higher crop yields. Conservation agriculture has been shown to be of immense utility in terms of resources conservation, productivity, economics and resource-use efficiencies, low green house gas emissions**.** In nutshell, adopting the innovative crop establishment, water and nutrient management technologies, productivity and resource-use efficiencies and farm profits can be enhanced.

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5

Precision Resource Management for Enhancing Crop Productivity and Quality

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Agriculture is facing a global challenge of increasing food production as the world's population increases in the coming decades. Between today and 2020, the world's population is going to reach 7 billion. The global demand for food will increase manifold with increase in population. At the same time, competition for scarce land resources between agriculture and urban interests are leading to a decline in per capita land availability. Unfortunately, it is often the best agricultural land that is used for urban expansion. Increasing population pressure has also led to fragmentation of land in India; current estimates show about 136 million landholdings in India. For sustainable access to food for a global population, crop production would have to increase on essentially the same or less land area, with less water, nutrients, fossil fuel, labor and as climate change. This requires that resources, including land, water, nutrients etc, has to be used in a precise manner to accommodate the growing demand for crop production without compromising the natural resources upon which agriculture depends. This is particularly true for smallholder systems in India where the economic viability of farming is continuously challenged by increasing input cost and decreasing size of landholdings. Precision management is also important to address the growing awareness about the environmental impact of production agriculture.

The present paper discusses the drivers of precision resource management, current advances in precision resource management to improve productivity and profit in smallholder systems and to reduce environmental footprint of agricultural practices.

Drivers of Precision Resource Management

Increasing input cost, unavailability of labor, concerns for economic viability of farming in smallholder systems and the increasing consciousness about environmental impact of intensive farming are forcing stakeholders to look for precision approaches.Farming in South Asia is dominated by smallholder farmers, operating under a wide range of soil, climate, andsocio-economic conditions (Ramakrishnan, 1992), where farm resource endowmentplays a potentially important role in determining profitability of production systems (Widawski and O'Toole, 1996). Development of such smallholder systems is strongly constrained by limited availability of key resources such as land, plant nutrients, cash, and labor (Giller *et al*., 2005). Furthermore, interactions between these limiting resources can strongly inûuence the efûciency with which the resources are used (Muralidharan *et al*., 1988; Namara *et al*., 2007). Typically, low resource availability to the farmers and low productivity of crops demand that inputs, including fertilizer, should be used in an efûcient manner to close yield gap and maintain farm profitability [Fisher, 1998; Hossain, 2000] in smallholder systems (Banerjee *et al*., 2014).

One of the major drivers of precision management in smallholder systems of agriculture is the high variability among farms within small distances. Such between- farm variability is evident in soil physico-chemical properties, and other farmer management practices. The genesis of soils at a particular topographic condition imparts spatial variability in soil physico-chemical properties to agricultural fields through a long-term process. However, difference in management among farmers, such as cropping systems followed, crop establishment, nutrient application and residue management, bring in quick changes in soil properties and adds complexity to the existing variability developed through long-term genetic processes. Sen *et al.* (2007) reported major variability in soil nutrient status within a small area of an intensively cultivated village. Descriptive statistics of the measured soil properties showed wide variations as revealed by the coefficient of variation (CV) (Table 1). Except for pH, all the other parameters had CV more than 24%, the highest being 90% in case of Fe. The cropping pattern and fertilization history of individual farm field seemed to be the cause of such variability. This suggests that fertilization plan of individual farmer should take into account this variability to optimize nutrient application rates for better yield and economics of crop production.

Table 1. Descriptive statistics of the measured soil properties at Sripurdanga, West Bengal

Property	Minimum	Maximum	Mean	Standard Deviation	CV (%)
pH	6.78	7.88	7.42	0.27	3.63
EC (ds m^{-1})	0.09	0.66	0.38	0.22	57.9
Organic C (%)	0.20	1.08	0.67	0.17	25.4
Total N (%)	0.017	0.093	0.058	0.014	24.1
P_2O_5 (kg/ha)	50.35	366.40	194.02	98.67	50.9
K_2O (kg/ha)	87.0	448.0	254.22	92.99	36.7
S (ppm)	7.75	82.5	19.47	12.75	65.5
Zn (ppm)	0.24	3.82	0.90	0.66	73.3
B (ppm)	0.38	4.96	2.02	1.16	57.4
Fe (ppm)	1.76	40.4	7.77	6.98	89.8
Cu (ppm)	1.10	3.52	1.96	0.48	24.5
Mn (ppm)	2.58	35.82	12.05	8.93	74.1

The above discussion pertains mainly to the management of bio-physical variability between farms. However, in smallholder systems, farmer resource availability is a major socio-economic variable that needs to be addressed as well. Consider the case of "one fits all" fertilizer recommendations that is prevalent in the country. Such recommendations assume that all farmers have the necessary financial resources to apply the recommended fertilizers; and the recommendations will equally benefit all farmers. In reality, farmers have variable financial resources and a static fertilizer recommendation may only help a section of farmers. A flexible fertilizer recommendation system that provides advice based on farmer resource availability is more likely to benefit the whole group and would be more acceptable to the farming community. Besides the resource endowment, other socio-economic considerations such as production orientation (for home use or for selling/bartering), peer influence, awareness of farmers, risk perception, land ownership etc. influence farmers' decisions.

So the major drivers of precision management are both the bio-physical differences among farm fields and financial resource variability between farmers and other socio-economic determinants. And management strategies that integrate farmer resource variability, along with bio-physical variability among agricultural fields, could be the best way forward.

Precision Management Interventions

The words "precision management" are not always associated with high-end agricultural machinery. Consider the case of a resource poor smallholder farmer in India. In general, the awareness level is low among such farmers. Simple advises such on

- Proper seed rate
- Right time of sowing
- Most suitable herbicide
- Pest/Disease specific pesticide recommendations
- Appropriate source, Rate, Time & Method of fertilizer application
- Post-harvest crop preservation

provide the opportunity to improve precision in smallholder systems. As farmer resource availability and awareness improve, more resource-intensive interventions could be implemented to improve precision in resource management.

Agricultural machinery development has been a significant part of precision management interventions. Small farm size and low resource availability in smallholder systems of India preclude the use of high-end large agricultural machinery that is prevalent in broad acreage farms of developed countries. However, the principles applied in developing such machineries could be adapted to fit the smallholder systems. Examples of such machineries that are cheap and works well in the small landholdings of India are plenty. A case in point is power tiller driven laser land leveler that is now available in the country. Use of tractor driven laser land levelers has shown significant improvement in water use efficiency and productivity of wheat in Northwest India. A ûeld experiment in rice-wheat system in the western Indo-GangeticPlaincompared various tillage and crop establishment methods under precision land leveling (PLL), using laser land leveler, and traditional land leveling (TLL) practices to improve water productivity, economic proûtability and soil physical quality. Irrespective of tillage and crop establishment methods, PLL improved RW system productivity by 7.4% in year 2 as compared to traditional land leveling. Total irrigation water savings under PLL versus TLL were 12–14% in rice and 10–13% in wheat. PLL improved RW system proûtability by US$113 ha^{-1} (year 1) to $175 ha^{-1}(year 2) (Jat *et al.*, 2009).

However, comparatively smaller landholding in Eastern India, as compared to Northwest India, necessitated the reduction in size and weight of the laser land leveler that can be driven by a power tiller instead of a four-wheel tractor. Recently Gathala *et al.* (2014) described power tiller operated seeder (PTOS), Strip till PTOS, and Bed planters that are operated with power tillers. The bed planters are single power tiller attachable unit that power tills the soil, places seed and fertilizer by inclined plates and ûuted roller systems, respectively, and ûnallyshapes beds by a trapezoidal shaped, rolling bed former.Similar examples of such adaptations in developing machineries for multi-crop planting, planting in standing residues, adjusting depth of seeding, fertilizer placement etc. are now available in the country that are now making precise management of resources far easier than before.

Precision Nutrient Management

The future demand for food must be met from higher yields per unit area, which will require a correspondingly larger quantity of plant nutrients, from one source or another. Consequently, scientists are faced with the twin challenges of producing more yields per unit area and also to advocate scientific nutrient management strategies that limit the potential of environmental risk under high input agriculture. The following section provides examples of some recent advances in the area of precision nutrient management.

The *Nutrient Expert®* for Wheat & Hybrid Maize (South Asia), developed by the International Plant Nutrition Institute and its partners, is a recent innovation for developing field specific fertilizer recommendation for individual farmer. The tool is based on the principles of site-specific nutrient management (SSNM) (Pampolino*et al*., 2012). It utilizes information provided by a farmer or a local expert to suggest a meaningful yield goal for his location and formulates a fertilizer management strategy required to attain the yield goal. The required information about the production system is gathered through a set of simple, easily answerable questions that analyses the current nutrient management practices and develops guidelines on fertilizer management that are tailored for a particular location, cropping system, farmer resource availability and considers the organic inputs as a part of the system nutrient balance. Farmers' field validation of the *Nutrient Expert*®maize and wheat showed that nutrient recommendation from the software significantly improved yields and profit (Table 2) over existing practices (Bhende and Kumar, 2014; Satyanarayana *et al*., 2014).

Table 2. Agronomic and economic performance of Nutrient Expert for wheat (WNE) as compared to farmers' fertilizer practice (FFP) (N=100)

Parameter	FFP	NE	NE-FFP
Grain yield, kg/ha	3,773	5,226	1,453***
Fertiliser N, kg/ha	117	123	6^{ns}
Fertiliser P_2O_5, kg/ha	54	62	8**
Fertiliser K_2O, kg/ha	0	83	83***
Fertiliser cost, INR/ha	4,911	10,190	5,279***
GRF*, INR/ha	53,566	70,813	17,247***

*** and **: significant at <0.001 and 0.01 level; ns = not significant. Prices (INR/kg): wheat = 15.50; N = 16.90; P_2O_5 = 48.76; K_2O = 26.67; Zn = 152.00; S = 44.4; * Gross return over fertilizer cost

Soil testing provides an excellent means of assessing fertility levels of individual fields, or portions of fields, on a farm. A series of experiments conducted by IPNI on SSNM in rice-rice and rice-wheat cropping systems in 18 different locations in India identified yield-limiting nutrients at each location and showed increases in crop yields and farmers' profits when compared with state-recommended and farmer practices (Singh *et al*., 2014; Tiwari *et al*., 2006). The future of soil testing in India appears to be entirely contingent on building demand from farmers. Small holder farmers appear to be either without the resources to pay for the service, or unwilling to use a service which cannot provide timely response given the multiple cropping systems prevalent in the country. While there are currently a large number of laboratories, in general they are slow and provide limited analysis. Several laboratories are providing prompt service to the farmers; however, the number of soil samples processed by such laboratories is miniscule relative to the number of farm fields in the country. This discrepancy has lead many in the science community to seek alternative options to individual field soil samples.

Under this context, Geographic Information System (GIS)-based soil fertility mapping has appeared as a promising alternative. Use of such maps as a decision support tool for nutrient management will not only be helpful for adopting a rational approach compared to farmer's practices or blanket use of state recommended fertilization but will also reduce the necessity for elaborate plot-

Table 3. Performance of Nutrient Expert-based recommendations for yield and economics of maize in southern region

Parameter	Kharif (Monsoon season)					Rabi (Winter season)				
(Unit)	NE	FP*	SR#	NE-FP	NE-SR	NE	FP	SR	NE-FP	NE-SR
ANDHRA PRADESH (n = 95)			(n = 44)					(n = 51)		
Grain Yield (kg/ha)	7943	6525	7297	1418***	646^{ns}	9736	8689	8813	1047***	923***
Fertilizer Cost (Rs/ha)	5398	5996	4991	-598^{ns}	407***	5515	7740	5220	-2225***	295^{ns}
GRF (Rs/ha)	74032	59254	67979	14778***	6053***	91845	79150	82910	12695***	8935***
KARNATAKA (n = 38)			(n = 27)					(n =11)		
Grain Yield (kg/ha)	8153	7591	7033	562^{ns}	1120**	10214	8831	9835	1383***	379**
Fertilizer Cost (Rs/ha)	4455	5385	5543	-930**	-1088**	4943	4481	5543	462^{ns}	-600***
GRF (Rs/ha)	77075	70525	64787	6550	12288	97197	83829	92807	13368	4390
TAMIL NADU (n = 24)			(n = 12)					(n = 12)		
Grain Yield (kg/ha)	8774	8154	7622	620**	1152^{ns}	7405	6550	7114	855***	291^{ns}
Fertilizer Cost (Rs/ha)	4232	8488	4514	-4256***	-282***	3546	8395	5960	-4849**	-2414***
GRF (Rs/ha)	83230	73058	71988	10172***	11242^{ns}	68099	57106	67595	10993***	504^{ns}
ODISHA (n = 34)			(n = 34)							
Grain Yield (kg/ha)	5394	3611	4334	1783***	1060***	-	-	-	-	-
Fertilizer Cost (Rs/ha)	3445	4264	2638	819^{ns}	807***	-	-	-	-	-
GRF (Rs/ha)	50495	31846	40702	18649***	9793***	-	-	-	-	-

* Farmers' Practice; # State Recommendation

Table 4. Yield of rice, potato, and sesame under different crop fertilization strategies

Treatment	Rice				Potato			Sesame			
	Yield, t/ha		Economics[1], Rs.		Yield, t/ha	Economics, Rs.		Yield, t/ha		Economics, Rs.	
	Grain	Straw	Net return	Return per Rs. invested	Tuber	Net return	Return per Rs. invested	Seed	Stick	Net return	Return per Rs. invested
Farm	4.2	4.6	20,592	1.90	28.7	38,210	1.50	0.8	3.0	3,928	1.22
State	4.4	5.0	21,544	1.91	22.5	20,962	1.30	1.2	3.9	8,278	1.51
Soil test	4.7	6.0	25,614	2.05	28.3	41,556	1.58	1.4	4.2	11,267	1.66
GIS (100m grid)	4.7	6.0	24,760	2.02	27.6	39,128	1.55	1.4	4.1	11,457	1.68
CD at 5%	0.26	0.32	-	-	6.4	-	-	0.3	0.4	-	-

[1]Economic comparisons considered all fixed and variable costs including fertilizers (urea= Rs.6/kg, SSP = Rs.6/kg, KCl = Rs. 6/kg) and revenues from rice grain (Rs.9/kg) and straw (Rs. 1.2/kg), potato tubers (Rs. 4/kg), and sesame seed (Rs.20/kg) and sticks (Rs. 100/t).

by-plot soil testing activities. In India, IPNI has demonstrated the use of grid soil sampling and GIS mapping to illustrate the spatial variability in soil nutrient status (Sen *et al.*, 2007), and subsequently used these maps to make site-specific fertilizer recommendations with rice farmers (Sen *et al*., 2008). The process of soil fertility mapping involved geo-referenced grid based soil sampling and using the soil analysis data in a GIS platform to develop surface maps across the study area. The spatial variability maps created by combining the location information of the sampling points (latitude/ longitude) and the analyzed soil parameter provide the ability to predict soil nutrient levels at un-sampled points by interpolation techniques. Success in using these GIS based maps has come through improved fertilizer recommendations to farmers leading to higher yield and economics of production, compared to either their current practices or state recommendations (Iftikar *et al.*, 2010) (Table 4).

The use of grid based sampling strategies also has great potential to reduce the cost of soil sampling for recommendations at the village level, especially when one considers the cost of sampling each field (Table 5). Along with being an effective extension tool where field agents work more directly with farmers, and farmers become more aware of how their fields rank within the landscape in

Table 5. Outline of implementation cost associated with improved village-scale sampling strategies

Total number of land holdings	543
Total cultivated area of the village in hectares	76 hectare
Actual cost of field-based soil testing (NPK analysis, commercial lab)	543 X Rs. 50 = Rs. 27,150
Actual cost of soil testing for GIS50m x 50m sampling	304 X Rs.50 = Rs. 15,200
100m x 100m sampling	76 X Rs. 50 = Rs. 3,800
250m x 250m sampling	19 x Rs. 50 = Rs. 950

terms of basic soil fertility and need for fertilizer nutrients to achieve their target yields.

Optical sensors have emerged on the agriculture scene in recent years as a means of making in-field adjustments of N application to crops as part of a split-N application program. These sensors use NDVI (Normalized Difference Vegetation Index) measurements to assess crop N status, and with appropriate

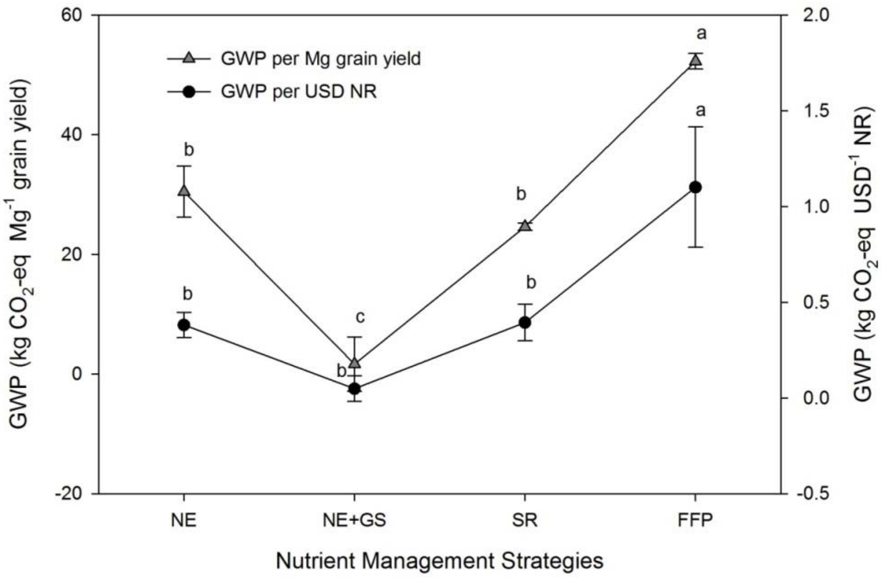

Fig. 1: Total Global Warming Potential (GWP) per Mg grain yield and per USD net return (NR) under different nutrient management strategies in no-till based wheat production in Haryana. The means are average of 15 farmers' field repeated over two years (n=30). Means followed by different letters within same variable are significantly different based on $LSD^{0.05}$. Vertical bar shows standard error of the mean. NE: nutrient expert, NE+GS: nutrient expert supplemented with GreenSeeker, SR: state recommendation and FFP: farmers' fertilizer practice.

calibration, make fertilizer N recommendations to address deficiencies in the crop. While developed and implemented first under conditions of mechanized agriculture, some of the optical sensors have been proposed as an effective tool where small-holder farmers are trying to make split-N application decisions across variable landscapes. Cost of the sensors, and adaptation to a hand held unit, are two factors, which slowed the progress of the technology in south Asia, and will influence any future opportunities.

Research on use of the optical sensor technology in South Asia has been carried out to evaluate its potential with the crops grown and management conditions used. The Green-Seeker sensor based technology provided for a saving in N application of 10-20% in comparison to blanket state recommendations, while maintaining crop yields (see: http://nue.okstate.edu/GreenSeeker/India.htm and Bijay Singh *et al*., 2011). Both higher N use efficiency, and higher wheat grain protein, was measured when the Green-Seeker was used to make N decisions at Feekes 7/8. Similarly for rice, less N was used while yields were either maintained or increased. Both of these reports concluded that the optical sensor had potential to improve N use efficiency and profits for farmers through either increased productivity or profitability. A recent study showed that combined use of *Nutrient Expert®* and GreenSeeker optical sensor, improved wheat yield with lesser environmental footprint than the existing practices (Sapkota *et al.*, 2014).

Conclusion

New technologies are changing the way smallholder farmers and their advisors make decisions. Farmers are searching for guidance on how to better evaluate and implement new management technologies that will allow them improve production economics. Modification of precision technologies to fit smallholder systems will require a coordinated effort across many disciplines and organizations. Such coordination has the potential to ensure sustainable food production in smallholder systems of India without stressing our natural resource base and the environment. Ultimately it will be the cost of the technology, and ease of use by advisors working with farmers, that will affect the adoption of these technologies.

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6

Innovations in Tillage, Subsoil Health Management and Planting Machinery for Enhanced Crop Productivity and Quality

T.C. THAKUR

The 'Green Revolution' technologies have performed exceedingly well up till now keeping pace with growing population. The stagnation in yields of many crops was, however, noticed during the last decade. In fact, the country needs a 'Second Green Revolution' to meet the future food demands. In the past, most of the research works in the field of agricultural sciences have been confined to top or surface soils with very little emphasis on subsoil zone. Accordingly, a variety of soil cultivation equipment has been developed and is used in the country. Moreover, the same old technologies of ploughing and harrowing are being practiced for soil cultivation in LASER levelled fields, thereby altering the field surface configuration which requires frequent levelling of the fields. There are several critical gaps identified between the current soil management practices and the root proliferation of different crops. Subsoil health management is the recent development in Indian agriculture needed for exploitation of genetic potential of field crops. The principle of 'feeding the soil rather than fertilizing the crops' must be adhered to for improving biological activities in the root zone and increasing the productivity and quality of produce in a sustainable manner. A decade of research carried out at Pantnagar on deep placement of plant nutrients while subsoiling has revealed yield increase of 16-40% in crops like sugarcane, wheat, barley, soybean, maize, mustard and potato. Yet another critical gap identified is the placement of seeds and fertilizers side by side with existing Indian seed drills resulting in poor nutrient utilization efficiency particularly in non-irrigated ecosystem. Placement of fertilizers at deeper depths of 10-15 cm or even more exactly below the seeds in a synchronized vertical plane has been found very effective in most of the crops.

India witnessed a remarkable growth on agricultural front particularly during 1970s and 80s which enabled the country to become self-sufficient in food grain production. The growth in food grain production started declining during 1990s and became almost stagnant in the later decade. The agricultural scenario during mid 1960s to 1990s was in favour of high input and high production technology, which enabled production enhancement to meet food grain demand of growing population. However, the 1990-2000 decade witnessed over-exploitation, causing widespread deterioration in soil and water resources. The conventional systems created problems of high production cost, low input-use efficiency, declining ground water, deterioration in soil health and environmental pollution. The efficiency and sustainability of a production system depends on system-based management optimization for crop yields, economic benefits and environmental impacts. Hence, the later half of 1990s witnessed the introduction of mechanized conservation agriculture system based crop management practices particularly the zero tillage in wheat after rice which was considered as a vehicle of change to produce more at less cost, reduced environmental pollution, promote conjunctive use of organics, improve soil health and promote timeliness of planting and other farm operations. However, like any other tillage and crop establishment technology, conservation agriculture may not be a complete solution for all the present day ill, but considered to be a way forward to bring about the cereal crop production out of its stagnated state. As the soil is dynamic and may become as hard as metal and as soft as porridge with moisture variation and weather change, the selection of tillage technology should be need based according to the field conditions rather than a fixed mind set for solution to tillage problems. This chapter, therefore, describes the tillage practices in vogue and innovations made in management of subsoil, almost a neglected area till date in India, and crop establishment techniques for a breakthrough in the stagnated yield barrier.

Tillage Implements for Basic Soil Cultivation

The unit operations required for general soil management include mainly soil loosening, clod disintegration, soil consolidation, clod sorting, mixing, levelling/smoothing etc., which are required to achieve desired seedbed for crop establishment. For every basic cultivation operation there is an optimum soil consistency state in which the operation should be performed. Whilst it is not always possible to work under the ideal soil condition, if work is carried out outside them, a greater amount of soil damage or a poorer result can be expected. In some cases, rather than carry out an operation under the wrong condition, it may be better to reach the desired point in some other way. An example of this could be seen in clod disintegration. If it is necessary to reduce the size of clods when the soil is in a plastic rather than friable condition, an efficient soil cutting tool should be used rather than disintegration implement. The summary of basic soil cultivation operations, soil consistency state and conventional implements in use is presented in Table 1.

Table 1 shows the basic operations required for scientific method of soil cultivation, however, many times the farmers do not follow these basic rules because of agronomical or management reasons which leads to damaged soil structure and consequent poor productivity of crops. For harnessing the maximum benefit, the tillage operations should match the soil condition and root system of crops to be grown.

The root development of different crops has received relatively little attention by Indian researchers. A thorough understanding of the activities of plants both above-ground and below- ground and the ways in which various activities are

Table 1: Basic soil cultivation operations in production agriculture

Basic operations	Objectives	Soil consistency	Direction of resultant implement force on soil	Conventional implement
Soil bursting/ Loosening	Reduce soil unit weight either generally or locally	Friable/ cemented	Upward	45° rake angle tines
Clod disintegration	Reduce clod size by breaking along cleavage planes	Friable	Downwards	Roll, clod crushers, rotary cultivator
Clod formation	Compact particles into clods	Plastic	Downwards or sideways	Mould board plough
Inversion	Invert soil completely, complete burial	Friable/ plastic	-	Mould board plough, disc plough (partial burial)
Rearrangement (sorting)	Increase soil unit weight by filling larger pores with smaller aggregates	Friable	Sideways	90° tine, spiked or oscillating harrow
Mixing	Mixing of soil, seeds, fertilizers, manures etc.	Friable/ liquid	-	Rotary cultivator, disc harrow, 45° tine
Smoothing	Leave smooth soil surface	Friable	-	Leveller, land plane, laser leveller
Puddling	Increase soil unit weight by destroying all structure and compacting	Plastic (Liquid)	Downwards or sideways (Any direction)	Disc harrow (Rotary cultivation)

modified by cultural practices should form the basis for scientific crop production. However, it is being observed that the soil cultivation being practiced in the field and its effect on yield without due consideration to the most important system i.e. the roots, is more or less empirical. The underground portion of the plant environment is relatively under the control of growers than the part which lies above-ground. One can do little towards changing the composition, temperature, humidity of air, or the amount of light. But much could be done by proper cultivation, fertilizing, irrigating, drainage etc. which influence the soil structure, fertility, irrigation and temperature of soil. Hence, a thorough understanding of the roots of plant and their behaviour with changes in the properties of soil is of utmost practical importance.

The root length and density of different crops vary dramatically with variety, soil type and condition, moisture and nutrient status as well as biotic and abiotic stresses. The maximum root lengths of different crops, viz. wheat (1.6 m), rice (0.7 m), maize (1.83 m), sugarbeet (0.9 m), soybean (1.8 m), cotton (1.83 m), barley (1.4 m), potato (1.4 m), carrot (3.0 m) etc. have been reported**.** In case of rice (Var. Saket 4) about 92% (puddled field) and in case of wheat (Var. UP 2338) about 60% roots have been found in upper 20 cm depth (Pandey and Singh, 2003). In case of sugarcane more than 50% roots upto 20 cm depth and 85% roots upto 60 cm have been reported but it could penetrate even deeper upto 6 m (Lee, 1926). The superficial roots (0.50-0.75 m deep) and buttress roots (1.0-1.5 m deep) absorb water and nutrients. The rope roots (up to 6 m deep) absorb water. For soybean only about 47% roots upto 18 cm depth have been found (Sanders and Brown, 1978), suggesting deeper soil management for better results.

The extent of root systems of most crops and their usual thorough proliferation in subsoil would undoubtedly develop interest in deeper soil layers. There are ample scientific evidence that the roots of different crops are active in absorption of both water and nutrients even to the maximum depth of penetration. The nutrients, when available, are absorbed from the deep soil layers in considerable quantities at least in annual crops, although to a lesser extent than from the soil closer to the surface which the roots occupy first. The deeper portion of root system is more active as the crop approaches maturity. The nutrients absorbed by the roots may produce a pronounced effect both upon the quantity and quality of crop yield. A cafeteria of equipment is available for performing specific soil cultivation operation. Hence, it is imperative to critically examine their role in production agriculture on one hand while the requirements of plants root system for uptake of nutrients on the other hand to bridge up the gap for obtaining higher productivity and quality of crops.

Recent Development for Soil Cultivation in LASER Levelled Fields

A precisely levelled field is the pre-requisite for efficient utilization of agricultural inputs. The LASER land levelling is rather new introduction in Indian agriculture with several benefits such as water saving of 15-30%, increase in nutrient use efficiency by 10-15%, increase in field efficiency of farm equipment by over 10%, increase in net cultivable area due to reduction in bunds/ridges and irrigation channels by 2-5% and yield advantages of 15 to 30% in different crops. It is to be emphasized that on one hand very precise LASER land levellers have been introduced while on the other hand, the same conventional technology of soil manipulation with mould board /disc ploughs are in vogue which quite often changes the level of fields. There is a need to develop such conservation tillage equipment which could cultivate not only the top soil but also the subsoil without soil inversion so that the biomass is maintained in the same soil zone or at the surface while disturbing the level of field surface to a bare minimum. Based on these broad principles, two innovative machines named Pant-ICAR Deep Soil

Volume Loosener-cum-Fertilizer Applicator and Pant-ICAR Conservation Tillage Combine were developed and are being popularized (Thakur, 2011).

Pant-ICAR Deep Soil Volume Loosener-cum-Fertilizer Applicator

This machine performs three main functions, i.e. (i) loosening of soil upto 30 cm depth with two V-shaped tines mounted exactly behind the tractor rear wheels on a rectangular frame, (ii) placement of fertilizers deeply in the root zone at 20±5 cm with a pair of inverted-T opener tines mounted behind each of the V-tines and (iii) pulverization of disturbed soil and its further consolidation for moisture conservation by mounting floating spiked clod crushers in synchronous longitudinal plane of each V-tine (Kumar and Thakur, 2013). This arrangement gives a completely levelled field with minimum changes in field surface configuration. The present design of machine is suitable for sugarcane ratoon management planted at 75 cm or 90x30 cm paired row spacing and also for general soil cultivation in LASER levelled fields. It is operated with a 55 h.p. tractor and protected by filing a patent in association with NRDC, New Delhi.

This machine has been adopted as a sugarcane ratoon manager over a large acreage since its introduction in 2009. There has been a substantial increase in ratoon yield with pooled mean of over 25% obtained from several farmers' participatory research trials. Moreover, no suitable machine is presently available for cultivation of crops in sugarcane ratoon but this technology has enabled cultivation of mungbean, urdbean and cowpea during summer in sugarcane ratoon.

(a) (b) (c)

Fig. 1: Pant-ICAR deep soil volume loosener-cum-fertilizer applicator (a), machine working as a sugarcane ratoon manager (b) and soil cultivation in a LASER levelled field (c)

Pant-ICAR Conservation Tillage Combine

Different types of conventional tillage equipment are available for seedbed preparation but the mould board and disk ploughs are the common implements for primary tillage operation. These equipments normally work upto a depth of 20 cm and invert soil by cutting and throwing action. The negative effects of these equipments are uneven field surface, disturbance of soil biota, rapid evaporation of soil moisture, more number of passes of secondary tillage implements for soil pulverization, compaction and formation of plough pan by slipping tractor tyres at tilling depths, and no retention of residues on the field surface. For modification of subsoil structure upto 55 cm depth and its fortification with plant nutrients, commercialized equipment named 'Pant-ICAR Subsoiler-cum-Differential Rate Fertilizer Applicator' is now available in the country. However, this equipment is recommended for use after 3-4 years intervals depending upon soil types and conditions. At present, no such equipment is available for soil manipulation without soil inversion at depths greater than heavy duty cultivator (>15 cm) but less than subsoiling depth (25 cm) which led to development of Pant-ICAR Conservation Tillage Combine (Fig. 2). This machine is protected by filing a patent in March, 2012.

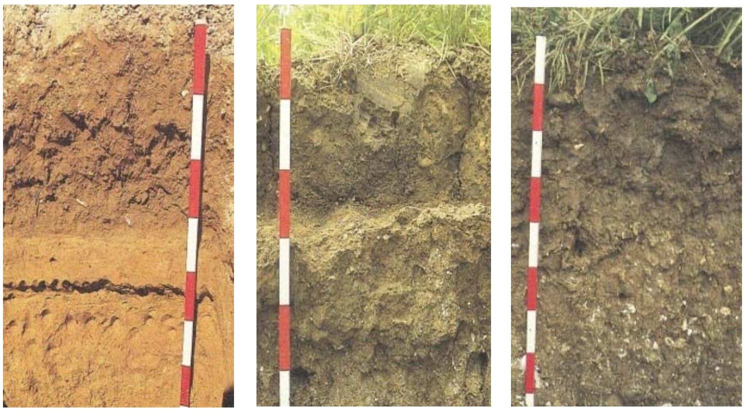
(a) (b) (c)

Fig 2: Pant-ICAR conservation tillage combine for complete tillage solution (a), Tillage in anchored stubbles (b) and Tillage in chopped stubbles (c)

The tillage combine consists of a soil working unit with five winged chisel tines positioned at 45° V- angle on three frames i.e. one tine at the centre of front beam, two tines at V-angle on middle beam and another two tines at V-angle on the rear beam, a fertilizer placement unit and a floating spiked clod crusher unit. It can till soil to the depth of 20-25 cm without soil inversion, retain crop residues at the surface needed for promoting conservation agriculture, place fertilizers in bands at the tilling depth, pulverize and consolidate soil to conserve moisture and maintain the level of field, all in a single pass. Since all the four wheels of tractor travel on a levelled field surface (in contrast to one side of tractor wheels always operates in the furrow, thereby compacting / smearing the furrow bottom and forming hard tillage pan incase of conventional mould board / disc ploughing), the formation of hard tillage pan could be all together retarded. The machine can be operated with a 55+ h.p. tractor while tilling to a depth of 15- 20 cm and could cover a width of 1.6 m as against a mould board / disc plough which covers a width of about 1.25 m only with 3-bottoms pulled by the same h.p. range tractor and changes the field surface configuration which requires additional levelling operation. This machine has, therefore, been developed to provide complete tillage solution as the operation of tillage combine followed by a roto-till ferti -seed drill manufactured in the country for sowing of different crops with only two passes of a tractor in the field. Depending upon the power available, the V-tines of deep soil volume loosener-cum-fertilizer applicator could also be mounted on the frame of tillage combine in place of chisel tines to serve as a three bottom V-plough or a ratoon manager for tilling and fertilizer application in widely spaced (120-150 cm) sugarcane. The V-plough disturbs the soil without inversion while retaining the residues at the surface.

Need of Subsoil Health Management in India

The soil cultivation in India changed over the years as per availability of farm power sources. A closer look at the history of soil cultivation practices reveals that during 1960s and 1970s, soil cultivation was limited to 10-15 cm depths mostly with dominant animate power sources. India started manufacturing tractors during 1960-61 with annual production of only 880 tractors manufactured by M/s Eicher Goodearth Ltd., Massey Ferguson and others. The most common power range was 25-35 h.p., therefore, subsoil cultivation (>25 cm depth) was beyond the capacity of those tractors. Fig. 3 illustrates three different field conditions which require different soil management operations for least energy consumption and higher productivity of crops.



a. Good soil **b. Compacted soil** **c. Plough Pan**

Fig. 3: Tillage options differ with nature of soil profiles

The soil profile in Fig. 3(a) shows a good soil structure throughout 70 cm depth. Under such a situation there is no need of any soil cultivation operation and objective should be to manage the surface residues as it is an ideal situation for zero tillage/ direct drilling of seeds. The soil profile in Fig.3 (b) shows a compacted soil throughout the depth and the objective here should be to select the tillage tool to modify the soil structure throughout by bringing minimum number of clods to the surface depending upon available power and crops to be sown. However, the soil profile in Fig. 3(c) clearly shows a hard pan / plough pan at a depth beyond 30 cm which invariably requires subsoiling operation to break open the impervious soil pan. Under such a situation, without the alleviation of this pan, it may not be possible to harvest the genetic potential of a crop, if direct drilling option is chosen.

The following points would explain the necessity of managing subsoil health in Indian agriculture:

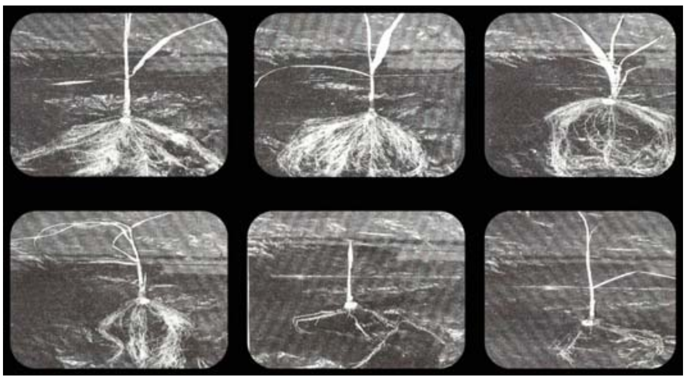
(a) Increasing weight of farm machinery

The dawn of 21^{st}century witnessed a definite shift towards high h.p. range (>50 h.p.) tractors in India and out of over 6 lac tractors presently manufactured in the country, about 10% are in high h.p. range. Although the tractors upto 90 h.p. are available, yet most of the farmers have adopted the shallow cultivation practices with cultivator, harrow and rotavator, and rarely use deep soil cultivation tools. On one hand, high h.p. tractors are available while on the other hand, soil management practices are no better than those of country/*desi* ploughs prevalent during 1970s. It could, therefore, be seen that the subsoils have not been cultivated in the past due to lack of suitable farm power. The weight of farm machinery in Indian agriculture is showing an increasing trend with weight varying from 2.8 t for 80 h.p. tractors (dead weight without dynamic load transfer by a mounted implement) to 6.0-7.5 t for grain combine harvesters and 7.5- 14 t for sugarcane harvesters. Such heavy weights on loose and wet soil would not only compact the top soil but also exert confining stresses in 30-40 cm depth range, hence the subsoil compaction is bound to occur over the years.

(b) Soil bulk density and root growth

The harmful effects of compaction on the soil and crops have been well documented and a wealth of information is available on these aspects. The soil

(a) 1.1 g/cc (b) 1.2 g/cc (c) 1.3 g/cc



(d) 1.4 g/cc (e) 1.5 g/cc (f) 1.6 g/cc

Fig. 4: Effect of compaction on sugarcane root development

(Source: Barnes *et al*., 1971)

bulk density plays an important role on plants root development and uptake of nutrients. A medium textured soil, having a bulk density of 1.2 g/cc is generally favorable for root growth. This density is comparable to seedbeds after secondary tillage operations. Excessive soil compaction impedes root growth, hence limits the amount of soil explored by roots. In general, the average minimum soil bulk density that restricts root penetration in the soils of various textures varies as 1.40 g/cc (clay), 1.50 g/cc (silty clay loam), 1.65 g/cc (clay loam) and 1.7 g/cc (loamy and sandy loam). The effect of bulk density on sugarcane root development illustrated in Fig. 4 clearly demonstrates reduced roots proliferation with the increase in bulk density from 1.1 to 1.6 g/cc.

(c) Root growth of crops and nutrient utilization

In India, limited studies have been reported on root proliferation and nutrients uptake by different segments of roots under varying soil and climatic conditions. Also, most of the studies are confined to top soil surface of 10-20 cm with very little attention to subsoil roots development. Various studies have indicated a very extensive root system of different crops. However, the soil management is normally limited to top 15-20 cm depth, thus affecting adversely the productivity of many crops. For efficient utilization of fertilizers, the knowledge of root distribution and nutrient uptake by different segments are of paramount importance. A study conducted in U.K. under simulated moisture stress condition revealed that the barley plants meet their 40% water requirement from 0-30 cm depth, 30% from 30-60 cm depth, 20% from 60-90 cm depth and 10% from beyond 90 cm depth. This infact, shows the importance of subsoil health management for higher productivity of crops.

(d) Threat of top soil loss

The loss of top fertile soil is enormous varying from 10- 40 t/ha/year and average at 16 t/ha/year in different agro-eco system of the country. The research work conducted at VPKAS, Almora has revealed even upto 80 t/ha/year of soil loss under hill ecosystem. According to an estimate about 5.5 billion tonnes of top fertile soil alongwith 6 million tonnes of nutrients is lost every year in India. On the other hand, it may take upto 100 years to form an inch (2.5 cm) of top soil. Another report from the University of Sydney, Australia revealed that in just 60 years, the world may lose all its top soil bank leading to a global food crisis, chronic food shortages and higher prices. The study revealed that the soil is being lost in China 57 times faster than it could be replaced through natural processes. In Europe this figure is 17 times, in America 10 times while 5 times as much soil is being lost in Australia. India, being a developing country with a large number of upcoming infrastructure projects, the top soil loss may be even worse than China.

The above information clearly indicates the importance of soil health management, not only the surface soil but also the subsoil for future food security of the country. It is more so because of adverse effects of climate change being projected on crop production. It must be realized that growing crops in compacted subsoil resembles to plants grown in a flower pot with frequent application of water and nutrients.

Technological Advances for Subsoil Health Management in India

The soils which produce low yields due to infertility, hard pan, fixation problems etc. can be improved by subsoiling and applying plant nutrients into the root zone of crops according to their root density. This problem was simplified by developing an innovative machine named 'Pant-ICAR Subsoiler-cum-Differential Rate Fertilizer Applicator' (Fig. 5). The machine consists of two main units, viz. subsoiling unit and fertilizer application unit. It is used for breaking of hard subsoil pans/compacted layers upto 55 cm and simultaneously apply varying amounts of fertilizers at two different depths. The shallow leading winged tines place 80% of fertilizers at 20- 25 cm depths whereas the central subsoiling tine places the remaining 20% fertilizers at 40-50 cm depths depending upon the depth of subsoiling. It can also place equal amount of fertilizers (33.3% by each of the three tines) at two different depths or at the same depth. The results of several multi-location research trials on subsoil fortification technology have revealed significant yield increase of sugarcane (30-40%), wheat and soybean (18-20%), potato (24%) and mustard (25%). It has also increased the productivity of sugarcane in sodic soil which frequently form hard pans and in rainfed agriculture by increasing the '*green water*' storage to a greater depth of soil profile. The machine is operated with a 50 to 75 h.p. tractor depending upon the depth of operation.

The technology has been adopted by the farming community of U.P., Uttarakhand, Gujarat and research workers in different states. A saving of 20% fertilizers for the same yield of sugarcane planted at 75 cm spacing as that of farmer's practice has been obtained. The technology is protected by a patent and

Fig. 5: Commercialized Pant-ICAR subsoiler-cum-differential rate fertilizer applicator (a) and a levelled field surface after operation (b)

is now commercialized. A non-exclusive license in association with NRDC, New Delhi has been awarded to M/s Punjab Engineers, Dashmesh Nagar, Bagpat Road, Meerut-250002 for a period of 10 years. This manufacturer has also developed a range of subsoiling equipment having 1 or 2 or 3 tines and with/without fertilizer application system for 45-75 h.p. range tractors.

Response of technology on different crops

The technology has been extensively evaluated on different crops, the results of which are briefly presented here under:

Response on Sugarcane

A large number of field experiments on the effect of subsoiling and differential rate placement of fertilizers on sugarcane have been carried out by P.G. scholars of the Departments of Farm Machinery and Power Engineering, and Agronomy at Pantnagar. Moreover, this technology has been demonstrated to a large group of farmers of Uttarakhand and U.P. since its development during 2006-07 till its commercialization in June, 2011. Therefore, it is difficult to report all the results of trials in this article. However, the results of a typical experiment carried out with different methods of tillage, fertilizer's dose and its method of placement on sugarcane (variety: Co-Pant 90223) with inter row spacing of 75 cm is presented in Table 2 (Mandal and Thakur, 2010).

It is evident from Table 2 that the subsoiling operation is effective in increasing the cane weight, number of millable canes and cane yield in comparison to the conventional tillage method. Subsoiling alone recorded higher cane weight, number of millable canes and cane yield by about 4.26%, 11.39% and 15.87%, respectively than that of conventional tillage method. Subsoiling-cum-deep fertilizer placement method showed 17.02% increase in cane weight, 15.78% increase in number of millable canes and 35.61% increase in cane yield. In another case, subsoiling-cum-differential rate fertilizer placement method produced 16.21%, 16.42% and 35.41% increase in cane weight, number of millable canes and cane yield, respectively. The significant increase in cane yield may be attributed to the placement of fertilizer in subsoil/root zone of plants increasing thereby the fertilizer use efficiency. When only 80% of recommended NPK was applied at differential rate while subsoiling, a higher yield of 28.37% than conventional method with 80% of recommended NPK was obtained. There was no significant difference found in the yield between subsoiling-cum-deep placement and subsoiling-cum-differential rate fertilizer placement methods.

Response on Mustard

This experiment was conducted during 2008-09 for observing the response of deep placement of organic and inorganic fertilizers on mustard crop (Var: Kranti). Seven treatments were selected after screening the results of a 'Field

Table 2: Yield attributes and yield of sugarcane as influenced by methods of tillage, fertilizer dose and its method of placement

Treatments		Cane length (cm)	Cane girth (mm)	Cane weight (g)	NMC (000/ha)	Cane Yield (t/ha)
	A. Fertilizer dose					
A_1	100% of recommended NPK (120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha)	231.7	83	1367	68.99	94.64
A_2	80% of recommended NPK (96 kg N, 48 kg P_2O_5 and 32 kg K_2O/ha)	230.0	82	1306	69.06	90.31
	SEm.±	**5.30**	**0.73**	**24.4**	**0.98**	**1.93**
	C.D. at 5%	NS	NS	NS	NS	NS
	B. Methods of tillage and fertilizer application					
B_1	Plough x 1 + Harrow x 4 + Furrow fertilizer application **(Control)**	224.2	81	1222	62.24	75.97
B_2	Subsoiling (400 mm) + Harrow x 2 + Furrow fertilizer application	235.8	82	1274	69.33	88.03
B_3	Subsoiling-cum-deep fertilizer placement (300 mm) + Harrow x 2	239.4	84	1430	72.06	103.02
B_4	Subsoiling-cum-differential rate fertilizer placement (80% at 250 mm and 20% at 400 mm) + Harrow x 2	236.1	83	1419	72.46	102.87
	S Em.±	**7.50**	**1.03**	**35**	**1.39**	**2.73**
	C.D. at 5%	**NS**	**NS**	**145**	**4.22**	**8.28**

Pot Experiment' conducted in the previous year with ten treatments (Singh and Thakur, 2012). The treatments selected for field experiment were as follows:

T_1: Broadcasting of inorganic fertilizer and mixing in top 100 mm soil with rotavator x 2 (Control)

T_2: 50% inorganic + 50% organic and mixing in top 100 mm soil with rotavator x 2

T_3: Subsoiling upto 400 mm depth with Pant-ICAR Subsoiler-cum-Organic Manures and Soil Amendments Applicator and mixing 100% inorganic in top 100 mm soil with rotavator x 1

T_4: Subsoiling upto 400 mm depth with machine as in T_3 and mixing 50% inorganic + 50% organic with rotavator x 1

T_5: Placement of 80% inorganic at 200 mm depth and remaining 20% at 400 mm depth with Pant-ICAR Susboiler-cum-Differential Rate Fertilizer Applicator followed by rotavator x 1

T_6: Mixing of 50% N (inorganic) and 50% N (organic) and placed with Pant-ICAR Subsoiler-cum-Organic Manures and Soil Amendments Applicator followed by rotavator x 1

T_7: Placement of 50% N (organic) and 400 mm depth and 50% N organic at 200 mm depth with Pant-ICAR Chiseler-cum-Fertilizer Applicator followed by rotavator x 1

N.B.: (Inorganic: Urea, SSP and MOP; (N:P:K:: 120:40:20 kg/ha), Organic: Vermicompost -1.5% N, 1.1% P and 1.3% K and 50% N inorganic: 50% N through urea and 100% P&K)

The results of the field experiment at the time of harvest are presented in Table 3. It is evident from the table that the test (1000- seeds) weight, oil content and harvest index were found to be non-significant in different treatments. However, the number of siliquae per plant, seed yield and oil yield varied significantly in different treatments. The maximum seed yield of 2.11 t/ha was obtained in treatment T_7 followed non-significantly by T_6. The lowest yield (1.72 t/ha) was obtained in control treatment (T_1). This showed 22.56% higher yield in treatment T_7 over control (T_1).

Table 3: Influence of deep placement of organic and inorganic fertilizers on yield and yield attributes of mustard crop

Treatments	Yield and yield attributes						
	No. of siliquae/ plant	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Test weight (g)	Oil content (%)	Oil yield (t/ha)
T_1	223.9	1.72	5.64	23.49	4.13	40.12	0.69
T_2	246.7	1.75	6.11	22.40	4.22	40.35	0.71
T_3	283.29	1.74	6.35	21.63	4.09	40.23	0.70
T_4	286.1	1.78	6.60	21.30	4.28	39.75	0.71
T_5	341.7	1.91	6.78	22.00	4.21	39.64	0.76
T_6	401.0	1.94	6.92	21.85	4.39	39.59	0.77
T_7	482.5	2.11	7.69	21.50	4.45	39.75	0.84
Sem±	13.09	0.06	0.32	0.77	0.09	0.22	0.26
CD at 5%	40.36	0.19	0.99	NS	NS	NS	0.08

Response on Potato

A field experiment was carried out during 2012-13 for observing the response of potato crop with deep and differential rate placement of organic and inorganic fertilizers. Five treatments which could be carried out with machines in a mechanized system of cultivation were selected after screening the results of a

'Field Pot Experiment' carried out in previous year with nine treatments and had higher tuber yields and quality in a descending order (Karuna *et al.*, 2014). The experiment was planned in RBD with three replications and the experimental procedure and data collection were carried out as per standard protocols. The treatments selected were as follows:

$T_{1:}$ Broadcasting of 100% inorganic fertilizer and mixing in top soil with rotavator x 2 (Control)

$T_{2:}$ 100% inorganic placed at 150 mm depth below ridge with Pant-ICAR Chiseler-cum-Fertilizer Applicator followed by rotavator x 2

$T_{3:}$ 80% inorganic fertilizer placed at 250 mm and remaining 20% placed at 350 mm depths with Pant-ICAR Subsoiler-cum-Differential Rate Fertilizer Applicator followed by rotavator x 2

$T_{4:}$ 50% N organic placed at 350 mm depth using Pant-ICAR Subsoiler-cum-Vermicompost and Soil Amendments Applicator, and 50% N (inorganic) placed at 250 mm with Pant-ICAR Chiseler-cum-Fertilizer Applicator followed by rotavator x 2

$T_{5:}$ Deep tillage up to 250 mm depths with Pant-ICAR Chiseler-cum-Fertilizer Applicator and 50% N inorganic + 50% N organic mixed together and placed at 150 mm depth with Pant-ICAR Subsoiler-cum-Vermicompost and Soil Amendments Applicator followed by rotavator x 2

Table 4: Yield attributes and yield of potato as influenced by different methods of fertilizer placement

Variety: Kufri Khyati | Seed Rate: 3.5 t/ha

Inorganic fertilizer (N: P: K): 160:100:120 kg/ha | Organic (Vermicompost): 5 t/ha

Sowing: October 22, 2012 | Harvesting: Feb. 12, 2012

Soil type: Sandy clay loam

Treatments	No. of tubers per plant	Tubers weight per plant (g)	Roots dry mass (g)	*Grade wise tubes yield (t/ha)				Total tubers yield (t/ha)
				A	B	C	D	
T_1	8	720	0.70	10.49	5.46	3.50	1.91	21.36
T_2	9	855	0.74	11.14	6.11	4.38	1.68	23.31
T_3	8	994	0.80	13.68	8.20	6.65	1.41	29.94
T_4	8	1030	0.87	12.93	7.60	6.00	1.84	28.37
T_5	8	909	0.78	11.94	6.47	5.03	2.03	25.47
S.Em.±	0.57	80.26	0.12	0.22	0.23	0.22	0.23	0.23
C.D. at5%	NS	261.59	NS	071	0.76	0.72	NS	0.75
C.V.	12.19	15.42	26.54	3.11	5.98	7.47	22.86	1.56

*Grades: A (> 75 g) B (50-75 g)C (25-50 g)D (<25 g)

The results presented in Table 4 revealed a significant maximum tuber yield of 29.94 t/ha with deep and differential rate fertilizer placement method (T_3) and the lowest tuber yield of 21.36 t/ha in control (T_1). Hence, approximately 28.66% higher yield was obtained with the innovative technique over control. This infact has happened due to complete soil disturbance upto 350 mm depth which reduced the soil bulk density with corresponding increase in soil porosity and hydraulic conductivity, thus allowing the plant roots to explore a greater volume of soil profile and utilizing the plant nutrients placed at different depths in the moist root zone throughout the cropping period. Similar result was obtained by Mc Even and Johnston (1979) who reported 16% higher yield by subsoil incorporation of P & K in sandy loam soil. In another study carried out by Thakur *et al.* (2005), over 11.70% higher yield was obtained by only subsoiling upto 350 mm depth as compared to conventional method. Hence, it is possible to increase the productivity and quality of potato by adopting the innovative technique developed in the ICAR National Professor Scheme.

Innovations in Crop Establishment Technology

The existing seed drills available in India place seeds and fertilizer side by side at the depth of around 5 cm which remain almost dry during most part of the cropping period. The immobilized P & K fertilizers are available to plants only when the soil is moist during irrigation but remain unutilized due to dry top surface of soil after few days of irrigation. In case of Inverted-T opener ZT drills, the fertilizer is placed at a little lower depth than the seeds in the same vertical plane and a good yield have been obtained at many locations depending upon the soil conditions and management practices. It must, therefore, be realized that for Indian condition the fertilizer should be placed at a depth where there is sufficient moisture and higher root density of crops. At present, no such machine is available in India which can prepare seedbed similar to the one prepared by commonly used primary and secondary tillage tools and at the same time can sow all kinds of seeds. Also, no drill is available which can place fertilizers at a deeper depth of 15-20 cm and simultaneously place seeds at a shallower depth of 5-6 cm in the same vertical plane.

a. Tiller-cum-seeder b. Primary tillage c. Sowing of pulses

Fig. 6: Pant-ICAR controlled field traffic tiller-cum-multi crop ferti-seeder: All-in-one machine

Keeping the above points in view, the research work on a new generation of machine called 'Pant-ICAR Controlled Field Traffic Tiller-cum-Multicrop Ferti-Seeder' or 'All-in- One Machine' was taken-up during 2011-12. This machine (Fig. 6) is under extensive field evaluation for seedbed preparation and planting of various crops such as wheat, rice, mungbean, soybean, cowpea, pea etc. It has also capability for sowing of maize, pigeon pea, lentil, gram and all other similar kinds of seeds with proper adjustment. The specific feature of this machine is five number of inclined tines equipped with broader winged type chisel share mounted on a three beam frame at 45° V angle such that one tine is positioned at the middle of front beam and two each on second and third beams along the V-angle. This arrangement gives least soil resistance while tilling and easy flow of loose residues at the rear of machine. It can till soil to a depth of 15-20 cm without soil inversion and can place the fertilizers at tilling depth in a band. During sowing operation, the main winged chisel shares are replaced with especially designed 'Jet Openers' for placing fertilizers at the tilling depth. The seeds are placed at around 5 cm depth with separate openers mounted behind each inclined tines in a synchronous vertical plane of fertilizer band. The seeds and fertilizer application rates are varied by three transmission ratios as well as by vertical adjustment of a common seed-cum-fertilizer hopper positioned above the metering housings. The seeds from the hopper are delivered to the metering housings each equipped with a grooved roller through a conical pipe to avoid bridging of seeds particularly rice, whereas the fertilizer from the main hopper is delivered through a variable height circular pipe to each of the metering housing equipped with a pair of grooved rollers. The rear of machine is provided with a floating plain roller alongwith an iron plank for breaking clods and levelling of field during seedbed preparation as well as for covering of seeds after sowing. The concept of deep placement of fertilizers below the seeds in the same vertical plane using the developed machine is being investigated by many research scholars of the Departments of Farm Machinery and Power Engineering, Plant Physiology, Soil Science and Agronomy of Pantnagar University. The field experiments carried out for sowing of direct seeded rice (DSR) as well as wheat at a wider row spacing of 25 cm instead of 20 cm for promoting mechanization of weeding and interculture operations have shown far superior results in terms of increased yield, quality of seeds, anti-lodging ability of plants, tillage energy saving etc. Similar response has been observed on pulses i.e. urdbean, mungbean, soybean, cowpea etc. in the exploratory studies carried out with the developed technology during 2012-13. A well planned experiment was carried out on wheat crop during 2013-14 by engaging a P.G. Scholar of the Department of Plant Physiology. All the data pertaining to soil, plant growth, root development, nutrient uptake efficiency, yield attributes etc. were collected and scientifically analyzed. However, only the yield and yield attributes at harvest are presented over here.

An experiment was conducted on wheat crop (Variety: DPW-621-50) with three machines i.e. (i) zero-till ferti-seed drill (T_1), (ii) roto-till ferti-seed drill

(T_2) and (iii) Pant-ICAR controlled field traffic tiller-cum-multicrop ferti-seeder (T_3) in randomized block design with eight replications. The field selected for the experiment was under rice-wheat cropping system for past one decade and had direct seeded basmati rice sown after chiseling to a depth of 25 cm and two passes of rotavator for preparing the field in the previous *Kharif* season, 2013.

The initial development of roots after eighteen days of sowing with three methods of sowing is presented in Table 5. The data clearly reveals a longer root development with deep placement of fertilizer below the seeds in vertical plane (T_3) as compared to other two treatments where fertilizer was placed in the vicinity of seeds. After eighteen days of sowing the treatment T_1 and T_2 clearly indicated the concentration of roots around the fertilizer placement zone whereas in treatment T_3 the roots were penetrating downwards in search of nutrients as the fertilizer was placed at the depth of about 15 cm from the surface and seeds at 5 cm in the same vertical plane.

Table 5: Root and shoot length of wheat at 18 days after sowing

Treatments	Root length (cm)	Shoot length (cm)
T_1	10.39	19.2
T_2	11.95	19.12
T_3	16.87	21.37

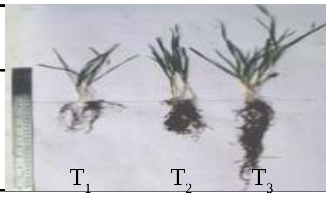


Table 6: Yield and yield attributes in wheat sown by different machines

Sowing methods	Row to row spacing (cm)	No. of plants/ m^2	Length of ear head (cm)	Test weight (1000 grains) (g)	Grain yield (t/ha)	Straw yield (t/ha)	Straw: Grain ratio	Harvest index
Zero-till ferti-seed drill (T_1)	20	441	9.26	36.00	6.45	8.14	1.25	0.41
Roto-till ferti-seed drill (T_2)	20	416	8.79	33.56	6.10	6.70	1.11	0.40
Tiller-cum-Multicrop ferti-seeder (T_3)	25	511	9.61	36.7 5	6.90	9.24	1.33	0.41
SEm±	-	24.3	0.24	0.84	0.24	0.35	0.57	0.005
CD at 5%	-	73.74	0.74	2.54	0.72	1.08	0.17	0.02

The yield and yield attributes in wheat at harvest are presented in Table 6. The data clearly indicates the maximum number of plants / m^2, length of ear head, test weight, grain yield and straw yield in treatment T_3 as compared to other two methods of sowing. The grain yield with tiller-cum-multicrop ferti-seeder (T_3) was found to be 12.93% higher over roto-till ferti-seed drill (T_2) and

7.65% higher over zero-till ferti-seed drill (T_1). The machine is being extensively evaluated on pulse crops during *Kharif* 2014.

The Way Forward

1. Little information is available in India on root proliferation of different crops and nutrient uptake from different segments of roots. Studies need to be carried out at least on prominent varieties of crops for developing efficient fertilizer application machinery.
2. In view of the possible climate change, developing crop varieties to withstand against *abiotic* stresses especially the moisture stress conditions need to be emphasized. Such root geometry when matched with deep fertilizer placement technologies could produce ideal conditions for crop growth and yield response.
3. There is a definite shift towards high horse power range tractors in Indian agriculture. Therefore, rather than increasing the width of tillage equipment to match the power source, it would be worthwhile to link two or three or more operations as a combination type implements to reduce the traffic in the field for overcoming soil compaction problems. Controlled field traffic system of farming would decelerate the formation of subsoil compaction, thereby would save the tillage cost and enhance the productivity of land.
4. Emphasis should be given on subsoil health management technologies for extensive root proliferation and efficient nutrient uptake from a large volume of soil. The increased root biomass could add more organic carbon than exclusive management of crop residue at the surface. The surplus biomass could be utilized by other sectors of economy such as animal feed, paper industry, board making, power generation and others.
5. The field experiments conducted at G.B. pant University of Agriculture and Technology, Pantnagar have revealed substantial yield increase by deep placement (15 cm depth) of fertilizers exactly below the seeds. This indicates that the existing ferti-seed drills used in India for placement of seeds and fertilizers side by side at the same depth are not scientifically designed and lacking in basic concept. More basic research studies need to be carried out with maize, wheat, pulses and horticultural crops to establish optimal location of fertilizer bands in the soil profile. The information so generated could help for the design of double stage furrow openers for deep placement of fertilizers in the moist root zone and simultaneous drilling of seeds at shallow depths in synchronized vertical plane above the fertilizer band for optimal nutrient utilization.
6. The seed-cum-fertilizer drills manufactured in India are equipped with rigid tines, placing thereby the seeds and fertilizers at varying depths depending upon undulations and depressions in the field. There is a need to develop

drills and planters with full floating type furrow openers incorporating four bar linkage for precision planting and placement of fertilizers irrespective of the field surface configuration.

7. Significant advances in soil chemistry, plant physiology, plant nutrition, molecular biology, subsoil modification and fortification, agricultural engineering and others must be integrated for a breakthrough in stagnated yield barriers in the country.
8. Deep and differential rate placement of fertilizers particularly P &K and organic materials in the subsoil zone has given very positive response in *Tarai* region of Uttarakhand and U.P. There is a need to launch a mega networking project at the National level to harness the benefits of this technology in other agro-climatic zones of the country.

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7

Maximizing Fertilizer Use Efficiency for Sustainable Agriculture

K.N. Tiwari and Rakesh Tiwari

With increased crop production and productivity over the years, the nutrient removal has increased by over four times during the last four decades putting four-fold pressure on soil. A yearly gap of about 10 MT of nutrient (NPKS) still exists between nutrient removal and supply through fertilizers. The gap varies widely among different agro-climatic regions of the country and this gap, if not bridged timely, will pose major threat to agriculture sustainability. The responses to nutrient application have been decreasing for the country as a whole. Some of the factors related with nutrient management contributing to low responses are : suboptimal and unbalanced fertilizer use in large irrigated and assured rainfall areas, excessive and imbalanced use of N and P in potato, sugarcane and many vegetable crops grown for commercial purposes, inappropriate methods and time of application, deficiency of sulphur and micronutrients and lesser use of organics. Site specific nutrient management based on the principles of IPNS has now assumed great importance firstly, because of the present negative nutrient balance and secondly, neither the chemical fertilizers alone nor the organic sources exclusively can achieve the production sustainability of soils as well as crops under highly intensive cropping systems. Discussed here are the issues and strategies of maximizing fertilizer use efficiency in India.

India witnessed a significant increase in productivity and cropping intensity till the 1980s; thereafter, new challenges caught up to slow down the growth rate. An agrarian country like India where population growth rate outstrips agricultural productivity, the need to produce more and more food compels the people to meet new challenges so as to maintain food security intact. Currently, Indian agriculture is faced with a major challenge of declining factor productivity, which needs immediate remedial measures to ensure food security and maintain access to food for all. With the intensification of agriculture after mid-sixties without supporting adequate replenishment of nutrients from external sources, the number of nutrients becoming deficient in Indian soils has increased with time. Apparently, the growth in foodgrain production is showing a trend of stagnation after 1980s and the main culprit for this is inadequate and unbalanced nutrient use causing continuous depletion of the soil's nutrient reserve and increasing instances of multi-nutrient deficiencies in soils. The inadequacy and imbalance are so well ingrained in Indian farming that it is difficult to recognize which made the most damage to agriculture production system. The main reason for increasing instances of the nutrient deficiencies all over the country is the total disregard of the replenishment of these nutrients as per crop needs and existing deficiencies of these in soils and crops.

It has been estimated that fertilization accounts for nearly 50% of all crop yield in India. In other parts of the world, where farm land has been abused for centuries or where new land is brought into production and quickly mined of its nutrients, fertilization might contribute as much as 75% of total food production. Proper crop fertilization is essential to prevent massive global starvation. It is important to consider all the roles that soil plays in the production of food and fiber for feeding the people. Soil is the medium in which plants grow and the source of most plant nutrients. Soil, water and air bathe plant roots and help keep them and above-ground plant parts healthy and growing. The quality of soil in which plants grow is extremely important in determining factor productivity, crop yield as well as the agriculture sustainability. The key role of balanced use of fertilizers in maintaining soil fertility and enhancing fertilizer use efficiency (FUE) is well established. The paper deals with the issues and strategies to enhance FUE for agriculture sustainability in India.

Changing Soil Health Scenario: A Big Issue

Nutrient removal by crops far exceeds nutrient additions through fertilizers. For the past 40 years, a gap (removals less additions) of 8 to 10 M t $N+P_2O_5+K_2O$/year has been documented. This situation is akin to mining the soils of their nutrient capital. At the all-India level, soil deficiencies of N, P, K, S, Zn, and B are now of widespread importance. Nitrogen deficiency is common in the vast Indian plains. The magnitude is also quite large in respect of P (>75%) and K (>50%) deficiency. In fact, potassium fertility of soils in India is not only neglected, but also under severe stress with the ongoing scenario where K removals vastly exceed K input. Recent studies have shown that production is also constrained by S deficiencies which are now estimated to occur in close to 250 districts and about 40% of soil samples have been found to be S deficient. Based on several years of data and 250,000 soil samples, 49% of soils were found to be deficient in Zn, 12% in Fe, and less than 5% for Cu and Mn. Boron deficiencies now need to be taken seriously in several areas with 33% out of 36,800 soil samples analyzed having been found to be B deficient. (Singh, 2001). Apparently, Indian agriculture is faced with the problem of multi-nutrient deficiency on a quite large scale. Although it may be useful to examine physical, chemical and biological aspects of soil quality individually, soil should be viewed as an integrated system. For example, physical and chemical properties are shaped by biological activity, and biological activity is enhanced or limited by chemical and physical condition. A healthy soil is 'biologically active' containing a wide diversity of microorganisms. Relevant biological properties include soil organic matter content, microbial biomass, respiratory activity, nitrogen mineralization, soil enzymes, soil fauna and population of suppressive organisms.

Declining Fertilizer Use Efficiency (FUE): A Major Threat to Sustainable Agriculture

FUE refers to the proportion of applied nutrient recovered by the crop. It is commonly expressed as a percentage of fertilizer used by the crop or alternatively in terms of crop yield per unit of fertilizer (e.g. kg grain per kg of applied nutrient). FUEs vary widely rarely exceeding 50 to 60% or even as low as 20% for nitrogen (N), 10 to 30% for phosphorus (P), and 20 to 60% for potassium (K), hardly 50% for sulphur (S) and <10% for zinc (Zn). The efficiencies can be greater over the long-term because of the residual properties of the immobile nutrients like P, Zn (and other micronutrients) and to some extent of K and S also. The FUE trend at national level has been showing a consistent decrease mainly due to unbalanced use of fertilizers, mostly limited to N and P and poor land and water management. For example, the FUE which indicated 16 kg of increase in foodgrain by per kg NPK applied during 1970's has dwindled down to 6-7 kg of foodgrain per kg NPK applied at present. Apparently, the responses to nutrient application have been decreasing. Some of the factors related with nutrient management contributing to low responses are : suboptimal and unbalanced fertilizer use in large irrigated and assured rainfall areas, excessive and imbalanced use in some commercial and horticultural crops, inappropriate methods and time of application, deficiency of sulphur and micronutrients and lesser use of organics. Evidently, the magnitude of increase in foodgrain production could not keep pace with the increase in fertilizer consumption showing a clear cut fall in FUE, thus, the money spent by the farmers on fertilizers and also the money spent by the Government towards fertiliser subsidy has not yielded the desired result. The disturbing trend of yield stagnation/decline can be reversed by increasing FUE. The following constraints are generally being faced by the farmers:

- Lack of access to improved farm technology
- Lack of awareness about importance of optimum and efficient use of fertilizers
- Lack of access to soil testing service, that too is confined to NPK only
- Lack of awareness about depletion of soils nutrient reserves and deterioration in soil health.
- Inadequate and timely supply of agricultural inputs
- Reluctance towards preparation of organic manures/composts and use of biofertilisers
- Frequent distress sale of farm produce, thus reducing the potential gains from the adoption of improved technology.

Measures to Enhance FUE

Crop's responsiveness to fertilizer or in other words fertilizer use efficiency (FUE) is maximized and environmental impact of fertilizer is reduced (and often eliminated) when crops are managed for improved nutrient efficiency through Best Management Practices (BMPs) which balance production inputs at the appropriate levels and utilize site-specific soil and water conservation techniques to maximize soil retention and minimize losses of plant nutrients to ground water. The BMPs are specific for individual farms, fields, soils, and climates. Past research, experience and knowledge of local soil and climatic conditions dictate the BMPs for a particular area. The BMPs help farmers achieve maximum economic yield (MEY) levels where costs per unit of production are lowered to the point of highest net return for existing soil and climatic conditions. The strategies for maximizing fertilizer use efficiency are given below.

Balanced Fertilization

The concept of balanced fertilization which endorses application of all required nutrients in a proportion and amount required by the crop, considering the nutrient supplying power of the soil as well as nutrient use efficiency and yield targets, was seldom suggested thus never practiced by the farmers. Most of the onus of such practice should go to the policy makers and scientists, who stuck to the 4:2:1 ratio as a synonym to balanced fertilization across the board. The total lack of site specificity in the nutrient prescriptions is the main reason for declining factor productivity and reduced growth in agricultural production in the country. Nutrient use on the principles of site-specific nutrient management can be the most vital weapon to reverse this negative trend.

Nutrient balance discussions are often confined to N, P and K because of their large scale deficiency and also larger demands by the crops. Unbalanced and inadequate use of major nutrients in general, and of P and K in particular, and utter negligence for secondary and micronutrients have created a situation where simply by increased use of N or N+P, the productivity of crops can not be increased. The yields obtained by joint application of NPK are significantly higher in most of the cases. However, balanced nutrient management goes well beyond NPK. As the yield goals increase, the nutrients demand of the crops increases both in number and the quantity. Apparently, Indian agriculture is now in the era of multiple nutrient deficiencies. At least five nutrients (N, P, K, S, Zn) are of great importance from application view point. It would not be surprising if progressive farmers in several areas must apply 4-6 nutrients to sustain high yields of premium quality crops.

Balanced Fertilization Improves Soil Health

As science progressed, it was discovered that long-term sustainability of crop production was dependent on building and maintaining soil fertility, an important soil quality measurement. Later, it was demonstrated that organic matter levels could be maintained and even increased through balanced fertilization. One of the greatest benefits of crop fertilization, aside from increasing crop yields and improving farmer profit, is its effect on soil organic matter. Harvested crop yields increase as a result of crop fertilization, as does un-harvested plant biomass left on the soil surface and crop residues (roots) remaining in the soil. Most of the un-harvested surface biomass and underground residues become soil organic matter. It has long been known that organic matter positively influences structure, tilth, bulk density, water infiltration rates, water holding capacity, and water and air movement within the soil, thus improving soil quality. Organic matter helps to bind soil particles together, reduces soil crusting, increases the stability of soil aggregates, acts as a reservoir for plant nutrients, and reduces soil runoff and erosion losses.

Data from 12 long-term experiments (LTE) conducted in India under the Indian Council of Agricultural Research (ICAR) Coordinated Project on Cropping Systems were analyzed to evaluate the effect of different sources of organic matter (farmyard manure (FYM) and green manure (GM)) in combination with inorganic fertilizer, on the productivity of rice-wheat systems. The average rice yield with 100% NPK was still significantly higher than with FYM. In wheat, average yields and yield trends were not significantly different among the fertilizer treatments. The fertilizer treatments showed no significant effect on final yield, although the initial yield was significantly higher with 100% NPK than with FYM. Other long-term rotation studies in India have also demonstrated that moderate amounts of fertilizers increase soil organic matter quantity and quality. The positive benefits of fertilization have been directly attributed to the amount of crop residues returned to the soil. In addition to higher grain yields, fertilizer increased straw and root production, the precursors of soil organic matter. However, the realities surrounding short supplies of FYM because of burning of cow dung for fuel and the high labor and transportation costs continue to restrict its extensive and widespread application in agriculture. It is most likely that the most immediate solution to sustaining crop yields in the absence of adequate FYM supply will come from the regular use of site specific application of inorganic fertilizers.

Balanced Fertilization Ensures Sustainable High Yield

People and plants are alike in several ways. In particular, both need balanced nutrition for normal growth and good health. Unlike people (who require complex - mineral, protein, etc. - foods) plants need only 17 nutrients, 3 obtained from air and water and the rest from soil, to grow normally - if those nutrients are supplied in a proper balance. When crops have balanced nutrition, added bonuses include higher nutritive quality and increased environmental protection.

Site Specific Nutrient Management (SSNM)

Another development of considerable interest in directing the course of balanced and efficient nutrient management refers to site-specific nutrient management (SSNM). Nutrient management is a major component of a soil and crop management system. SSNM is a systematic agronomic approach which considers field-scale variability in soil fertility and crop responses to applied nutrients. In recognition of the potential applicability of SSNM, the IPNI-India Program in collaboration with Project Directorate for Cropping Systems Research (PDCSR-ICAR) has established collaborative SSNM research with the rice–wheat system and at 6 locations with the rice–rice system (**Table 1**). In the SSNM experiments, 4 to 8 nutrients were applied in a pre-planned manner to evaluate responses to each of these at one or more levels (except N). Both crops received N, P, and K. Only *kharif* rice also received S and micronutrients implying that the *rabi* crop, whether rice or wheat, benefited from the residual effect of these nutrients.

Table 1: Experimental locations and the nutrients applied in the rice-wheat and rice-rice systems according to SSNM.

Location	State	Rice	Wheat
		(A) Rice-Wheat System	
Sabour	Bihar	NPK S	NPK
Palampur	Himachal Pradesh	NPK S B Zn	NPK
R. S Pura	Jammu & Kashmir	NPK S Mn Zn Cu	NPK
Ranchi	Jharkhand	NPK S B Zn	NPK
Ludhiana	Punjab	NPK S B Mn Zn Cu	NPK
Faizabad	Uttar Pradesh	NPK S B Mn Zn	NPK
Kanpur	Uttar Pradesh	NPK S Zn	NPK
Modipuram	Uttar Pradesh	NPK S B Mn Zn	NPK
Varanasi	Uttar Pradesh	NPK S B Mn Zn Cu	NPK
Pantnagar	Uttaranchal	NPK S B	NPK
		(B) Rice-Rice System	
Maruteru	Andhra Pradesh	NPK B	NPK
Jorhat	Assam	NPK S B Mn Zn Cu	NPK
Navsari	Gujarat	NPK S Fe Mn Zn	NPK
Karjat	Maharashtra	NPK B Fe Zn	NPK
Coimbatore	Tamil Nadu	NPK Fe	NPK
Thanjavur	Tamil Nadu	NPK S Mn	NPK

Source: Tiwari, K.N. (2006). Site Specific Nutrient Management for Increasing Crop Productivity in India. PDCSR (ICAR)–PPIC, India Programme, pp 92.

Rice-wheat data averaged over 2 years show that annual grain yields of 15 to 17 t/ha were achievable. Average annual grain productivity of the system was 13.3 t/ha of which 60% was from rice and 40% from wheat. None of the SSNM locations had annual grain productivity less than 10 t/ha. Averaged over locations, SSNM caused a 3.4 t/ha annual advantage or 34% more yield than common farmers' practices (FP). SSNM increased the expenditure on fertilisers by Rs.4,170/ha (US$104) compared to FP but generated additional produce valued at Rs.20,530 (US$513) – returning an extra net income per unit extra expenditure, or benefit-to-cost (BCR) ratio of 4.9. A frequency distribution of economic returns for the rice-wheat system (84 location x nutrient x rate combinations) found BCRs under 2 in 13% of cases, 2 to 5 in 17% of cases, 5 to 10 in 24% of cases, and above 10 in 46% of cases. The majority of cases with very high BCRs reflect very high grain yields achieved through high rates of response per unit applied nutrients.

Similarly, two years of rice-rice data revealed grain yields of 15 to 18 t/ha. Average annual grain productivity was 13.3 t/ha – the contribution of *Kharif* and *Rabi* rice being almost equal. The annual grain productivity under SSNM was more than 10 t/ha at all locations except one. Averaged over locations, SSNM brought a 2.5 t/ha advantage, or a 23% increase over FP. SSNM also increased fertilizer expenditure by Rs.4,540/ha over the FP but generated additional produce valued at Rs.11,900/ha – a BCR of 2.6. The application of several nutrients was profitable at most sites.

The major benefit of improved nutrient management strategy to the farmers is increased profitability. The SSNM avoids indiscriminate use of fertilizers by preventing excessive/inadequate rates of fertilization, and by avoiding fertilization when the crop does not require nutrient inputs. It also ensures that N, P and K are applied at proper rate and in proper ratio commensurate with crop's nutrient needs. The nutrient use on the principles of SSNM can accommodate a wide range of socio-economic variations, including those situations of labor shortage. Additional labor may be required, but labor costs for nutrient management are relatively small compared to those for land preparation, transplanting or harvesting. Efficient N management may also result in off-farm environmental benefits through a reduction of fertilizer N use without a reduction in yield especially in situations where N inputs are large compared to other nutrients, which may increase profitability.

Site-specific crop and soil management is really a "repackaging" of management concepts that have been developed and promoted for many years. It is basically a systematic approach to apply sound agronomic management to small areas of a field that can be identified as needing special treatment. The components of site-specific management may not be new, but now we have the capability with new technology to use them more effectively. Site-specific management includes practices that have been previously associated with MEY management, best management practices (BMPs), as well as general agronomic principles. The systematic implementation of these practices into site-specific systems is probably our best opportunity to develop a truly sustainable agriculture system.

The introduction of SSNM strategies should start with the priority areas facing one or more of such problems (1) Areas having inadequate or unbalanced use of fertilizer nutrients with low yield levels; (2) Areas with crops showing nutrient deficiency symptoms at large scale; (3) Areas with occurrence of pest problems linked to nutrient imbalance or overuse of fertilizer N; (4) Areas with inefficient fertilizer N use at higher rates (no proper splitting and timings) with insufficient use of P and K; (5) Areas with the evidence of large mining of soil's P and K reserves; and (6) Areas having evidence of multi-nutrient deficiencies including secondary and micronutrients in soils and crops.

Fertilizer Best Management Practices (FBMPs)

To enhance FUE, all attempts should be made to practice "Fertilizer Best Management Practices" (FBMPs) on the principles of IPNS. The ideal model for fertilizer best management practices is exhibited in **Fig 1.**

Fig.1: FBMPs for maximizing fertilizer use efficiency

When crops are managed for improved nutrient use efficiency through FBMPs on the principle of "**Four Rs"** ie. 1. Right Fertilizers, 2. Right Quantity, 3. Right Time and 4. Right Methods. FBMPs help improving FUE through increased nutrient uptake by crop plants and reduced nutrient losses from the soil. Thus, responsiveness of crops to applied fertilizers is maximized and the environmental impact of fertilizer is reduced. FBMPs help farmers achieve maximum economic yields (MEY) thus costs per unit of production are lowered to the point of highest net return. FBMPs, in fact, should ensure perfect adoption of all cultural practices from seed to grain or say from seeding to harvest. FBMPs are specific for individual farms, fields, soils and climates. The knowledge of local soil and climatic conditions, crops and cropping systems and resources available with the farmers often dictate FBMPs. Application of N in 2-3 splits and drilling/placement of entire quantities of P and K and a part of N as basal ie. at the time of sowing/transplanting depending on soil, crop, and availability of irrigation water, is ideal for improving FUE. Nitrogen use efficiency can further be increased through modified fertilizers like *neem* coated urea, urea super granules etc. particularly in paddy where the FUE is generally very poor due to many path ways to N losses (volatilization, leaching of nitrates, denitrification etc.). Adequate supply of other nutrients depending upon their deficiencies in soils enhances nitrogen use efficiency. Foliar application of urea under moisture stress condition can be of great help to increase N use efficiency. Increasing deficiency of S in soils is constraining crop productivity. Deficiencies of micronutrients are on increase. If the deficiencies of S and Zn have already been confirmed through soil tests or through visual symptoms in the previous crops, then basal application of 30-40 kg S/ha and 20-25 kg zinc sulphate should invariably be done. In case of boron deficiency, borax can be applied @ 5-10 kg/ha. In standing crops, micronutrient deficiencies can be corrected successfully by foliar fertilization. Foliar application of iron and manganese has been found more efficient than soil application. Application of specialty fertilizers like water soluble fertilizers through drip/foliar can further improve FUE. Customized and fortified fertilizers can be great help towards enhancing FUE.

Box 1. The Key Features of Optimum Plant Nutrition

- Maximizing the adoption of optimum nutrient application rates (no deficiencies, no toxicities)
- Ensuring balanced nutrient application (to supply all deficient nutrients, not only NPK) in addition to their optimum rate of application. This can often be achieved as lower cost.
- Ensuring the most efficient and productive use of applied nutrients, for which balance itself is a pre-requisite
- Using soil analysis, plant analysis and production goals as guidelines so that the external nutrient applications are used to supplement supplies expected from soil reserves without undue depletion of the soil from medium-long term sustainability point of view.
- Technologies available for optimizing plant nutrition must not only be adopted at the farm level but researchers must fine tune these to match local conditions and resources (as for example through SSNM).

Box 2. Important Tools for Enhancing FUE

Soil related: Soil testing for available nutrient status, soil conservation, reclamation of problem soils.

Water related: Water resource development, rain water harvesting, its conservation and recycling, water management to enhance nutrient and WUE.

***Crop related*:** Use of best available varieties (hybrids, other HYVs, stress-tolerant genotypes), intercropping, adoption of best management practices, diversification and intensification of agriculture with most suitable crop rotations as part of farming system development.

Nutrient supply related: On-farm production of organic manures, green manures, development of integrated nutrient supply system (IPNS), improvement in supply chain of required fertilizers containing major and micronutrient as also biofertilisers of genuine quality at correct price, at right time and right place in adequate quantity.

Transfer of technology: Promotion of best management practices through field programmes to enhance fertilizer use efficiency, on-farm demonstrations/trials, creating awareness about practices associated with deteriorating soil health through various programmes and media including help lines, promotion of fertiliser best management practices (FBMP/BMP) and correct/responsible nutrient use based on validated research findings in improve nutrient/fertilizer use efficiency (NUE/FUE).

Integrated Nutrient Management: A Basic Need

The unexpected price hike of both the fertilizers and the raw materials in the international markets has exorbitantly increased the subsidy bill which is now becoming unaffordable. This fact emphasizes the need for chalking out sound strategies and preparing a performing action plan to meet the goal of Second Green Revolution without increasing the fertilizer consumption. To fight with this problem, the best approach should be the adoption of integrated nutrient supply system (IPNS) ie. rational use of external input (fertilizers) supplemented by on-farm produced inputs to minimize the increasing demand of fertilisers. The major components of INM are fertilizers, organic manures, crop residues and biofertilisers. These must be appropriately integrated in a pre planned manner to meet the total nutrient needs of a cropping system. In most cases, the package of improved practices prepared by various institutions include the application of organic manures, appropriate biofertilisers, green manures etc along with fertilisers. But they rarely provide truly integrated packages. Indian agriculture is operating at a negative nutrient balance of 10 million tones. This is the gap between nutrient removals by the crops and the nutrient additions through fertilizers which needs to be bridged through increased applications of organics and biofertilizers. Both Organic and inorganic sources of nutrients contribute to crop productivity though the contribution of each sources varies considerably from one cropping system and from one soil climatic region to another under irrigated conditions. Judicious use of fertilisers, organics, agro-industrial wastes/ byproducts, biofertilizers (Rhizobium, Azotobacter, Azospirillum, Phosphate solubilizing microorganisms cultures, Blue green algae, Azolla etc.), and soil amendments (gypsum in sodic soils and lime in acid upland soils) can substantially augment soils nutrient supplying capacity and thus meet enhanced nutrient needs of sustainable high yield agriculture. This is very essential to maintain soil health for sustainability of Indian agriculture. Simultaneously, the IPNS would help not only cutting down the import of fertilizers significantly but also minimize the costs of crop production.

Organics

Among the organic manures, the most common is the compost / FYM. However, scientific technology either for the composting or in situ incorporation of residues has not been popularized amongst the farmers. The farmers do not make a serious efforts in preparation and conservation of organic manures and recycling of crop and animal residues because of competitive uses of organic materials such as dung cakes for domestic cooking fuel and sugarcane bagasse as fuel in sugar factories and villages. Organic materials are a scattered resource and have to be collected. The production of organic manures involves labour for collection of materials, their processing with appropriate technology to obtain good quality compost with minimum nutrient losses, transportation to field and incorporation into soil. The extension activities on the whole have been weak in this aspect. Standard method such as proper moisture (50-60%) and turning of organic mass during composting of FYM preparation (2-3 turnings) are not followed resulting in nutrient losses and poor quality organic manures. The compost prepared at the mechanical compost plants from city garbage are poor in plant nutrients. There are several factors which affect the proper adoption of the recommendations of different types of organic manures by the farmers.

Technologies for Improvement of Compost Quality

In situations where the crop residues because of high C:N, C:P ratios cannot be directly applied to soil as a source of nutrient, can be composted and in turn nutrient contained are converted into plant usable forms. The preparation and use of compost is handicapped due to low nutrient content and large volume. Recently, the technology for preparation of enriched compost in India has been standardized. For producing 100 tonne phosphocompost, the materials required will be 80 tonne organic wastes, 10 tonne cattle dung, 10 tonne soil, 5 tonne FYM/compost and 26 tonne rock phosphate which is sprinkled with each 15 cm layer of these composting materials. The mixture is allowed to decompose for a period of three months with periodic turnings. The end product contains 6-8% P_2O_5. It has been observed that 50% of the insoluble P or rock phosphate is converted into citrate soluble form. However, this compost contains less N than the conventional compost. Fertilizers like urea, DAP can also be used to fortify conventional composts either during composting or by mixing with ready compost during its field application. On equivalent P basis agronomic efficiency of rock phosphate enriched compost was at par to same dose of P applied through water soluble P carriers.

Green Manures

Green manuring with legumes has long been known to be beneficial for sustainable crop productivity. In several studies conducted in India green manure was able to replace 60 kg N/ha. A fertilized green manure crop would substitute more mineral fertilizer N than an unfertilized green manure crop. A wide variability in N substitution through green manuring to the order of 45-120 kg has been reported. Most commonly observed N additions through an array of green manures are in the range of 40-60 kg N/ha. Inspite of the many virtues of green manuring, its use at the practical level is rather unsatisfactory, particularly in intensive cropping systems, for agro-economic and operational reasons. An estimated 2.1 million ha was green manured in 2010-11 which is 1.5% of he net cultivated area. However, where practiced, green manures have a significant proven positive impact on soil health, not only chemical but also physical and biological.

Constraints to use green manuring: Green manuring has a special place in view of the limited availability of other organic manures. However, with intensification of agriculture and the advent of mineral fertilizers, farmers enthusiasm for this practice declined. With increased irrigation facilities, intensive agriculture is being adopted and as such farmers do not wish to set apart 6-8 weeks exclusively for growing green manure crop with no direct crop with no direct cash benefit. Green manure crop in rice-wheat cropping is taken as a catch crop after harvest of wheat during May-June and the intense heat constrains field operations. To overcome this problem, on the basis of experimental results it is being advocated to grow a pulse crop, pick up the pods just prior to full maturity and turn the biomass into the soil when still green thus the twin benefit of crop production and soil health improvement is obtained. Incorporation of straw of summer grown greengram in soil just before rice transplanting help improving rice yield equal to the application of 60 Kg N/ha.

Crop rotation as a key to sustainability: To overcome the ecological diseases of monoculture, the first solution that man found was the changing of crops from one to another or from one season to another. Even before the modern agriculture was established the farmer had discovered the restorative power of legumes. The legumes restore soil fertility and enhance crop productivity through increased utrient use efficiency in many ways. Some of them are: (1) Fix atmospheric N_2 and leave part of it in soil after their harvest (2) Deeper tap root system absorbs moisture and nutrients from deeper soil layers and some of the nutrients absorbed are left in the root mass in the surface soil (3) Improve soil permeability (4) Lesser disease and pest problem and (5) Better weed control

Legume in crop rotation can contribute upto 40-60 kg N/ha to the succeeding crops. Even when grown as a inter-crop, legumes may transfer significant amount of nitrogen to co-growing cereals. Quick growing leguminous shrubs grown as a part of the cropping system and incorporated into the soil at an appropriate stage as green manure, leguminous trees grown in hedge rows and their lopping used as mulch materials or incorporated into the soil of the cropped alleys between them and leguminous forage, pulses and oilseeds properly inoculated with Rhizobium grown in cropping systems provide significant quantity of N to the succeeding crops and also increase availability of other nutrients along with nitrogen and improve soils physical and biological properties. Preceding leguminous pulse and oilseed crops also leave behind substantial amount of residual nitrogen (about 30 kg/ha). Inclusion of legumes and use of biofertilizers, should, therefore, find place in crop rotations and mixed/inter-cropping systems to improve FUE and in turn enhance soil health and crop productivity. Legumes in cropping systems provide the first link towards integrated plant nutrient system (IPNS).

Crop Residue

In India, the burning of non-conventional fuel and resultant emission of greenhouse gases is severe in northern states. Incorporation of crop residue improves soil productivity due to over all improvement in physical, chemical and biological properties of soils. Regular return of residues to soil contributes to the build up of soil nutrient pool over a period of time. Incorporation of crop residue is known to enrich soils with organic C, N and other nutrients.

Biogas Slurry and Press Mud

Biogas slurry is semi-solid residue to biogas plants. Its typical composition is 1.4-1.8% N, 1.1-1.7% P_2O_5 and 0.8-1.3% K_2O and is a useful manure as such or as an ingredient for composting. Press mud which is a "waste product" discharged by sugar factories about three tones of press mud or filter cake is generated for every 100 ton of cane crushed. Press mud can be used in many ways (i) mud produced from the carbonation process can be used as a liming material, (ii) sulphitation press mud as a source of plant nutrients, particularly S as it contains 2.3% S on dry basis and (iii) as a n ingredient for making compost.

Biofertilizers

Biofertilizers by rendering unavailable sources of elemental nitrogen, bound phosphates and decomposed plant residues into available forms help enhancing soil fertility and crops yields. In India, during recent years due emphasis is being laid on biofertilizers.

Rhizobium

Extensive studies in different parts of the country under the All India Coordinated Pulses, Oilseeds, Legumes and Soybean Improvement Research Programmes it has been very well established that the yields of pulses and oilseed crops can be stepped up substantially by the use of rhizobial cultures. Some of the results from rhizobium inoculation trials show percent increase to the order of 9-54 in chickpea, 23-85 in moong bean 13-20 in urdbean 14-30 in pigeonpea, 15 in lentil and 23 in cowpea over un-inoculated controls. Among various soil factors, the organic matter and P and K contents of the soil influences the growth and survival of the rhizobia in the rhizosphere of legumes. It is, however, felt that in the era of multi-nutrient deficiency, application of S, Zn and B are also needed. As legume inoculation sometimes proves unsuccessful in acid and alkaline soils, seed pelleting with lime in acid soil conditions and with gypsum in alkaline soils protect rhizobia from the effects of acidity/alkalinity. Other pelleting agents like rock phosphate, tale, bentonite clay, charcoal etc. have also been used.

Azospirillum/Azotobactor: Multi locational trials with pearl millet, sorghum, finger millet, barley and vegetables have shown significantly increased yields due to inoculation with Azospirillum and Azotobacter, the effects of inoculation being more conspicuous under low levels of added nitrogen. Apart from nitrogen-fixing ability, Azospirillum is known to produce auxins, like cytokinins and gibberellins.

Blue Green Algae

Extensive field trials conducted in many parts of India on the use of the blue-green algae in rice fields indicate that algae could contribute about 30 kg N/ha through the inoculation. Algae are known to provide the crop plant with many other useful organic substances like growth factors, vitamins etc. Normally continuous inoculation for 3-4 consecutive cropping seasons results in an appreciable population build up without any further inoculation, unless some unfavourable ecological conditions supervene.

Azolla

The increase in yield of rice due to Azolla inoculation has been reported to be varying from 18-47 percent depending on the cultivar of rice used. Further, field experiments have shown that consistent increase in yield of rice could be obtained by the use of Azolla as a green manure in conjunction with fertilizer N. It has been estimated that a saving of atleast 30 kg N/ha in rice could be obtained by the use of Azolla biofertilizer besides residual effect for the succeeding crop.

P-Solubilizers

Bacteria such as *Pseudomonas* and *Bacillus* excrete acids into the growth medium and hence solubilize bound phosphates. These organisms are quite useful in the solubilization of rock phosphates. Field experiments conducted with P-solubilizers like *Aspergillus awamor*i, *P. striata* and *B. polymyxa* significantly increased the yield of various crops like wheat, rice, cowpea, etc. in the presence of rock phosphate and a saving of 30 kg P_2O_5/ha with the use of phosphate solublizing microorganisms has been reported. Reports dealing with the interaction of VAM fungi with N_2 fixers present in soil are also increasing.

Constraints to use biofertilizers

In spite of the aforesaid benefits, effective exploitation of biofertilizers in India is constrained mainly because of quality of the inoculants, lack of knowledge about inoculation technology for the extension personnel and the farmers, ineffective inoculant delivery system and formulation of the policy dictating the desire to exploit biological N fixation successfully. The National Project on Biofertilizers sponsored by the Ministry of Agriculture, Government of India and other agencies like NAFED and fertilizer industries GSFC, IFFCO, KRIBHCO etc. are producing biofertilizers. These are important developments to enhance FUE and economize fertilizer consumption.

Conservation Agriculture

India witnessed over exploitation of natural resources threatening agriculture sustainability due to soil and water stress, technology fatigue and stagnation in crop productivity during 90's. Introduction of Conservation Agriculture (Resource Conserving Technologies) is an important breakthrough for sustaining productivity, natural resource base and economic growth of the farmers. Adoption of Laser Land Leveling, retention of crop residues on soil surface in combination with no-tillage and crop diversification /intensification resulted in improvement in soil quality, overall resource enhancement, and savings in non-renewable energy use and carbon as well as methane emission and finally increase in farm income.

Attention to soil physical health is as essential as that to chemical and biological health for continuously increasing and sustaining high crop productivity level. This demands site specific technologies viz., optimum tillage practices and mulching, use of suitable cropping system, amendment of acid soils and salt affected soil and amelioration of soil physical constraints, efficient use of organic manures and fertilizers, which can improve the soil physical health. Rice-wheat is the dominant system of this region wherein conventional method of land preparation/sowing, not only disturbs the soil environment but also leads to atmospheric pollution. One of the most important principles of conservation agriculture (CA) is minimal soil disturbance. In no-till or zero till system, the seed is placed into the soil by a seed drill without prior land preparation. This technology has been tested and is presently being practiced over 2.0 million hectares of India and proves more relevant in the high yielding and more mechanized areas of north western India, where most land preparation is now done with four-wheel tractors. However, in order to extend the technology in Eastern parts of the IGP, drills for small tractors, 2-wheel hand tractors and bullocks have been modified and the drills are made available to the farmers. The benefits of zero-till system could be summarized as (1) water saving by 20-30% (2) energy saving by 80% because of less tillage and labour for crop establishment (3) increase in yield by 10-30% due to timely planting and increase in fertilizer use efficiency and (4) decreased pollution due to less consumption of diesel. Zero-till seedling performs better on a well leveled field compared to unleveled or fairly leveled field due to better seed placement, germination and uniform distribution of irrigation water and plant nutrients.

Managing Fertilizer Use in Cropping Systems

Farmers always grow the crop in different cropping sequences but fertilizer recommendations are done for individual crops and not for the cropping systems. Fertilizers applied in the preceding crop benefits the succeeding crops because of the residual effect of fertilizers and also due to favorable effect of leguminous pulses and oilseed crops. Precise quantification and phasing of nutrients in the light of preceding crops and fertilizers applied can improve the system productivity through increased FUE. Few examples are given below: Proper phasing of fertilizer application help improving FUE in the cropping systems as mentioned below:

(a) Adequate P fertilization in *Rabi* crops in rice-wheat, maize-wheat, pearl millet-wheat and sorghum-wheat systems is desirable. For example, in rice – wheat cropping system, 60 kg of P_2O_5 /ha is recommended to each rice and wheat. Experimental evidence show that need based allocation of total P quantity of 120 kg/ha for the system gives higher yield of the system due to enhanced FUE. Application of 30 to 45 kg P_2O_5/ha to rice and 75 to 90 kg/ha to wheat improves responses to applied P than its application @ 60 kg/ha to each crop. As *kharif* crops are grown in wet conditions, P availability is relatively higher due to increased moisture regime.

(b) In rice-wheat cropping system, rice crop becomes more vulnerable to Zn deficiency. In case of severe deficiency, application of Zn becomes the deciding factor for the success/failure of the crop. Therefore, Zn should preferentially be applied to rice crop and the succeeding wheat or other *Rabi* crops will be benefitted with the residual zinc and as such no fresh Zn application is needed.

(c) Potassium should invariably be applied in all the crops along with N and P for sustainability. Split application of K in light textured soils help improving FUE. Crop residue recycling and organic manuring should be promoted to cut down the K demand.

(d) Oilseeds and pulse crops respond relatively more to sulphur fertilizers. Adequate S supply should be ensured in such systems.

(e) Applications of compost/FYM prove more effective in wet season (*kharif*) crops with residual benefits on succeeding crop. Cumulative effect improves soil health by enhancing soils organic matter capital and by improving soils physical and biological properties. The residual and cumulative effects of organic manures should be taken into account while preparing fertilizer schedules for cropping systems. Nutrient enriched compost like Phospho-

Sulpho-Nitro-Compost (PSNC) can supply 30-40 kg P_2O_5/ha along with other nutrients.

(f) In rice-wheat cropping sequence, green manuring in rice by growing green manure crop (*dhaincha/*sunhemp) as a catch crop after harvest of wheat and before transplanting of paddy helps supplementing 60 – 80 kg N/ha through biological N fixation and also enhances availability of other nutrients through recycling of nutrients in the soil. As a thumb rule, with one ton production of green biomass, about 4 kg N is added. A good crop of green manure can supplement 60-80 kg N/ha. Deep rooted legumes utilize plant nutrients from the various depths of the soil in such a way that they maintain favorable balance among nutrients not only in the surface soil but in the sub-soil also and thus play a vital role in curing the increasing deficiencies of various nutrient elements in soils.

Technology Transfer and Development Priorities

Research and education can be seen as the two sides of the technology coin. However, in fertilizer use, the full picture is provided not by a 2-dimentional coin but by a 3-dimentional cube, the third side being commerce or supply-related. When technology is generated or is put together, its correct dissemination is extremely important. In arid and semi-arid regions, water conservation and management are crucial to efficient utilization of nutrients. Specific research objectives should aim: (i) developing alternative sources of nutrients, (ii) developing methods for efficient techniques of nutrient utilization, (iii) improving retention and recycling of nutrients, (iv)evaluating effects of organic matter content on soil fertility and physical properties, (v) improving soil structure to effectively control erosion and reduce soil degradation, and (vi) restoring productivity of degraded soils. Innovative cropping/farming systems, which must be highly productive and fit within the socio-economic, political and cultural frame work of the farming community, should be developed. Resource inventories will provide the much-needed information on soil, climate or eco-region-specific technologies for addressing specific production related constraints. These technologies, with farmer participation and support, are ready for transfer following on-farm validation and adaptation. The resource inventory also identifies knowledge gaps for research needs on farming systems, and biophysical or socioeconomic and cultural environments. Development priorities, in relation to institutional support and marketing or logistic support, also are identified on the basis of resource inventory. The problem of adequate supply of the deficient nutrients at right time and right place need to be resolved. It must also be ensured that what is needed, is promoted and supplied through genuine quality products. Under conditions of food shortage, the major goal of fertiliser use is a high crop yield giving lower priorities to food quality and possible negative influences on the environment. However, when production efforts have resulted in meeting the food demand or even in surplus, the quality aspect and the potential pollution effects on soil, water and air receive the same importance than the crop yield itself or even more. The department of agriculture and industry should address all these issues in a systematic manner. Use of information technology (IT) in fertiliser promotion and agricultural development should be fully tapped. At the same time, the glamour of IT should not be allowed to dominate over the need for sound technical content, user friendly access, and speedy updating of websites and portals. This will be possible when more and more rural areas have access to computers, internet and use-friendly software in local language.

Fertilizer retailers will have to be involved more intensively in promotion, input supply, after sale service and even customized fertilizer application. Dealer training after the initial phase should essentially be through informal briefings, trouble shooting sessions, question - answer drills supported by visits to service centers and demonstration plots. With increasing availability of IT related services, dealers can be networked into not only using these but also providing the much needed feedback from the field. Successful dealers and farmers should be invited as speakers in fertilizer seminars, training efforts and workshops. They will also need more efficient display materials and modern tools of communication. One would like to see dealers as regular visitors to technology dissemination centers to pick up and deliver the latest findings to the farming community. Farmers themselves can benefit from organizing themselves into groups, clubs or societies and hire even trained agricultural personnel to serve as farm advisors to the members. Such efforts can receive technical support from the directorates of extension from SAUs, soil testing laboratories and the KVKs.

Epilogue

To enhance FUE, "Site-Specific-Nutrient-Management" coupled with fertilizer best management practices should be adopted in letter and spirit purely on the principles of IPNS. As current soil testing service in India is confined to N, P and K testing in contrast to the fact that the problems of multi-nutrient deficiencies are very common all over the country, the national soil testing system needs to be readily energized and made more farmer-friendly, under the SSNM approach. To achieve the goal of enhancing FUE, timely supply of needed fertilizers, soil amendments, biofertilizers, seeds for green manuring and best seeds of high yielding varieties and hybrids of various crops in adequate quantities should be ensured. To harness full benefits from agri-inputs inputs, the needed knowledge must be provided to the farmers through specific training programs. In addition to N, P and K fertilizers, supply of specialty fertilizers and sulphur (S), zinc (Zn) and boron (B) containing fertilizers will have to be ensured for maximizing FUE. Supply of plant protection chemicals and availability of sprayers/dusters etc. both for sale and for custom services should be ensured at Farmers' Service Centers. Micro-irrigation systems should be promoted to enhance fertilizer and water use efficiency. Modern agri. Implements, for example, laser leveler, rotavator, seed cum ferti – drill, paddy transplanter, potato/sugarcane planter etc. which can be of great help to timely operations, energy and labor saving and for enhancing FUE should be available on custom service basis. Conservation agriculture needs to be promoted in letter and spirit. Needed literature in local languages will be of great help. The fertilizer industry and the department of agriculture should refine and redesign the promotion programs on the principles of IPNS that should be soil, crop, cropping system and climate specific with due consideration of the resources available with the farmers in a particular area. There is no alternative to site- specific BMPs.

8

Fertilizer Use Efficiency: An Industry Perspective

M.N. BHASKARAN

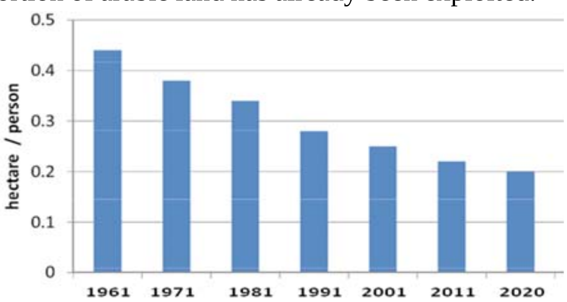
Given scarcities of suitable agricultural land in several developing countries, there is no escaping from the necessity for a good part of the required production increases to come from extracting more output from each area cultivated. That is, agriculture will be become more intensive. Obviously, what is required is intensification that can keep threats to the resource base and the wider environment within bounds, while not threatening the sustainability of the system. However, intensive fertilizer application is linked to nutrient losses that may lead to eutrophication of water bodies, soil acidification, and potential of contamination of water supply with nitrates. Fertilizer use efficiency can be optimized by fertilizer best management practices that apply nutrients at the right rate, time, and place. The highest nutrient use efficiency always occurs at the lower parts of the yield response curve, where fertilizer inputs are lowest, but effectiveness of fertilizers in increasing crop yields and optimizing farmer profitability should not be sacrificed for the sake of efficiency alone. There must be a balance between optimal nutrient use efficiency and optimal crop productivity.

Nutrient Use Efficiency

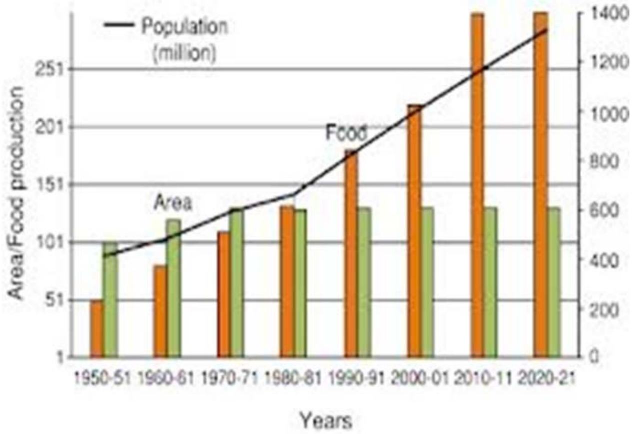
Nutrient use efficiency (NUE) may be defined as yield per unit input. In agriculture this is usually related to the input of fertilizer. Improvement of NUE is an essential pre-requisite for expansion of crop production into marginal lands with low nutrient availability. The nutrients most commonly limiting plant growth are N, P, K and S. NUE depends on the ability to efficiently take up the nutrient from the soil, but also on transport, storage, mobilization, usage within the plant, and even on the environment.

Current Scenario

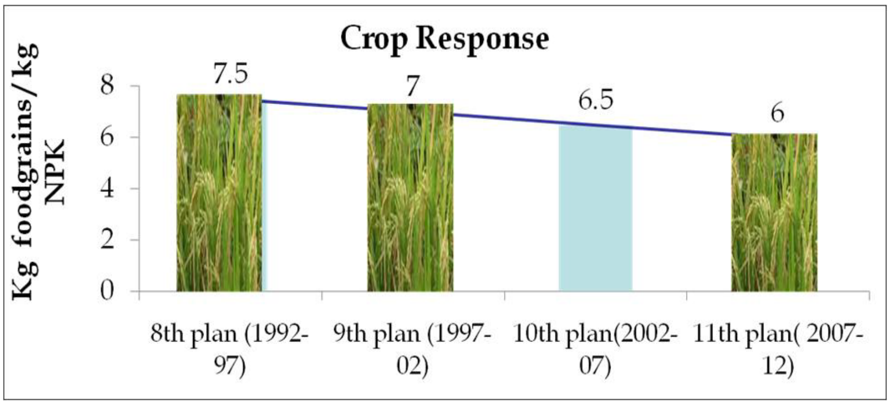
- Major portion of arable land has already been exploited.



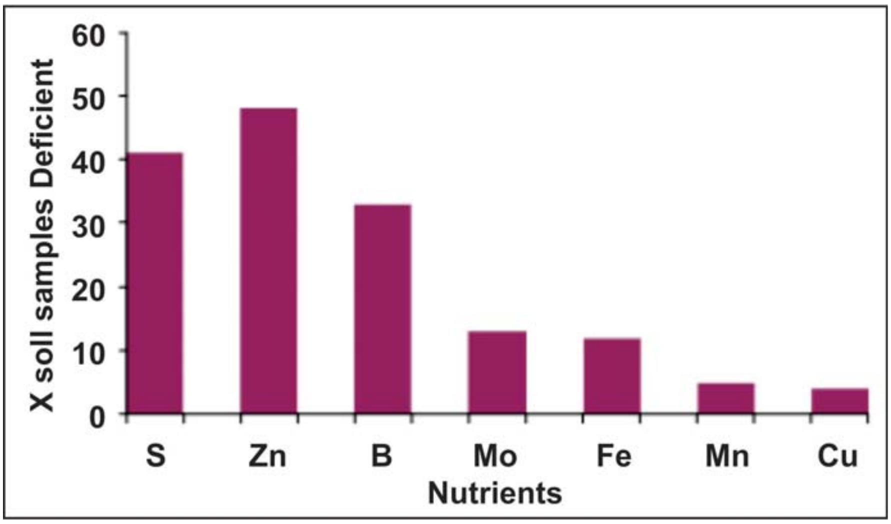
- Little scope exists for bringing new area under cultivation.



- Existing potential could be exploited only through increase productivity by intensive cropping.
- Increasing food production on arable land will be possible where the fertilizer use potential does not yet appear to be fully realized.
- Food productivity is a challenge due to declining crop response.



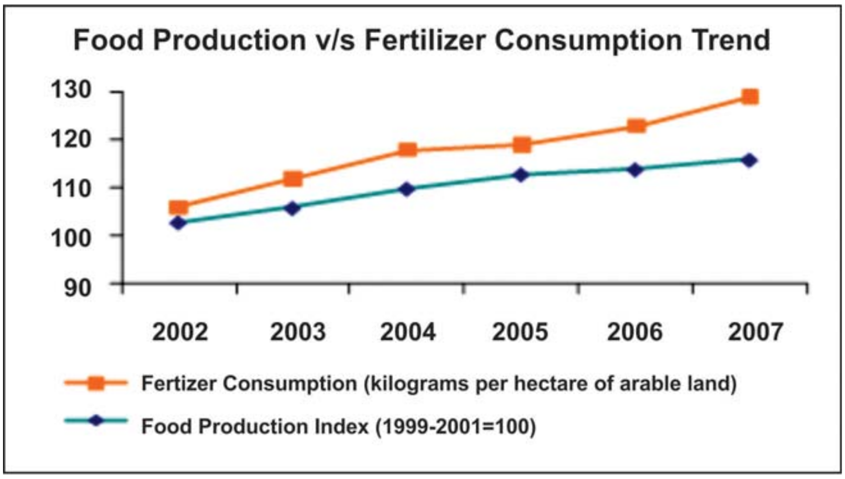
- The factors resulting in such situation are (but not limited to),
- Low organic content
- Lack of customized products based on local soil and crop requirement
- Poor awareness levels of the Farmer community about balanced plant nutrition
- Furthermore, Indian soils are afflicted with numerous deficiencies,



Source: M.V. Singh

Optimizing Nutrient Use Efficiency

Fertilizer application contributes greatly towards increasing yields (~50%).



The fertilizer industry supports applying nutrients at the right rate, right time, and in the right place as a best management practice (BMP) for achieving optimum nutrient efficiency.

Right Rate

Most crops are location and season specific- depending on cultivar, management practices, climate, etc., and so it is critical that realistic yield goals are established and that nutrients are applied to meet the target yield. Over- or under-application will result in reduced nutrient use efficiency or losses in yield and crop quality. Soil testing remains one of the most powerful tools available for determining the nutrient supplying capacity of the soil, but to be useful for making appropriate fertilizer recommendations good calibration data is also necessary. Unfortunately, soil testing is not available in all regions because reliable laboratories using methodology appropriate to local soils and crops are inaccessible or calibration data relevant to current cropping systems and yields are lacking. Nutrients removed in crops are also an important consideration. Unless nutrients removed in harvested grain and crop residues are replaced, soil fertility will be depleted.

Right Time

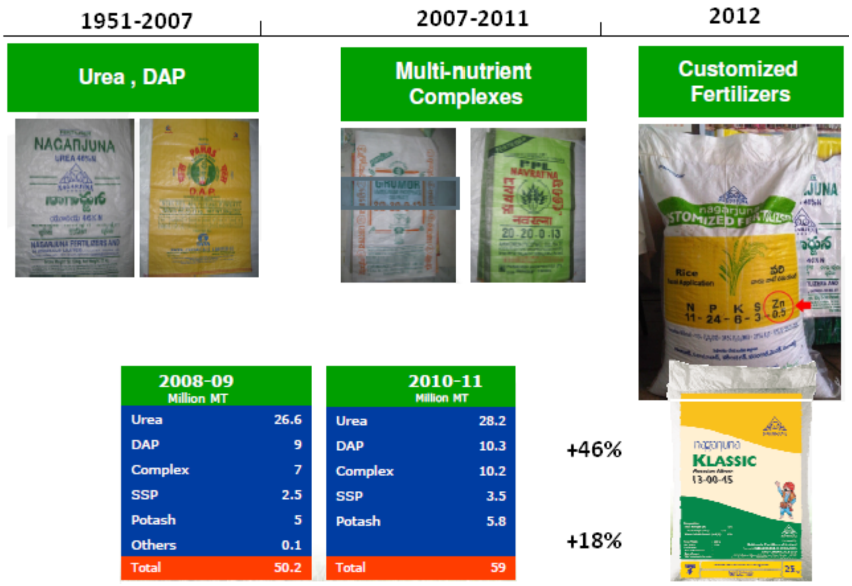
Greater synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency, especially for N. Split applications of N during the growing season, rather than a single, large application prior to planting, are known to be effective in increasing N use efficiency. Tissue testing is a well known method used to assess N status of growing crops, but other diagnostic tools are also available. Chlorophyll meters have proven useful in fine-tuning in season N management and leaf color charts have been highly successful in guiding split N applications. Another approach to synchronize release of N from fertilizers with crop need is the use of N stabilizers and controlled release fertilizers. Controlled-release fertilizers can be grouped into compounds of low solubility and coated water soluble fertilizers. Most slow-release fertilizers are more expensive than water-soluble N fertilizers and have traditionally been used for high-value horticulture crops and turf grass. However, technology improvements have reduced manufacturing costs where controlled-release fertilizers are available for commodity grains. The most promising for widespread agricultural use are polymer-coated products, which can be designed to release nutrients in a controlled manner. Nutrient release rates are controlled by manipulating the properties of the polymer coating and are generally predictable when average temperature and moisture conditions can be estimated.

Right Place

Application method has always been critical in ensuring fertilizer nutrients are used efficiently. Determining the right placement is as important as determining the right application rate. Numerous placements are available, but most generally involve surface or sub-surface applications before or after planting. Prior to planting, nutrients can be broadcast (i.e. applied uniformly on the soil surface and may or may not be incorporated), applied as a band on the surface, or applied as a subsurface band, usually 5 to 20 cm deep. Applied at planting, nutrients can be banded with the seed, below the seed, or below and to the side of the seed. After planting, application is usually restricted to N and placement can be as a top dress or a subsurface side dress. In general, nutrient recovery efficiency tends to be higher with banded applications because less contact with the soil lessens the opportunity for nutrient loss due to leaching or fixation reactions. Placement decisions depend on the crop and soil conditions, which interact to influence nutrient uptake and availability. Plant nutrients rarely work in isolation. Interactions among nutrients are important because a deficiency of one restricts the uptake and use of another. Numerous studies have demonstrated those interactions between N and other nutrients, primarily P and K, impact crop yields and N efficiency. Adequate and balanced application of fertilizer nutrients is one of the most common practices for improving the efficiency of N fertilizer and is equally effective in both developing and developed countries.

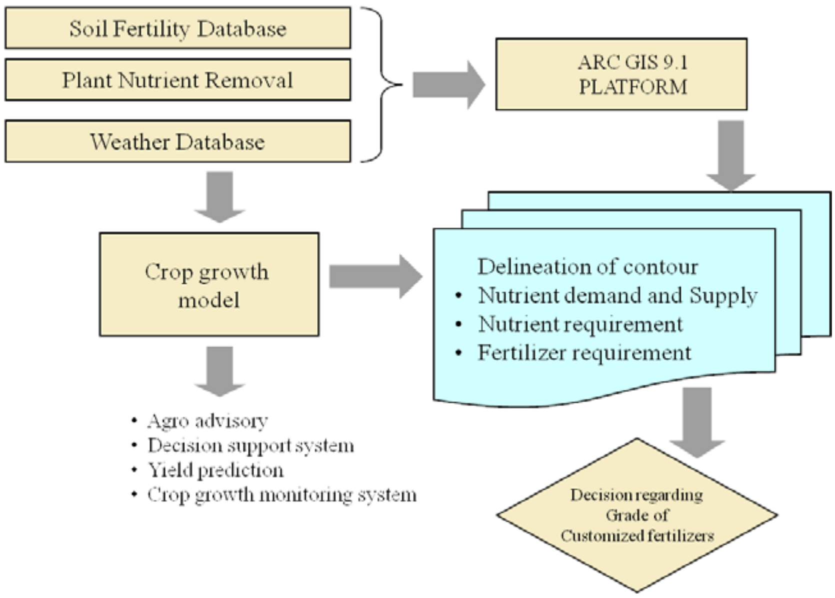
NFCL's Innovative Products and Processes

Innovating and developing *customized fertilizers* through *site specific nutrient management* (SSNM) is one of the key areas of focus in the industry. Such approaches can be re-enforced by pursuing nutrigation systems for efficient feeding. Such adaptation requires paradigm shift from general to specific and focused approach.

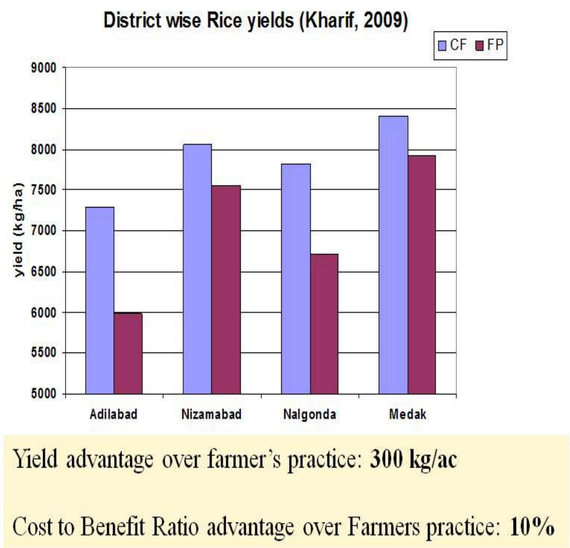


Customized Fertilizers

Customized fertilizer solutions aims to provide right nutrients at right dose and right time (stage of growth). It offers significant value through improved nutrient use efficiency. NFCL employs a robust diagnostic and decision support system for customized plant solution has been implemented in order to facilitate efficient grade development.

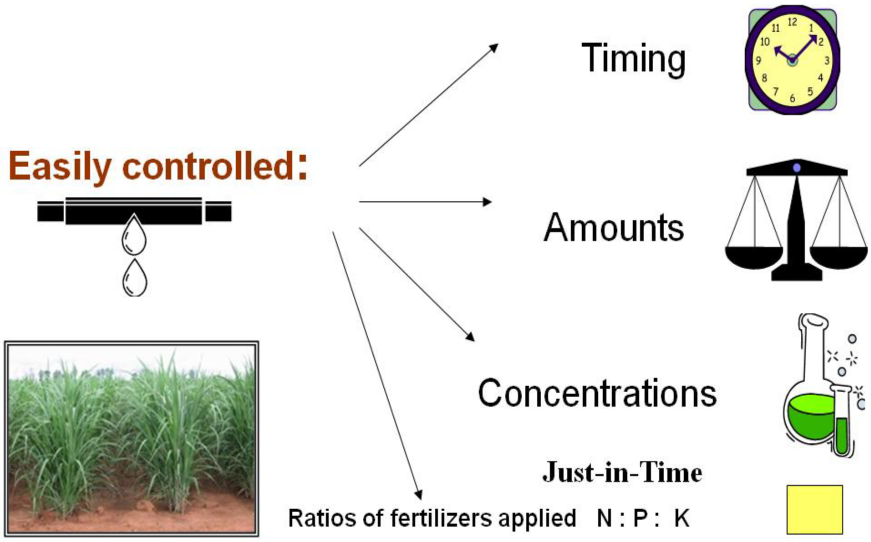


The approach has enabled the farmers to benefit from improved yields and quality of the produce, contributing to better farming economics.



Nutrigation

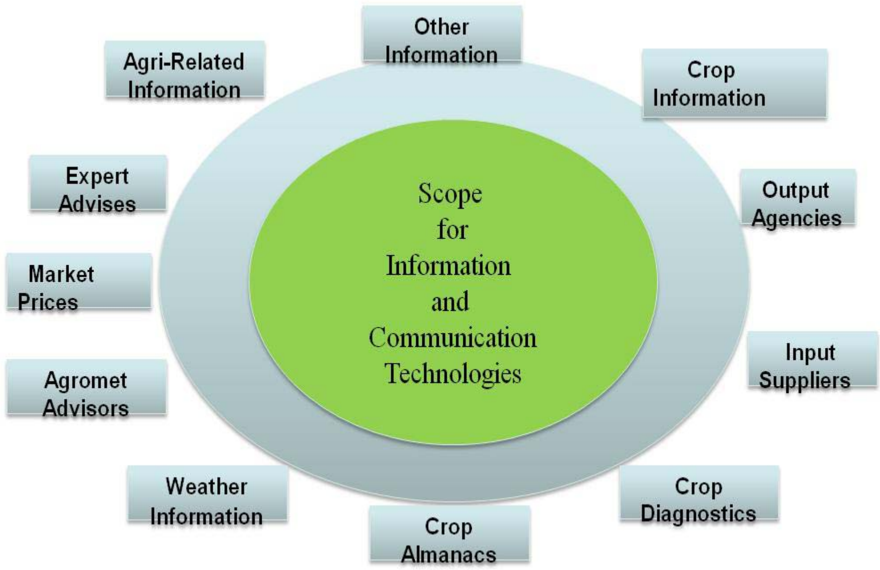
Is a method ensuring desired nutrient delivery in an efficient manner (water, cost saving). The advantages offered by such practice are, labor cost saving, ecology conservation and avoids problem of flood irrigation.



A testimonial of NFCL's satisfied customer indicates over 30% improvement in farming economics.

Information and Communication Technology (ICT)

Implementing ICT tools in agriculture would greatly enhance farm productivity. ICT offers scope for timely information on weather, market scenarios and critical expert advices. Moreover, ICT can facilitate bringing together of input suppliers and output agencies along with farmers. Such synergy can result in streamlining of value chain requirements.



Conclusion

Improving nutrient efficiency is a worthy goal and fundamental challenge facing the fertilizer industry, and agriculture in general. The opportunities are there and tools are available to accomplish the task of improving the efficiency of applied nutrients. However, we must be cautious that improvements in efficiency do not come at the expense of the farmers' economic viability or the environment. Judicious application of fertilizer BMP's, right rate, right time, right place and targeting both high yields and nutrient efficiency will benefit farmers, society, and the environment alike.

9

Nanotechnology for Better Fertilizer Use

RAJEEW KUMAR AND PRIYANKA PANDEY

Agriculture is facing challenges of increasing resources use efficiency, as resources like land, water and inputs are becoming limited day by day. Simultaneously, decreasing availability, increasing cost of fertilizer, soil health, and rhizospheric resources required urgent attention to increase nutrient use efficiency. Utilization of modern technology in agriculture is one of the ways to solve this problem. Nanotechnology has the potential to revolutionize the agricultural systems by nanostructure formulation of fertilizers which have mechanisms of targeted delivery or slow/controlled release and conditional release, or could release their active ingredients in responding to environmental triggers and biological demands more precisely. Nano fertilizers are the nanoparticles based fertilizer, where supply of the nutrients precisely for maximum plant growth, have higher use efficiency, and can be delivered in timely manner to a rhizpspheric target or by foliar spray. Studies show that the use of nanofertilizers causes an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries. The systematic work on nanomaterials in fertilizers at Pantnagar started form 2010, by the master student of the agronomy department and considerable of research have been done since than on various aspects. It is an endeavour to put our experiences for the reference and benefit of students, researchers, academicians and policy makers.

Food riots in some part of the world, remind us that feeding the world is of critical importance. Factors that can create food crisis are multiple and complex, including higher global prices for energy. Each year, the world's population grows by 80 million individuals and millions of new consumers are becoming wealthy, who requires healthy, balance and quality diet. However, this is the situation that if world's farmers stopped growing food today, we would only have enough grains in the world's storage bins to feed the world's population for 58 days. As we look to address the challenges of feeding a world of over 9 billion people in 2050. India still struggles with widespread poverty and hunger, and 25 percent of the world's hungry population dwells in India. However, India remains an important global agricultural player; despite the fact that agriculture's share in the country's economy is declining. Indian retained the world's largest area under cultivation for wheat, rice, and cotton, and is the world's largest producer of milk, pulses, and spices (World Bank 2012). The challenges of the next century are to be tackled within our limited resources. Specially, expansion in agricultural production is to be achieved within the available land, water and energy resources.

Therefore judicious use of resources, evolving technologies which are cost effective, resource saving are essential. The tasks are to be achieved within the frame work of protection of environment and preservation of natural resource base. This calls for a firm commitment to evolve new technologies for increasing the productivity and continuous use of available resources in the 21st century by all concerned with agricultural development. Indian agriculture is faced with the twin challenges of enhancing productivity and ensuring sustainability of production system. To achieve global food security by 2050, primary production must almost be doubled by increasing production per unit of land (Stamp and Visser, 2012). South Asia, including Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka has high population pressure on land and other natural resources to produce food and meet other developmental needs. South Asian countries have made significant advancement in food production during the past three decades, transforming the region from a food deficit to a food self-sufficient region. This could occur due to developments in agriculture research and effective dissemination of research output. India always has aimed to reduce hunger, food insecurity, malnourishment and poverty at a rapid rate. Keeping this overarching goal in mind, the emphasis which was initially on keeping food prices low, shifted to macro food security and subsequently to household and individual food security. Later, the food security of vulnerable, sustainable use of natural resources, and equity between rural and urban or farm and non-farm population became the issues of dominant discourse related to agricultural development.

Fertilizers Scenario

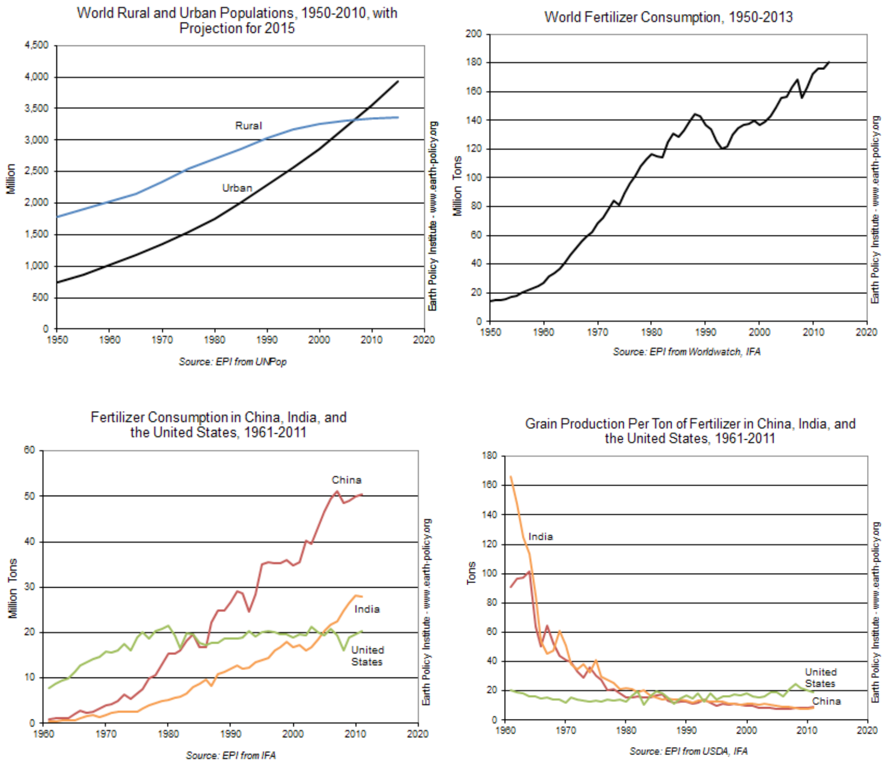
World

When German chemist Justus von Liebig demonstrated in 1847 that the nutrients that plants removed from the soil could be applied in mineral form, he set the stage for the development of the fertilizer industry and a huge jump in world food production a century later. Now fertilizer is a precious resource, responsible for between 40 and 60 percent of the world's food supply and fertilizers will continue to play the key role in food production. No country in the world has been able to increase agricultural productivity without expanding the use of mineral fertilizers. If we look towards history, the growth in food production during the nineteenth century came primarily from expanding cultivated area. It was not until the mid-twentieth century, when land limitations emerged and raising yields became essential, that fertilizer use began to rise. The growth in the world fertilizer industry after World War II was spectacular. Between 1950 and 1988, fertilizer use climbed from 14 million to 144 million tons. This period of remarkable worldwide growth came to an end when fertilizer use in the former Soviet Union fell precipitously after heavy subsidies were removed in 1988 and fertilizer prices were moved to world market levels. After 1990, the breakup of the Soviet Union and the effort of its former states to convert to market economies led to a severe economic depression in these transition economies. The combined effect of these shifts was a four-fifths drop in fertilizer use in the former Soviet Union between 1988 and 1995. After 1995 the decline bottomed out, and increases in other countries, particularly China and India, restored growth in world fertilizer use.

The natural nutrient cycle was disrupted due to urbanization. In traditional rural societies, food is consumed locally, and human and animal waste is returned to the land, completing the nutrient cycle. But in highly urbanized societies, where food is consumed far from where it is produced, using fertilizer to replace the lost nutrients is the only practical way to maintain land productivity. Therefore, the growth in fertilizer use closely tracks the growth in urbanization. The big three grain producer i.e China, India, and the United States, accounts for more than half of world fertilizer consumption. In the United States, the growth in fertilizer use came to an end in 1980. China's fertilizer use climbed rapidly in recent decades but has leveled off since 2007. In contrast, India's fertilizer consumption is still on the rise, growing 5 percent annually. While China uses 50 million tons of fertilizer a year and India uses 28 million tons, the United States uses only 20 million tons. Given that China uses 2.5 times more fertilizer than the United States. However, their average annual grain output totals are similar, 450 million tons in China compared to 400 million tons in the United States. The grain produced per ton of fertilizer in the United States is roughly twice that in China. This is partly because American farmers are much more precise in matching application with need, and leading soybean crop, which fixes nitrogen in the soil that, can be used by subsequent crops. Despite this U.S. advantage in fertilizer use efficiency over China, over application poses serious pollution problems in both countries. Fertilizer runoff from the U.S. Corn Belt, for example, contributes heavily to an annual oxygen-starved "dead zone" in the Gulf of Mexico, an area where sea life cannot exist, which in some years grows to the size of New Jersey. Research suggests that U.S. and Chinese farmers could use substantially less fertilizer and maintain or even increase productivity. In many other agriculturally advanced economies, fertilizer use has actually fallen in recent decades. France, Germany, and the United Kingdom, which together account for over one third of the European wheat harvest, have maintained high production levels despite significant declines in fertilizer use. Farmers in France and Germany now use half as much fertilizer as they did in the 1980s, while U.K. fertilizer use has dropped by 40%. And in Japan, 56% less fertilizer is now used than in the peak year of 1973. There are still some countries with a large potential for expanding fertilizer use. But in the many countries that have effectively removed nutrient constraints on crop yields, applying more fertilizer has little effect on yields. For the world as a whole, the era of rapidly growing fertilizer use is now history.

India

Fertilizer contributed more than 50 per cent in food grain production in our country and subsidized food grains under Indian National Food Security Act. 2013, also increased the burden on fertilizer sector. Fertilizer is an essential



Sources: http://www.earth-policy.org/data_highlights/2014/highlights43

component of modern Indian agriculture and efficient fertilizer management is an integral part of crop production to boost the productivity. India is the second largest consumption in the world after China. India accounted for 15.3% of the world's N consumption. 19% of phosphatic and 14.4% of potassic nutrients in 2008 (FAI, 2010). Per hectare fertilizer consumption in India is very low (156.1 kg NPK/ha) as compared to Pakistan (204.4 kg/ha), Bangladesh (188 kg/ha), China (396 kg/ha). Each crop has its own pattern of nutrient uptake but farmers give undue importance to nitrogen fertilizers than others, resulted imbalanced fertilization and decreased response ratio. The consumption of NPK ratio in the country has also changed over a period of time. During 2008-09, the consumption of NPK ratio was 4.6:2.0:01 which has changed to 8.2:3.2:01 during 2012-13. This resulted the crop productivity decreased from 14 kg yield / kg applied fertilizers during 1970-71 to 6.30 kg during 2007-12. Such a skewed utilization of fertilizers has led to loss in soil productivity. Besides N, P, K, crop also needs nutrients like Ca, S, Zn, Fe, Cu Mn, B and Mo. Thus, the balanced use of chemical fertilizer is important not only for increasing the agricultural productivity but also for sustaining soil fertility. Statistics revealed that, during last sixty years fertilizer consumption increased forty six fold however, during same period food grain production was increased only four fold, shows that there is a big gap in fertilizer response, which needs to be corrected. Country would require 45 million tonnes of nutrients in 2025 as against a current consumption level of 28.12 million tonnes. The demand-supply gap of fertilizers in India, increased the dependency on imports, which were about 2 million tonnes in early parts of 2000 increased to 10.2 million tonnes of fertilizers in 2008-09. The entire requirement of potassic fertilizers and raw materials for phosphatic fertilizers are met through imports as India does not have commercially viable source of potash. The low nutrient use efficiency by the crops increased the amount of fertilizer use. Nutrient use efficiency varied from 25-35 percent for major nutrients and 1-5 percent for micronutrients (Chaudhary *et al*., 2010). Fertilizer response ratio or nutrient use efficiency can be enhanced by two ways, one either genetic manipulations and other or agronomic manipulations. Under agronomic manipulations, NUE can be improved either reduce the losses or improve the internal utilization of the nutrient by the plants. To reduce losses, scientists have developed slow or control release fertilizer. But slow release fertilizer have little success due to the mismatch between the nutrient release and crop demand. Therefore, farmers and scientists are seeking alternatives either by a new fertilizer product which provide the nutrient as per the plant requirement or enhancing the photosynthetic use efficiency. The photosynthetic use efficiency can be increased by improving the ability of crop canopy to intercept and capture light; the duration of light capture and the photosynthetic capacity of the crop as well as speed up the reaction occurs in light and dark. Therefore, improved nutrient use efficiency is an important issue for reducing cost of cultivation protect the environment and save foreign currency.

Nanotechnology

Nano is used in the world of science to mean one billionth. A Nanometre is a billionth of the meter. A nanometre is only ten atoms across. Generally nanotechnology is used to mean technology at nanometre level to achieve something useful through the manipulation. The Royal society defines "Nanotechnologies are the designs, characterization, production and application of structure, device and system by controlling the shape and size at nanometre scale". Nanoparticles are atomic or molecular aggregates with at least one dimension between 1 and 100 nm, that can drastically modify their physico-chemical properties compared to the bulk material **(Nel *et al.*, 2006)**. At such scales, the ordinary rules of the physics and chemistry no longer apply, for instance, materials, characteristics, such as colour, strength, conductivity and reactivity can differ substantially between nano scale and macro. Today, nanotechnology is a new techno-scientific platform, where range of exiting techno-scientific disciplines like as chemistry; physics, biology, biotechnology, neurology and engineering are able to shift down to the molecular level **(Hunt and Mehta, 2006).** Despite nanotechnology has been exploited wide range of applications in natural science, medicine and engineering, its role in agricultural sciences is yet to be explored. **N**ano materials have been defined as tiny minerals, which are brought to a scale of 10-100 nm through a system and process. Particles size and size distribution are the most important characteristics of nano particles system. They determine the distribution, biological fate, toxicity and the targeting ability of nanoparticles in the system. In addition they can also influence the nutrient loading, nutrient release and stability of nanoparticles. Many studies have demonstrated that nanoparticles of sub micro size have a number of advantages over micro-particles as a drug delivery system (Panyam *et al.,* 2003)**.** Generally nanoparticles have relatively higher intracellular uptake compared to micro particles and available to a wider range of biological target due to their small size and mobility. **The** 100 nm nanoparticles have greater uptake from the 10 micro size micro particles (Dasai *et al.,* 1997)**, they also said that** only sub micron particles can be taken up efficiency, but not the longer size micro particles.

Nanotechnology and Nutrients Use Efficiency

Improving nutrient use efficiency is a worthy goal and fundamental challenge facing the fertilizer industry, and agriculture in general. Now nutrient use efficiency is driven by a growing public believe that the crop nutrients are excessive in the environment. Farmer concerns about rising fertilizer prices and stagnant crop prices, exerted pressure to person concerned to improve nutrient use efficiency. Most agricultural soils in India have low native fertility and successful and sustained crop production on these soils requires regular nutrient inputs. The quantum of nutrients available for recycling via crop residues and animal manures is grossly inadequate to compensate for the amounts removed in crop production. Thus, mineral fertilizers have come to play a key role in areas with low fertility soils, where increased agricultural production is required to meet growing food demand. Chemical fertilizers as source of plant nutrients are considered as the major contributor to enhancing crop production and maintaining soil productivity.

Fertilizers have been acknowledged for 50 per cent of the yield increases in developing countries including India. Though the consumption of chemical fertilizers in India increased steadily over the years, the use efficiency of nutrients applied as fertilizers continues to remain awfully low (40-50% for N, 20-25% for P and 2-5% for Zn, Fe & Cu). When nutrient inputs are used inefficiently then both cost of cultivation and threat for biosphere pollution increase. Thus, economic and ecological highlights the compulsive need for more efficient use of nutrients in crop production. Since fertilizer nutrients are expensive and used in large quantities at national level, any increase in use efficiency will lead to a substantial cut in nutrient requirement and huge economic benefit at national level. For example, if we consider at the present level of fertilizer consumption are 14.05 Mt N and 5.66 Mt P_2O_5 in 2006-07 with nutrient use efficiency of 50% for N and 20% for P. The increase in the efficiency of N and P use by just 2 percentage that would lead to a saving of 5.38 lakh tonnes of N and 5.15 lakh tonnes of P, which together translate to a saving of Rs.14,920 million annually.

This amply highlights the importance of enhancing nutrient use efficiency. This staggering annual economic benefit is in addition to reduced risk of environmental pollution. Since fertilizers, particularly synthetic fertilizers have a major potential to pollute soil, water and air, in recent years, many efforts were done to minimize these problems by agriculture practices and the design of the new improved fertilizers. The appearances of nanotechnology open up potential novel applications to solve these problems.

Nanostructure fertilizer exhibits novel physico-chemical properties, which determines their interaction with biological substances and process. The application of nanotechnological formulation to agricultural crop inputs is one of the proposed tools for sustainable intensifications. These applications includes increase uptake efficiency in plants, developing DNA based nano sensor in a polymer coated fertilizers which would release only as much fertilizer as “demanded” by plant roots. Nanofertilizer mainly delays the release of the nutrients and extends the fertilizer and extends the fertilizers effect period. Encapsulation of fertilizers within a nanopaticle is one of this new facilities which are done in three ways a) the nutrient can be encapsulated inside nanoporous materials, b) cotad with thin polymer film, or c) delivered as particle or emulsions of nanoscales dimensions (Rai *et al*., 2012). Nano-sized fertilizer provides nutrients more available to nano scale plant pores, and therefore results in greater nutrient use efficiency. Nano materials may help to improve nutrient use efficiency because of their small size (between 1 to 100 nm), more surface area and their slow rate of release, which facilitate to the plants to take up most of the nutrients without any waste. It is claimed that controlled nutrient release and increase water retention in the soil are responsible for better yield under nanofertilzier application. Nano sized TiO2 promoted photosynthesis and nitrogen metabolism (Zheng *et al*., 2005), carbon nano-tubes penetrate tomato seeds and affect their germination and growth rates. Nanofunctionalized carbon nanotubes enhanced root elongation (Canas *et al*., 2008). Nanofertilizers combined with nanodevices synchronize the release of fertilizer N and P with their uptake by crop, so preventing undesirable nutrient losses to soil, water and air via direct internalization by crops, which comes by avoiding the interaction of nutrients with soil, microorganisms, water, and air (DeRosa *et al.*, 2010). Nano clay and zeolites that are a group of naturally occurring minerals with a honey comb-like layered crystal structure, which can filled with nitrogen, potassium, phosphorous, calcium and a complete set of minor and trace nutrients. This helps to achive maximum nutrient use efficiency. Coating and bonding of nano and subnano-composites are able to regulate the release of nutrients from the fertilizers capsule (Lin and Xin, 2007) and the application of a nano-composite consists of N,P,K, micronutrients, mannose and amino acids enhance the uptake and use of nutrients by grain crops. Fertilizers incorporation in to co-chleate nanotubes had improved crop yield (DeRose *et al.*, 2010). The nanofertilizers release the nutrients in a controlled manner in response to reaction to different signals such heat, moisture

Table 1: Some of advantages related to ransomed of conventional fertilizers using nanothechonology (Cui *et al.*, 2010)

Desirable Properties	Examples of nanofertilizers-enabled Technologies
Controlled release formulations	So-called smart fertilizers might become reality through transformed formulation of conventional products using nanotechnology. The nanostructured formulation might permit fertilizers intelligently control the release speed of nutrients to match the uptake pattern of crop
Solubility and dispersion for mineral micronutrients	Nanosized formulation of minerals micronutrients may improve solubility and dispersion of insoluble nutrients in soil, reduce soil absorption and fixation and increase the bio-availability.
Nutrient uptake efficiency	Nanostructured formulation might increase fertilizers efficiency and uptake ratio of the soil nutrients in crop production and save fertilizers resource.
Controlled release modes	Both release rate and release pattern of nutrients for water-soluble fertilizers might be precisely controlled through encapsulation in envelope forms of semi-permeable membranes coated by resin-polymer, waxes and sulphur.
Effective duration of nutrient release	Nanostructured formulation can extend effective duration of nutrient supply of fertilizers in to soil.
Loss rate of fertilizer nutrients	Nanostructured formulation can reduce loss rate of fertilizer nutrient supply of fertilizers in to soil by leaching and/or leaking.

and etc. It is known that crops secrete carbonaceous compounds in to rizosphere under nutrient stress which can considered as environmental signals for incorporation in to novel nanofertilizers (Sultan *et al.*, 2009). These fertilizers can also improve the performance of fertilizers in other ways. For instance, due to its photocatalytic characteristic, nanosize titanium dioxide added in to fertilizers as a bactericidal, nanosilica particles that absorbed by roots can improve the plant's resistance to stress and thus increases the crop yield (DeRose *et al.*, 2010). Therefore, such nano fertilizers have a significant influence on energy, the economy and the environment. Some of advantages related to nano-technological tools in fertilizers are presented in Table 1.

Research Experiences at Pantnagar

Nutrients act as a source for food biomass, fibre production in agriculture and are the most important in term of the energy requirement for its synthesis, and finally monetary value. However, compared with amount of nutrients applied into the soil the nutrient use efficiency is very low. Three strategies can be used to enhance the nutrient use efficiency by applying nanotechnological tools in fertilizers. First strategy consider that nutrient may encapsulated with nano layer or loaded inside the nano materials, in this strategy, nanozeolite, nano polymer, mesoprus silica etc can be used as vehicle for nutrient load, transport and release in the soil plant system. The different lobes of these materials can be loaded separately by different nutrients without interacting with each other. Therefore, we may have capability to develop such a fertilizer which retained all the sixteen nutrient in same molecules. The main essence of this system that these materials or highly sensitive to changes occurs in surrounding (due to the presence of nanobio sensor), and accordingly they release the nutrients, matching with the nutrient demands of the plants. Thereby, they prevent the nutrients from premature converting into the chemical and gaseous farm which cannot be absorbed by the plants. This can also be achieved by preventing nutrients from the interacting with soil, water and microorganism. Second strategy is based on reducing the particle size of nutrients bearing rock and minerals up to nano levels. This activity results increase the surface area to volume ratio, means the results fertilizers have capability to cover more plant parts for nutrition with same volume. That would highly reactive and interact with the plant organs, and deliver the nutrients at their site of action. For example Phosphorus is requiring for lipid synthesis, so the nano sized rock phosphate able to deliver the phosphorus at the site of lipid synthesis. One more important aspect of such strategy is that, the solubility problem of different minerals like mica for potassium, appetite for phosphorus, olivine for molybdenum can be solved. Third strategy, followed the concept of Anulom and Vilom (Baba Ramdev), where movement of oxygen within the body system have capability to detoxify the toxins synthesize in the body and provoke to the cell for better utilization of energy already available within the system that resulted efficient utilization of energy and better human health. The same concept can be utilized in plant system, for example nano materials have no barrier to entry in plant system, they can enter anywhere by penetrating plasma membrane and may excite the inner surface of the membrane by pinching them, which transfer the signal to other cell and finally whole plant body. The excitement artificially generated in the plant body may help to efficiently utilize the energy already present in the plant system and or provided externally in the form of fertilizers. This ultimately results to enhance nutrient use efficiency. Considering second and third strategies, experiments were planned and executed by the Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture & Technology, Pantnagar. The experiments were actually executed by the master's student of the department. For the second strategy experiments the nanoparticles were purchased from Intelligent Material Pvt. Ltd., Punchkula, Hariyana, which was manufactured by Nanoshel, Washington, USA. However, for the third strategy experiment, the nanoparticles of rock phosphate and gypsums were prepared in our own lab by following the top down approaches and confirmation of their size were done by TEM (Transmission electron microscopy) analysis from IIT Roorkee. The TEM images confirm that the resultant particles were ranged 20-100 nano metre sized. The experiments were conducted during 2010 to 2014. Three modes of nano materials applications i.e Soil application, foliar application and Seed treatment were choosing for studies. The findings of the materials can be summarized as under.

Crop Performance and Fertilizer Use Associated with Application of Nanomaterials

Soil application

The nanomaterials of gypsum and rock phosphate were prepared in laboratory and was applied in field @ 3 kg/ha. The nanomaterials were tagged with urea and applied two times at first and second top dressing in wheat. The hypothesis of the experiment is given in diagram and the results obtained are as under. Wheat morphology and phenology were markedly changed with nanoparticle application along with fertilizer dose. Tillers/m^2 and drymatter accumulations were found better when nanomaterials were applied. RDF (i.e. 150:60: 40 kg NPK/ha) with nano materials produced less tillers and dry matter, however the nanomaterials with 50 percent of RDF gave synergistic effect. The reason might be, crop gets satisfied with lower doses of fertilizer when nano materials applied, but at higher doses nutrients become toxic to the plants. Phenological changes such as days taken to 50 percent flowering; physiological maturity and harvest maturity were significantly influenced by the treatments (Table 2). Application of nanomaterials and fertilizer took more days for different phonological stages, and provide an opportunity to the crop for better utilization of solar radiation. The crop performance subjected to nanomaterials application is basically dealt by physiological changes. The different physiological parameters viz. LAI, SPAD value, Green seeker value, LCC Value, FV/FM value, and chlorophyll content were significantly influenced by nanomaterials with fertilizer applications (Table 3). The LAI, SPAD, Green seeker, FV/Fm value and chlorophyll content obtained at 50% RDF with nanomaterials was significantly higher than 50% RDF without nanomaterials, but in all the cases 100% RDF with nano materials gave negative response. Table 3 clearly vindicated that the yield parameters and yield obtained at 50% RDF with nanomaterials was almost statically similar with 100% RDF without nanomaterials. The yield parameters which greatly influenced by the application of nano materials was 1000 grain weight, might be coming from physiological process facilitated by nano materials. Total nutrient (NPK) uptake and B:C ratio were also followed the similar trend. Recovery Efficiency (%), Physiological Efficiency (kg grain/kg nutrient uptake), Agronomic Efficiency (kg grain/kg nutrient applied) were calculated on the basic of results obtained and summarized in table 4. The maximum recovery efficiency and agronomic efficiency of NPK was noticed under 50% RDF applied along with nano materials but in case of physiological efficiency, 50% RDF applied along with nano materials and 100% RDF had similar result.

Foliar applications

Cell wall of plants acts as barrier for entry of external agents including nanoparticles. The sieving properties of cell wall are determined by the pore diameter, which is ranging from 5-20 nm, and permit only those nanoparticles or

Table 3: Physiological indices at 60 days crop growth stage in wheat as influenced by fertilizers and nanomaterials

Treatments	LAI	SPAD Value	Green seeker value	LCC value	FV/Fm value	Chlorophyll (mg/g FW)
Control	1.0	25	0.44	3.0	0.66	0.31
50% RDF	1.6	30	0.53	4.0	0.71	0.32
100% RDF	3.5	34	0.78	4.0	0.72	0.34
125% RDF	4.0	36	0.78	4.0	0.73	0.42
50% RDF+ NM	2.9	34	0.73	3.8	0.71	0.38
100% RDF+ NM	3.3	34	0.72	3.6	0.69	0.39
S.Em±	0.08	0.9	0.01	0.0	0.01	0.02
C.D (at 5%)	0.2	2.9	0.04	0.1	0.04	0.06
C.V (%)	5.7	4.9	3.23	4.0	3.09	8.85

Table 4: Yield indices, nutrient uptake and B:C ratio of wheat as influenced by fertilizers and nanomaterials

Treatment	Spike/ m^2	Grains/ spike	1000 grains weight (g)	Grains yield (q/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)	B:C ratio
Control	244	23	28	12	34.1	6.4	33.3	0.4
50% RDF	340	41	32	37	100.3	19.3	101.4	2.4
100% RDF	381	46	37	45	126.5	26.1	120.5	2.6
125% RDF	377	47	36	48	120.0	26.9	125.5	2.7
50% RDF+ NM	352	45	37	41	112.7	23.7	109.4	2.6
100% RDF+ NM	374	42	39	40	97.8	20.0	94.5	2.1
S.Em±	17	2.4	1	2.0	6.4	1.5	6.0	-
C.D (at 5%)	56	7.8	2	5.0	14.4	3.4	13.4	-
C.V (%)	8.3	10.3	3	8	7.9	9.0	7.5	-

Table 5: Nutrient use efficiency in wheat as influenced by fertilizers and nanomaterials

Treatment	Recovery Efficiency (%)			Physiological Efficiency (kg grain/kg nutrient uptake)			Agronomic efficiency (kg grain/kg nutrient applied)		
	N	P	K	N	P	K	N	P	K
50% RDF	88.3	32.3	340.5	0.38	1.94	0.37	0.33	0.83	1.25
100% RDF	61.6	32.8	218.0	0.36	1.68	0.38	0.22	0.55	0.83
125% RDF	45.7	27.3	184.4	0.42	1.76	0.39	0.19	0.48	0.72
50% RDF+ NM	104.8	43.3	380.5	0.37	1.68	0.38	0.39	0.97	1.45
100% RDF+ NM	42.5	22.7	153.0	0.44	2.06	0.46	0.19	0.47	0.70

Table 2: Phenological indices as influenced by fertilizers and nanomaterials

Treatment	Days taken to phonological indices		
	50% heading	**Physiological maturity**	**Harvest maturity**
Control	81	120	130
50% RDF	82	125	135
100% RDF	84	122	132
125% RDF	83	123	133
50% RDF+ NM	83	122	132
100% RDF+ NM	84	123	133
S.Em±	1	0.4	1
C.D (at 5%)	2	1	1
C.V (%)	1	1	1

nano conjugates having diameter less than pore diameter. Considering this, an experiment was executed where nano-TiO_2 (size less than 20 nm) at different concentration were sprayed two time along with the combination of nutrient omission. The first spray of nano-TiO_2 was done at maximum tillering stage (54 DAS) and second spray was done at booting stage (80 DAS). For each spray four different concentrations 0.00%, 0.02%, 0.04% and 0.06% of nano-TiO_2 were prepared. Results indicated that the foliar application of nano materials along with fertilizer application had pronounced effect on days taken to 50 per cent flowering (Fig 2). The maximum days taken to 50 per cent flowering was noticed, when foliar application of nano particles @ 0.06% were applied along with Recommended NPK. This showed that nano particles help to increase the duration of vegetative growth. Balanced fertilizers along with higher concentration of nanomaterials (0.06%) took maximum days for harvest maturity, but the omission of P penalized maximum for the day taken to maturity. Foliar application of 0.04 per cent nano TiO_2 results maximum duration taken for harvest maturity, in case omission of nutrients. Spikes/m^2 were influenced by foliar application of the nanomaterials. The increasing concentration of nanomaterials responded more with balance doses of fertilizer. (Fig 4). Cholorophyll content, Relative leaf water content, Memberane thermostability index (MSI) and SPAD value were significantly influenced by the foliar application of nanomaterials along with the fertilizer (Table 5). Cholorophyll content in leaves at 60 days of crop growth were penalized due to nano particle application and the maximum penality was noticed when foliar application of nanomaterials were given under K omission plots. However the relative leaf water content was higher under increasing concentration of nanomaterials, and best response was noticed at RDF with 0.06% of nanomatreials. MSI, which is an indicator of stress in plant was also higher under 0.06% concentration of nanomaterials. SPAD value at 60 days growth stage was maximum when 0.04% of nanomaterials sprayed along with omission

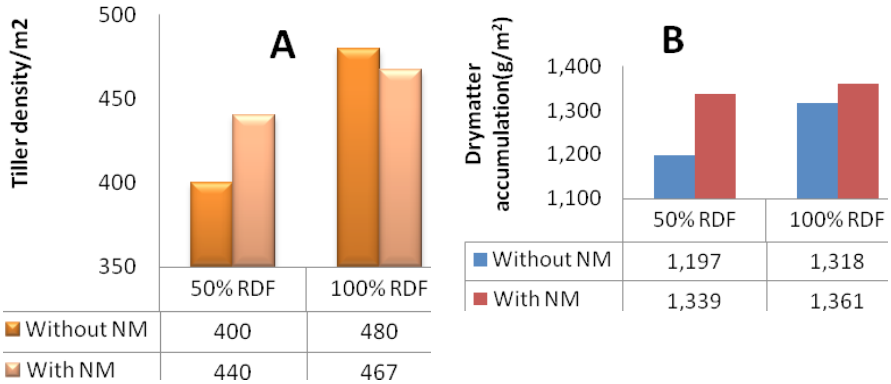


Fig 1(A): Tiller density /m2 at 90 days crop stage as influenced by the fertilizers and nanomaterials; **(B):** Dry matter accumulation (g/m2) at 90 days crop stage as influenced by the fertilizers and nanomaterials

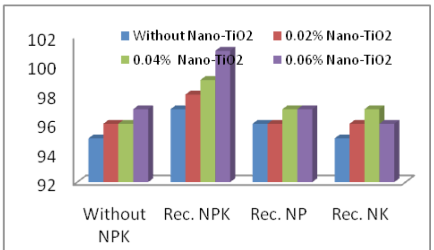


Fig. 2 Days taken to 50 % flowering in wheat as associated with fertilizer and foliar spray of nanoparticles

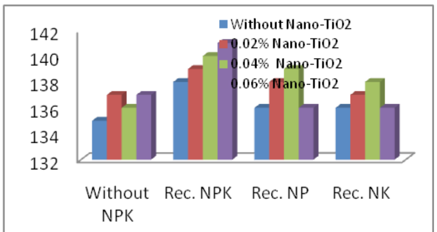


Fig 3. Days taken to harvest maturity as in wheat as associated with fertilizer and foliar spray of nanoparticles

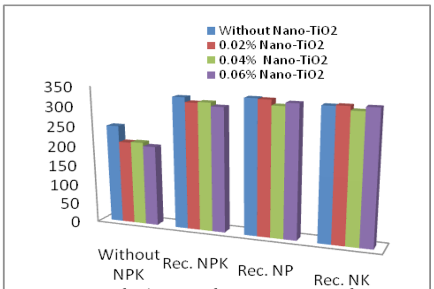


Fig 4. Spike/m2 in wheat as associated with fertilizer and foliar spray of nanoparticles

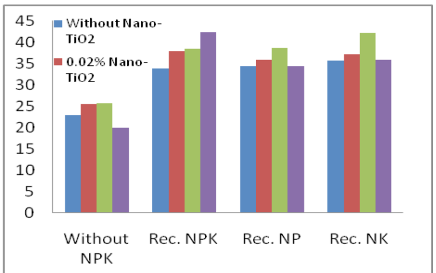


Fig 5. 1000 grain weight (g) of wheat as associated with fertilizer and foliar spray of nanoparticles

of K. The spray of 0.04% nanomaterial with Recommended NP, and omitted P produced maximum 1000 grain weight, however in case of balanced NPK, 0.06% spray of nanomaterials gave maximum 1000 grain weight. Nanomaterials sprayed without fertilizer also influenced the 1000 grain weight. Spray of 0.02, 0.04% nano materials without fertilizer produced better 1000 grain weight, than 0.06% spray which negatively affect the 1000 grain weight (Fig 5). The grain yield was recorded maximum under balanced NPK along with 0.06% spray of nano materials

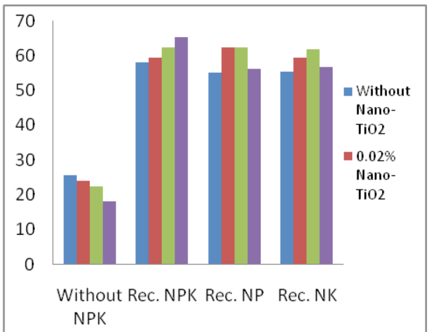


Fig 6. Grain yield (q/ha) of wheat associated with fertilizers and foliar spray of nanoparticles

Fig 7. Germination percentage in wheat associated with different hours of soaking and nanoparticles

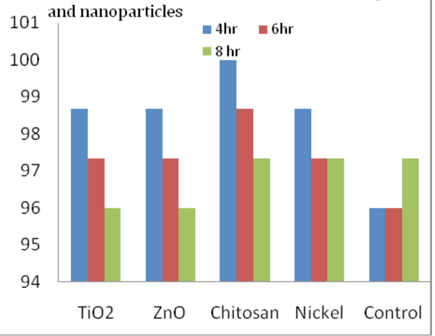


Fig 8. Tiller density/m2 as influenced by fertilizers and nanoparticles application

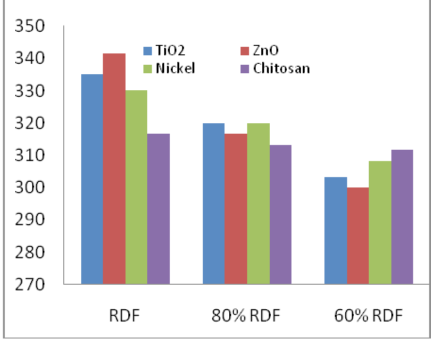
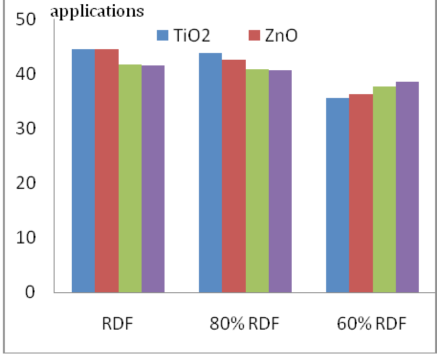


Fig 9. Grain yield (q/ha) as influenced by nanoparticles treated seeds and fertilizer applications



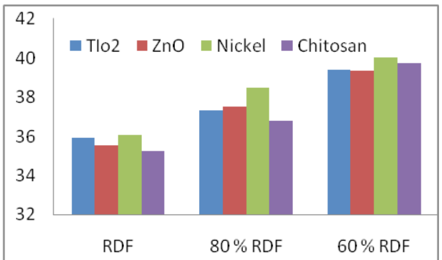
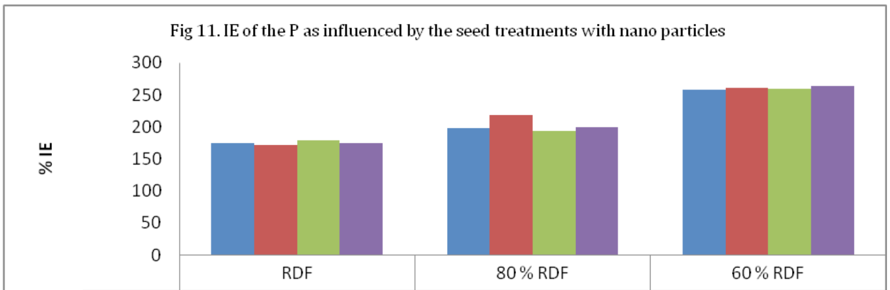


Fig 10. IE of the nitrogen as influenced by the seed treatments with nano particles

(Fig 6), but the lower concentration of nanomaterials responded better with omission of either P or K. However, the grain yield negatively affect by the spray of nanoparticle alone.

Seed treatments

Nano-materials application as seed treatment has the potential to revolutionize the agriculture, this enhance the ability of plants to absorb nutrients.



	RDF	80 % RDF	60 % RDF
TIo2	174.04	197.09	257.32
ZnO	171.5	218.63	260.1
Nickel	178.88	193.08	258.66
Chitosan	173.76	199.36	263.67

Fig.11: IE of the P as influenced by the seed treatments with nano particles

Nanoparticles have interactions at molecular level in living cells and impart some beneficial effects to the crop. Nanopartcles of size below 100 nm fall in the transition zone between individual molecules and the corresponding bulk materials, which generates both positive and negative biological effects in living cell. The seed coat act as a good barrier to penetrate the materials inside the seeds. Nanomatreials provide an opportunity to increase the nanopores on seed surface, which facilitate more moisture and oxygen penetration for better seed germination and crop establishment. Consider this, four nanoparticles (ZnO, Ni, TiO2 and Chitosan) at concentration level of 50 ppm. The results revealed that the Chitosan nano material gave maximum seed germination at 4 hrs of soaking (Fig.7). However, 8 hrs of soaking was better option for control (No nanomaterials). Tillers /m^2 were highest under RDF, and were reduced with reducing fertilizer doses (Fig.8). Zn nano material along with RDF, nickel nano material along with 80% RDF and Chitosan nano material along with 60% RDF gave maximum tiller/m^2. Grain yield was found maximum at RDF with nano material of TiO_2 & Zn, but 80% RDF with nano TiO_2 gave similar yield (Fig 9). The internal use efficiency of the nutrient was higher under 60% of RDF. Application of nano particle of nickel gave maximum internal nitrogen and potassium use efficiency with all the cases (Fig 10), but the maximum internal use efficiency of phosphorus was recorded in nanomaterials of Zinc.

Conclusion

Nanotechnology have potential to revolutionize the fertilizer use in agriculture. Nanotechnology plays an important role in crop nutrition and they mainly target at cellular level action resulted physiological changes in crops, which ultimately results the good yield and fertilizer use. The salient findings of the experiment are indicating the usefulness and effectiveness of nanofertilizers to enhance the growth and yield of the crop. Nanomaterials can be used as seed treatment, soil application and foliar application. Nanomaterials performed better under lower concentration, but under the situation of high fertilizer dose crop requires higher concentration of nano materials. Over all fertilizer/nutrient use efficiency can be enhanced by using nano materials. Hence< Nanofertilizer might be one more tool in the toolkit for increasing nutrient use efficiency and thereby soil fertility along with environmental protection.

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10

Integrated Farming System Research in View of Managing Climatic Adversities

B. GANGWAR AND N. RAVISANKAR

Climate adversities have the potential to irreversibly damage the natural resource base on which agriculture depends and it is increasing production risks in many farming systems and reducing the ability of farmers and rural communities to manage these risks on their own. Around the world, resource-poor farmers are trying to adapt to the effects of climate change, which affect them disproportionately. In a context where the impact of climate change on the natural resource base is dramatically increasing, adoption of location-specific integrated management of natural resources for higher productivity and better resilience to erratic climatic events is becoming even more crucial. Since small farmers and rural communities are the starting point for efforts to adapt to climate change, the problems and solutions should be defined with their direct and active participation. It is necessary to use participatory farming system processes that empower smallholders to: draw on their expertise about ecology and management; overcome the constraints they face; create a sense of ownership; and share their visions and experiences with other partners. Farming system approach in small and marginal holders are expected to play a vital role in management of natural resources thereby reducing the climatic adversities. Thermophilic anaerobic digestion (TAnD) and integrated farming is a new agricultural ecosystem. TAnD converts animal waste into useful resources including biogas (65% methane and 35% carbon dioxide) energy, nutrients for aquaculture and bio-fertilizer for horticultural produce. The duck integration in rice field increases the rice yield by reducing weed growth, insect population, improving soil physical properties and thereby root growth and tillering. It also increases the dissolved oxygen content in rice field. However, ducks in rice farming reduces the greenhouse effect; prevent the release of methane gas which is important to check global warming. Duck provides additional benefit in terms of egg and meat to the small land holders apart from the environmental benefits. Developing of climate risk-coping production system, resilient to weather vageries, require diversified structures in space and time such as crop rotations, crop- -livestock associations and the use of hedges, vegetative buffer strips and other farm landscaping practices such as raised and sunken bed , three tier systems etc. Accomplishing this can have an enormous impact on adaptation to drought, heavy rains and winds which are expected to be a common phenomenon under changed climatic scenario. Diversification of sensitive agricultural production systems (egrainfed farming) into less sensitive agricultural microenterprises has the potential to mitigate climate adversities.

The smallholder farmers of developing countries are facing unprecedented challenges in the 21st century. With an estimated 9.2 billion people to feed by

2050 of whom 8 billion will be in developing countries and increasing scarcity of land and water, productivity gains will have to be the main source of growth in agriculture and the primary means to satisfy increasing demand for food and other agricultural products. With globalization and new supply chains, farmers will need to continuously innovate to respond to changing market demands and remain competitive. Moreover, "climate change has the potential to irreversibly damage the natural resource base on which agriculture depends. Climate adversity is increasing production risks in many farming systems and reducing the ability of farmers and rural communities to manage these risks on their own. Around the world, resource-poor farmers are trying to adapt to the effects of climate change, which affect them disproportionately: (i) dwindling crop yields; (ii) desertification and land degradation processes, exacerbated by changes in rainfall patterns; (iii) rising sea levels, affecting in particular the livelihoods of coastal communities; (iv) diminishing natural resource productivity; and (v) in some areas, irreversible loss of biodiversity. Planned farming activities has strong potential to reduce greenhouse gas (GHG) emissions by promoting clean and efficient energy, reducing deforestation and promoting sustainable farming system practices such as the rehabilitation of degraded lands, water conservation and management, and increased biomass production.

Climate Adversities and Farming Systems Approach

Climate change is real and its effects are already being experienced in several parts of the world, as is evident from the increase in average maximum temperature all over the world. In India, the changes in temperature and rainfall are predicted to vary from 0.87°C to 6.31°C and –24.83% to +15.18% respectively, by 2080s (Jat*et al*., 2012). Though C3 crops like pulses and oilseeds might benefit from increased CO_2 levels, these benefits are likely to be offset by warmer climate and changed rainfall pattern. The simulation outputs indicate that climate change in the dryland regions characterized by existing high temperature, will reduce crop productivity by reducing length of growing period and crop duration (faster crop development, there by using less natural resources), radiation interception, harvest index, biomass accumulation and increasing water stress in plants as a result of increased evapo transpiration demand due to high temperature (Dimes *et al*., 2008). There is need to identify climate resilient crops and cultivars for different regions to fit in to the cropping systems. Under the climate change scenarios, many of the conventional cultivation practices and strategies may no longer be relevant and farming system approach to diversify the activities will reduce the risk and ensure round the year livelihood.

Farming system approach envisages the integration of agroforestry, horticulture, dairy, sheep and goat rearing, fishery, poultry, pigeon, biogas, mushroom, sericulture and by-product utilization of crops with the main goal of increasing the income and standard of living of small and marginal farmers. Integrated systems are about bringing crops and livestock into an interactive relationship with the expectation that together, as opposed to alone, they will generate positive effects on outcomes of interest, such as profitability overall productivity, and conservation of non-renewable resources. It is, however, much more than this. The "system" includes the environment, soil characteristics, landscape positions, genetics, and ecology of plant and animals. It involves management practices, goals and lifestyles of humans, social constraints, economic opportunities, marketing strategies and externalities including energy supplies and costs and impacts of farm policies. Systems also reflect natural resources available and the impact on their use, wildlife issues, target and non-target plant and animal species, micro-organisms, and indeed all of the definable and indefinable factors that ultimately interact to result in an outcome that is never constant. (Allen *et al.*, 2007).

Water Harvesting and Recycling: Key Strategy in Farming System for Rainfall and Temperature Adversity

The production system adopted during green revolution was explorative and the natural resources like soil and water were subjected to immense pressure beyond carrying capacity (Mahapatra *et al.*, 2007). This in turn results in degradation of growing environment and in the absence of integrated management of these vital resources, it will be difficult to achieve the desired level of food production especially rice with threat from the long term changes in weather and micro climate of production system. Farm ponds, as one of the suitable options of land manipulation, form the centre of integrated farming system especially rice based farming system in rainfed environment. Farm ponds may store in-situ rainfall or harvest surface runoff from surrounding areas depending upon the available rainfall in a region. In high rainfall areas, like A&N Islands where average annual rainfall is about 3100 mm, even in-situ rainwater storage in farm pond serves the purpose. However, in areas where surface runoff is the main source of water, the contributing drainage area or watershed should be large enough to maintain desired water level in the farm pond. Following steps should be considered while planning, designing and constructing a farm pond: (i) rainwater availability, (ii) crop water requirements, (iii) design dimension of farm pond, (iv) location of the farm pond and (v) lining requirement for seepage control.

A comprehensive work on rainwater management in Sundarbans delta, West Bengal is presented by Ambast *et al.* (1998). They analyzed historical annual, monthly and weekly rainfall and evaporation data and fitted to different probabilistic distributions for various planning. The statistical analysis of rainfall and evaporation data indicated that the region has an average annual rainfall of 1768 mm (82% is received during June-October) and evaporation of 1581 mm. July and August being the wet months indicated the probability of severe crop damage due to waterlogging. Monthly water balance analysis indicated considerable scope of excess rainwater storage in on-farm reservoir (OFR).

Hydrological modelling for rainfed humid rice lowlands is used to estimate the excess rainwater availability for optimal design of OFR. It is recommended to convert 20% of the farm/watershed area into OFR to harvest excess rainwater. Further, simulation of surface drainage improvement by rainwater harvesting in OFR in low-lying rice areas of the East Mograhat Drainage Basin was conducted. The hydrographs with and without OFR indicated surface drainage improvement up to 75%. It provides scope for practice of rice based farming systems along with other components such as fish and vegetables in rainfed humid lowlands of rice.

Excess rainwater available during May to December in A&N Islands should be stored *in-situ* or harvested in the dugout farm ponds to provide supplemental irrigation in dry spells during rainy season and life saving irrigation for crop cultivation during dry months. Further, Gupta *et al.*, (2007) optimized the size of the farm pond on the basis of crop evapotranspiration and water requirement of different crops (Table 1) as 15% of the land holding to irrigate the remaining 85% area for summer crops. On this basis, the size of the farm pond for 1 ha land should be 40 m x 40 m with effective storage volume of about 2700 m^3 and its water balance is presented in Table 1. It is expected that the loss of income due to the land converted into farm pond would be offset by generation of income from fresh water fisheries and crop cultivation in the remaining 85% area. The dykes can be effectively used for raising fruit plants, medicinal, aromatic and energy crops. It is clear from Table 2 that rainwater availability for rice cultivation during *kharif* season (May-August) is quite sufficient. The irrigation requirement for rice cultivation during *rabi* season (September-December) is quite high and therefore, rice area should be limited to 25-30% of the total area. In the remaining

Table 1: Evapotranspiration (ET), crop water requirement (CWR), effective rainfall (R_{eff}), grossand net irrigation requirement (GIR, NIR) for different crops

Crop	ET_{crop} (mm)	CWR (mm)	R(Eff.) (mm)	NIR (mm)	GIR (mm)
Rice (Kharif)	468	1300	1200	150	215
Rice (Rabi)	447	1280	691	589	840
Groundnut (Rabi)	478	478	554	-	-
Maize (Rabi)	442	442	436	-	-
Sorghum (Rabi)	361	361	403	-	-
Rabi veg (Cauliflower/tomato)	328	328	358	-	-
Pulses (Summer)	456	456	238	218	311
Summer veg1 (Brinjal/ bitterguard/cucumber/ pumpkin)	429	429	180	249	356
Summer veg2 (Chilli/ watermelon)	358	358	112	246	351

area, low water requiring crops should be grown. Storage of water in farm pond would help in meeting the irrigation requirement of rice and summer season crops apart from culturing of sweet water fisheries and vegetables in the embankments of farm pond.

Table 2: Estimation of available water in the pond for rice based farming system in Islands

Item	Details
Dimension of the pond	40 m x 40 m
Depth of pond	3 m
Dead storage	0.5 m
Water losses (@5 mm/d for 100 days)	0.5 m
Effective rainfall during summer	0.1 m
Available depth for agriculture	2.1 m
Available storage for agriculture (Rice+ fish, vegetables, summer crops etc)	2700 m^3
Extent of Irrigated area	0.85 ha

Farming Systems vis-a-vis Management of Natural Resources

The Asian green revolution has shown that if high inputs technology can be effective in terms of productivity, there is a price to pay in terms of environmental degradation, soil infertility, water depletion and contamination, and a loss of biodiversity. In a context where the impact of climate change on the natural resource base is dramatically increasing, adoption of location-specific integrated management of natural resources for higher productivity and better resilience to erratic climatic events is becoming even more crucial. Since small farmers and rural communities are the starting point for efforts to adapt to climate change, the problems and solutions should be defined with their direct and active participation. It is necessary to use participatory farming system processes that empower smallholders to: draw on their expertise about ecology and management; overcome the constraints they face; create a sense of ownership; and share their visions and experiences with other partners**.**Farming system approach in small and marginal holders are expected to play a vital role in management of natural resources thereby reducing the climatic adversities.

Mitigation of GHG Emissions through Farming System Approach

With a view to mitigate risks and uncertainties of income from crop enterprises and to reduce the time lag between investment and returns it is essential that farmers include multi-enterprises in their production programme that yield regular and evenly distributed income throughout the year and are not subjected to vagaries of nature. The choice of a components in a farming system must ensure that interaction among the components is complementary with least competitiveness. System Approach with careful exploitation of agro-biodiversity involving crops and species requires proper identification of varieties and other management practices including processing and value addition to fully harness the potential. Diversification of crops with the use of possible biodiversity will not only enhance the returns but also bring in sustainability besides preserving valuable biota as compared to monocropping. Rice-brinjal + mushroom + poultry integrated system recorded the highest total system productivity (21,487 kg rice grain equivalent yield) followed by rice-cowpea + mushroom + poultry integrated system (18,027 kg rice grain equivalent yield). The contribution of poultry component in these systems was to an extent of 28 to 34 per cent to the total system productivity. Inclusion of mushroom production in the system enhanced the productivity of these systems by 20 and 23 per cent, respectively, indicating the superiority of integrating poultry with rice based cropping systems. The crop contribution towards the mean system productivity ranged from 33 to 52 per cent. Highest contribution was from the rice-brinjal system due to its higher productivity. Rice-cowpea system contributed 43 per cent to the total system productivity (Korikanthimath et al., 1998)

Recycled paddy straw with mushroom spent substrate was found better over no recycled manure in retaining more moisture (7.70 and 6.69 cm. of soil moisture in top 30 cm. depth, respectively). The depletion of soil moisture was found faster during December–January period as compared to later months. Only recycled poultry manure treatment was able to retain more moisture (4.28 cm.) in the surface layer (0-15 cm depth) compared to sub surface layer (4.18 cm) (Korikanthimath et al., 1998). The pooled mean economic analysis of the integrated systems indicated that rice-brinjal with mushroom and poultry recorded higher gross returns (Rs.1,60,195/ha) as well as net returns (Rs.77,305/ha) although the cost of production was relatively higher (Rs.82,890/ha). The system also recorded a moderate benefit-cost ratio (0.93) with better per day net return (Rs. 204/day). Thermophilic anaerobic digestion (TAnD) and integrated farming is a new agricultural ecosystem. TAnD converts animal waste into useful resources including biogas (65% methane and 35% carbon dioxide) energy, nutrients for aquaculture and bio-fertilizer for horticultural produce. Cashew Apple Waste (CAW) contains Dry matter- 18 % Crude protein-11 %, Crude fibre - 8.5 % At 20 % replacement of maize by CAW reduced the feed cost by Rs1.43/- for production of 1 Kg body weight gain in dual type backyard poultry, Vanaraja. It is suggested from this the present study that CAW could replace up to 20 % maize in the diet of vanaraja chicks without any adverse effect on their performance. Rice-duck farming system is a traditional practice in some of the Asian countries and duck farming is closely associated with wetland rice farming (Panda 2004). The duck integration in rice field increases the rice yield by reducing weed growth, insect population, improving soil physical properties and thereby root growth and tillering. It also increases the dissolved oxygen content in rice field. However, ducks in rice farming reduces the greenhouse effect; prevent the release of methane gas which is important to check global warming. Duck provides additional benefit in terms of egg and meat to the small land holders apart from the environmental benefits.

Rice-fish farming can also decrease water salinity in fish refuge/micro-watershed by about 50% after five year of practice. The cumulative emission of potent green house gas N_{-2}-O reduces by 24 % (by 32% /t of grain yield of rice) under rice-fish system. In the case of another green house gas $CH_{4,}$ there are reports of either decrease (Lu and Li 2006) or increase - in this system, but the emission remains much lower compared to intensive rice farming in irrigated ecology (Datta*et al.,* 2009). Incremental returns obtained from fish under rice-fish rotational farming in Kuttanad is given in Table 3. Rice+ duck+fish farming system is a traditional practice in some of the Asian countries and found to reduce the release of methane from rice field.

Table 3: Incremental returns (Rs/ha) from fish component of rice-fish rotational farming in north Kuttanad (Padmakumar *et al.,* 2002)

Farm size	Gross income	Net income	Fish yield(kg/ha)
Single large farmer having 8.1 ha	33125	14487	1145
Single large farmer having 3.8 ha	39050	23560	1562
34 small farmer group having 21.8 ha	21527	5845	979

Sustainable Round the Year Livelihood through Farming System

Rice-poultry-fish-mushroom integration studies conducted during 1987-1992 at Coimbatore revealed that a net profit of Rs 11,755/year can be obtained in 0.4 ha area while in conventional cropping system with rice-rice-greenmanure/pulses gave a net income of Rs 6334/year only (Table 4) from the same area (Rangaswamy*et al.*, 1996). Murugan and Kathiresan (2005) revealed that among the different farming enterprises compared for integration along with lowland transplanted rice, fish culture, rabbit rearing and poultry rearing resulted in positive interactions among the components and higher net return of Rs 155920/ha was recorded during first year. Higher post harvest soil nutrient status with regard to N, P and K was also observed with rice+fish+poultry systems. The land based enterprises such as dairy, poultry, fishery, mushroom, biogas etc were included by Behera and Mahapatra (1999) to complement the cropping programme to get more income and employment for small farmers of Odisha. A net return of Rs 58367 can be realized with an investment of Rs 49286 in 1.25 ha area which also generated 573 man days of employment with a resource use efficiency of Rs 2.18/Re invested thus ensuring the livelihood of small farmers (Table 5).

Rice based farming system comprising of crop components (Rice-pea-okra and sorghum-berseem-maize), dairy, poultry and fishery was the most suitable

Table 4: Economics of rice based farming systems for a marginal farmer (0.4 ha) under lowland eco systems in Tamil Nadu (mean of 1987-1992)

Component	Expenditure (Rs)	Gross retruns (Rs)	Net returns (Rs)
IFS (Crop +poultry+fishery+mushroom)			
Crop	11398	19076	7678
Poultry	1944	2861	917
Fishery	1486	3568	2082
Mushroom	5078	6156	1078
Total	19906	31661	11755
Conventional system	7202	13536	6334
Additional income	-	-	5421

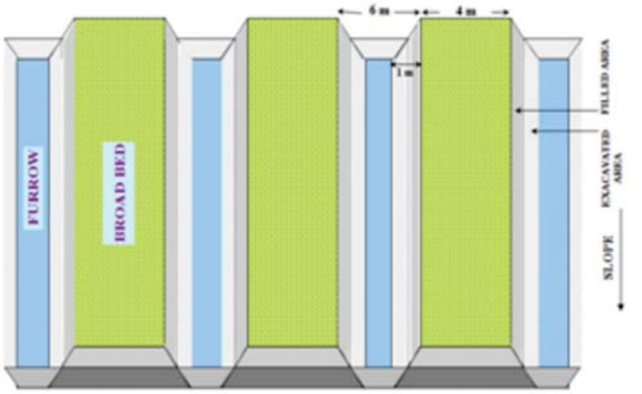
(Rangaswamy*et al.*, 1996)

Table 5: Rice based farming systems for increasing income and employment of small farmers (1.25 ha) at Odhisha

Components	Total Expenditure (Rs)	Net retruns (Rs)	Return/Re invested	Employment generation (man days)
Field crops	3315	5638	2.70	98.2
Multi-storeyed cropping	3831	9089	3.37	87.0
Pomology	900	1466	2.63	18.4
Olericulture	3812	8302	3.18	96.4
Floriculture	125	100	1.80	4.0
Pisciculture	3722	16603	5.46	31.0
Poultry	9240	981	1.11	23.0
Duckery	5387	713	1.13	23.0
Mushroom	18184	12856	1.70	180.0
Apiary	170	1180	7.94	1.0
Biogas	600	1431	3.38	11.0
Total	**49286**	**58360**	**2.18**	**573.0**

Behera and Mahapatra (1999)

and efficient system and recorded higher system productivity and profitability under irrigated ecosystem of eastern Uttar Pradesh (Singh et al., 2006). Rice based farming systems study at Ludhiana revealed that rice-wheat+poultry+dairy+piggery+poplar+fishery produced significantly higher system equivalent yield and net returns (Rs 73973/ha) when compared to conventional system of rice-wheat (Rs 53221/ha). IFS also generated additional employment of 48 man days (Gill*et al.*, 2005).



Climatic Adversity vis-à-vis Land Manipulation based Farming Systems

System also known as Broad Bed and Furrow (BBF) system in Andaman and Nicobar Islands can serve as climate proof technology in the rice based farming systems especially in the coastal areas where in inundation of rice fields are expected due to the sea level rise. It is a technique of land manipulation to grow vegetables, fish and fodder right in the midst of rice fields. The technology involves making of broad bed and furrow alternatively. In the BBF, depressed area is used for rice cultivation and the raised broad bed area, which is above the water level of the paddy field, are used for cultivating of seasonal vegetable or fodder crop during monsoon season. Because of the long term sustainability, easy to adopt and efficient utilization of land area, this techniques is having lot of potential especially for the coastal areas**.** After through study on dimensions, it was found that beds of 4 m width and furrows of 6 m width with minimum 1 m depth are found suitable for the island conditions having high intensity rainfall. The length of beds and furrows can be according to the length of field. Thus, in one ha area of flat paddy field, 10 beds of 4 m X 100 m X 1 m and 10 furrows of 6 m X 100 m X 1 m can be made which envisages 60 % area of furrows and 40% area of beds. The 40% area of beds can be utilized to grow high value vegetables during monsoon season. The broad beds are stabilized by planting two rows of hybrid napier on the edges on either side. Above all this technology is being practiced in rice fields provides best sunshine for growing crops. The system also increases cropping intensity from the present level of 100% in the rice to 300% in the beds and 200% in the furrows of the BBF system. Options of cropping for beds are given in Table 6. The raised bed helps to reduce the salinity problem in degraded land & water. Net return of Rs 1.2 lakhs/year can be obtained from one ha area (Ravisankar*et al.*, 2010*)*.

Three Tier System

Three tier system of farming which involves the shaping of low lying land into three equal portions as pond, original or mid land and raised land. Pond area

Table 6: Options of cropping programme for beds of BBF

Cropping sequence	Period	Expected net returns (Rs/4000m^2)
Option 1		
Cucumber	July -October	17136
Chillies	October - June	192570
Total		209706
Option 2		
Amaranthus	July - September	12932
Cabbage	November - February	48394
Amaranthus	February - March	15164
Amaranthus	May – June	24656
Total		101146
Option 3		
Bhendi	July - October	12676
Amaranthus	October - November	13916
Coriander	December - February	26068
Bhendi	February - June	12784
Total		65444
Option 4		
Crossandra	July – June	20625

should be downward side of slope. The dug out soil from the pond area should be taken to upper side of slope for raising the land. The pond can be used water harvesting during rainy season, fish cultivation & supplemental irrigation. Stored fresh water in midland and pond keep field relatively salt free. Pond also creates better drainage to mid /raised land to prevent damages of crops due to occasional heavy rains in dry season. During wet season, paddy can be grown in the mid land along with vegetables on the raised bed. The system is in practice at coastal areas where in water logging is the major limitation for crop production.

Agroforestry/Agri-horticulture

It meets the human needs of food, fuel, fodder, timber and pesticides (eg. neem) and provides sustainable income with low cost of cultivation and returns are higher as compared to any cropping system involving only annual crops. It also controls soil erosion and improves soil fertility and productivity by regular leaf fall and tapping the nutrients from lower regions of the soil besides very well adjusts with any vagaries of nature. Efficient use of erratic rainfall is possible by trees. Trees act as resting place for birds, which are relatively beneficial for agriculture, since harm done by birds is more than compensated by their action for control of insect pests. Shade created by trees is beneficial in raising certain shade loving crops and horticulture nursery and for vermiculture.

Conclusion

Guided by natural resource limitations and with changing demand portfolio of various commodities diversification of the farming systems has become imminent in many areas to meet the climate adversities. Efficient utilization of scarce and costly resources in farming system approach is the need of the hour to meet the various climate related adversities. Following the concept of integrated farming systems through supplementation of allied agro-enterprises by recycling the waste of one enterprise in another is a right step which will subsidise the risk of weather vageries besides providing round the year employment and livelihhod. The crisis for shortage of water has already begun in many regions. Better utilization of this scarce resource will bring in more dividends in the long run. Different farming systems modules for small and marginal farmers need to be developed and validated both on-station and on-farm so that the key drivers of high income generation in each of the modules can become the strategic interventions in development programmes across diverse agro-eco conditions.

Future research

- Study on the sustainability of the identified systems under different topographical situations in the long run including high value crops.
- Modeling of the identified farming system options to suit a given agro-climatic and socio-economic situation.
- Need to identify the constraints in adoption of identified farming systems by the farmers for further refinement.
- Development/refinement of research methodologies and analytical tools suited for farming system research and analysis using on-farm databases
- Participatory technology development including varietal improvement for various climate related risk patterns.

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11

Concept and Framework for Development of Soil Quality Index: Implications on Soil Management and Environmental Quality

T.J. PURAKAYASTHA AND SAVITA KUMARI

Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. In recent years lot of interests develop on soil quality research due to anthropogenic induced deterioration of soil quality. Soil management and assessment framework (SMAF) is widely used to develop soil quality indices to assess the impact of different management. The three steps used under SMAF are indicator selection, indicator interpretation and indicator integration into unified soil quality index. Minimum data set (MDS) are decided in conceptual framework which is further reduced by principal component analysis. The MDS are transformed in to unit less in a scale of 0 to 1. Finally the summation of weight and score on minimum data set gives rise to soil quality index. Soil quality index thus developed is used to assess the management induced changes in soil quality. Soil quality can be altered by natural and anthropogenic factors including land use and farming practices. Decline in inherent soil quality can occur due to accelerated soil erosion, loss of organic matter, compaction, desertification and other degradative processes. On the other hand, soil quality can be improved by appropriate restorative measures, e.g., using organic material, adopting conservation tillage, and using improved crop rotation, based on legumes. Organic sources like crop residues, green manure, sewage sludge and combination of organic sources is reported to be more effective in improving soil quality indicators. Application of either full organics (100% N) or 25% substitution of fertilizer N with organics showed higher soil quality indices in rice-wheat cropping system in Alluvial soil of north India. Puddling, irrigation after 3 days of drainage and substitution of 25% recommended fertilizer N dose with FYM in rice could be practiced for maintaining or enhancing soil quality. No-tillage, two irrigations, and domestic sewage sludge in wheat can safely be recommended for achieving higher soil quality. However, the inclusion of a cover crop with the reduced tillage (RT) treatment increased predicted soil organic carbon (SOC), which more than compensated for the higher N_2O flux resulting in a lower total GHG balance compared with the conventional tillage (CT) treatment.

The response of soils to different management and inputs also depends on soil quality. It is therefore important to identify the soil characteristics responsible for changes in soil quality, which may eventually be considered as soil quality indicators for assessing agricultural sustainability. Soil quality refers to its ability to sustain productivity and maintain environmental quality (Lal, 1993). Soil quality has three distinct attributes: chemical, physical, and biological. Soil's productivity and its environmental moderation capacity depend on interactive effects of these three attributes (Bezdick *et al.*, 1996). The soil management and assessment framework (SMAF) frame work put forward by Andrews (1998) is widely used as a new paradigm to develop soil quality indices. In this model the management goal is decided first e.g., productivity, environmental protection or waste recycling followed by supporting soil functions and the indicators defining each soil function. The minimum data set is created either in conceptual framework of principal component analysis. The soil quality indicators are transformed into unit less score to a scale between 0 to 1n by standard scoring function. Finally the summation of weight and score would led to develop soil quality indices. Over-exploitation of soils over many decades has resulted in exhaustion of the intensive agricultural production systems and steadily declining productivity has been noticed in long-term experiments in India (Ladha *et al.*, 2003; Manna *et al.*, 2005). Evaluation of individual physical, chemical and biological parameters of soil is one way to study the impact of soil management on soil quality. However, these parameters are generally interdependent, and more importantly, diverse tillage and rotation may affect each parameter differently, confounding the assessment of overall quality (Weil *et al.*, 1996). Soil quality can be altered by natural and anthropogenic factors including land use and farming practices. Decline in inherent soil quality can occur due to accelerated soil erosion, loss of organic matter, compaction, desertification and other degradative processes (Robinson *et al.*, 1996). On the other hand, soil quality can be improved by appropriate restorative measures, e.g., using organic material, adopting conservation tillage, and using improved crop rotation, based on legumes (Lal, 1997; Carter, 1998).

Soil Quality: Concept and Definition

Soil is a dynamic, living, natural body that is vital to the function of terrestrial ecosystems and represents a unique balance between physical, chemical and biological factors. Quality is represented by a suite of physical, chemical and biological properties that together (i) provide a medium for plant growth; (ii) regulate and partition water flow and storage in the environment; (iii) and serve as an environmental buffer in the formation and destruction of environmentally hazardous compounds (Larsen and Pierce, 1991), Historically, soil quality meant suitability or limitations of a soil for a particular use (Warkentin and Fletcher, 1977). Presently, soil quality has been defined by scientists as the "fitness for use" (Pierce and Larson, 1993; Acton and Gregorich, 1995), and by others as the as the "capacity of a soil to function" (Doran and Parkin, 1994; Karlen *et al.*, 1997), while according to Arshad and Coen (1992) soil quality is "the sustaining capability of a soil to accept, store and recycle water, and energy for production of crops at optimum levels while preserving a healthy environment". Karlen *et al.* (1992) defined soil quality as "the ability of the soil to serve as a natural medium for the growth of plants that sustain human and animal life". Soil quality refers to its ability to sustain productivity and maintain environmental quality (Lal, 1993; NRC, 1993). "The capacity of a soil to function within boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health", was the definition of soil quality put forth by Doran and Parkin (1994). As per Holden and Friestone (1997), soil quality is the degree to which the physical, chemical and biological characteristics of the soil to attenuate environmental pollution. The soil quality definition given by Karlen *et al.* (1997) mentioned as: "The capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". Sojka and Upchurch (1999) defined soil quality in terms of distinct management and environmental condition specific to one soil under explicit circumstance for a given use.

Soil Quality Indicators

Soils have chemical, physical and biological properties that interact in a complex way to give a soil its quality or capacity to function. Thus soil quality cannot be measured directly, but must be inferred measuring changes in its attributes of the ecosystem, referred to as indicators. Indicators of soil quality should give some measure of the capacity of the soil to function with respect to plant and biological productivity, environmental quality, and human and animal health. Some of the soil quality indicators as mentioned in Table 1 are very much sensitive of changes induced by various management practices.

It would be unrealistic to use all ecosystems or soil attributes as indicators, so a minimum data set (MDS) consisting of attributes encompassing chemical, physical and biological soil properties are selected for soil quality assessment.

Table 1: Some of the important soil quality indicators

A.	Physical indicators	Bulk density, Aggregate stability, Infiltration rate, water holding capacity
B.	Chemical indicators	Soil organic carbon (SOC), pH, electrical conductivity, available phosphorus
C.	Biological indicators	Microbial biomass carbon (MBC), potentially mineralizable nitrogen (PMN), microbial metabolic quotient,

Development of soil quality indices

Soil Management Assessment Framework (SMAF) is designed to follow three steps: indicator selection, indicator interpretation and integration into a soil quality index value (Andrews, 1998) (Fig. 1).

Indicator selection

Two approaches were used for creating minimum data set (MDS): (1) conceptual framework and (2) principal component analysis. In conceptual framework, ‘Productivity’ and ‘Environmental Protection’ under rice-wheat cropping system were chosen as primary management goals. The supporting soil functions under ‘Productivity’ as the management goal were (1) nutrient cycling (2) water relation (3) physical stability and support (4) resistance and resilience (Andrews, 1998). The supporting soil functions under ‘Environmental Protection’ as management goal were (1) nutrient cycling (2) water relation (3) physical stability and support (4) filtering and buffering (5) resistance and resilience (6) biodiversity and habitat (Andrews, 1998).

1. Indicator selection

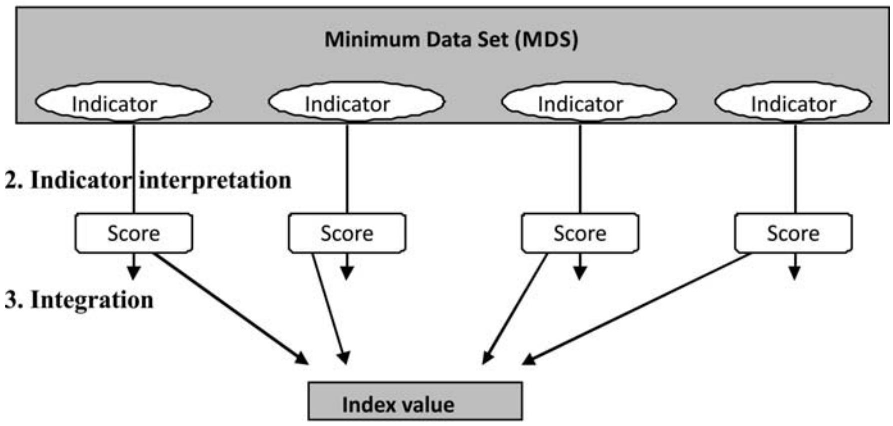

Fig. 1: Conceptual framework for the soil management assessment tool (Andrews, 1998)

A subset of potential indicators for the soil functions and associated management goals is provided in Table 2 (Andrews, 1998). Each indicator has a unique combination of goals, functions, and additional criteria that must be satisfied for it to be suggested for minimum data set (MDS) indicator. The above data set was further reduced by using principal component analysis (PCA) in a PC based SPSS package. The indicators with high factor loading were selected as important soil quality indicators.

Indicator interpretation

Knowledge on the variations in soil quality indicators in similar type of soils under various distinct management systems is necessary to convert the raw data on soil parameters/soil quality indicators into unit less numerical scores. This will help us to set the limits or thresholds for the soil quality indicators. Based on the range of each soil quality indicators and its measures and reported critical values, the limits/thresholds were fixed. After finalizing the thresholds or limits the numerical score was given in more widely used non-linear scoring function (NLSF).

Table 2: A subset of potential indicators for each function under a specific management goal

Management goal	Supporting soil functions	Indicators
Productivity	Nutrients cycling	Microbial biomass C (MBC) Potentially mineralisable N (PMN) Dehydrogenase activity (DHA) Soil respiration Available N Available P Available micronutrients
	Physical stability and support	Soil aggregate stability Bulk density (BD)
	Water relations	Water holding capacity (WHC) Hydraulic conductivity (HC) Soil organic C (SOC)
	Resistance and Resilience	Soil organic C (SOC)
Environmental protection	[All functions of productivity goals] plus	
	Filtering and Buffering	Bulk density (BD) Hydraulic conductivity (HC) Soil organic C (SOC)
	Biodiversity and habitat	Metaboilc quotient (qCO_2)

Non-linear scoring function

For this method, indicators were transformed using the following equation given below, which is the modified form of the one given by Wymore (1993).

$$\text{Non-linear score (Y)} = 1/\left[1+e^{-b(X-A)}\right]$$

Where, X is the soil property value, A is the baseline or value of soil property, where the score equals 0.5 and b is the slope.

Using the equation three types of standardized scoring functions typically used for soil quality assessment was generated: i. more is better, ii. less is better and iii. optimum is better. The equation defines a 'more is better' scoring curve for positive slopes, a 'less is better' curve for negative slopes, and 'optimum' curve is defined by the combination of both. The shape of the curves generated by the scoring curve equation is determined by critical values. Critical values include threshold and baseline values. Threshold values are soil property values where the score equals one (upper threshold) when the measured soil property is at an optimum level, or equals zero (lower threshold) when the soil property is at an unacceptable level. Baseline values are soil property values where the scoring function equals 0.50; it may or may not be the midpoints between threshold soil property values. Slope is mainly decided by the upper and lower threshold values. The slope (b) of individual indicator was either obtained from the established literature or modified slightly in order to get a better fitting of curve. The scores for individual indicator under various soil management practices were calculated and these were tested statistically by using the same b value as reported in the literature or by modifying the b value in order to get a better fitting of data (score) in logistic curve. The b value which gave higher regression coefficient was selected for calculation of score. In conceptual framework all the indicators as listed in Table 2.2 and in PCA based framework only the screened indicators with higher factor loading were provided score. By using non-linear scoring equations, all the raw data on soil quality indicators were converted into a 0 to 1 scale separately. Thus, the scores obtained were employed in calculating soil quality index, explained in the following section.

Indicator integration into indices

The last and final step will be integration of indicator scores into a comparative index of soil quality. Soil quality indicator values were normalized on a scale from 0 to 1. The following two soil quality indexing methods were compared:

1. Conceptual framework for analyzing soil quality
2. Principal component analysis based soil quality index

Conceptual framework:

The Conceptual Framework model has been used to determine soil quality was primarily as described by Karlen *et al.* (1994) with some modification, as follows:

Soil quality index (SQI)P = $q_{nc}(wt)+q_{pss}(wt)+q_{wr}(wt)+q_{rr}(wt)$
(for productivity goal)

Soil quality index (SQI)EP = $q_{nc}(wt)+q_{pss}(wt)+q_{wr}(wt)+q_{rr}(wt)+q_{fb}(wt)+q_{bdh}(wt)$
(for environmental protection goal)

where, q_{nc} is the rating for the soil's ability to nutrient cycling, q_{pss} to facilitate physical stability and support, q_{wr} to water relations, q_{rr} to resistance and resilience, q_{fb} to filtering and buffering, q_{bdh} to sustain biodiversity and habitat and (wt) is a numerical weighting for each soil function. Numerical weights to each soil function were given according to the soil function's importance in fulfilling the overall goals of maintaining soil quality. Weights for all soil functions sum to 1.00. An ideal soil would fulfil all the functions considered important and under the proposed framework will receive a SQI of 1.00. As a soil fails to meet the ideal criteria, the SQI would fall, with zero being the lowest rating. Associated with each soil function are soil quality indicators that influence, to varying degrees, that particular function. As with soil functions, numerical weights assigned to selected soil quality indicators must sum 1.00 at each level.

Principal component analysis

Principal component analysis (PCA) is the method for reducing correlated measurement variables to a smaller set of statistically independent linear combinations having certain unique properties with regard to characterizing individual differences. Principal components (PCs) for a data set are defined as linear combinations of the variables that account for maximum variance within the set by describing vectors of closets fit to the n observations in p-dimensional space, subject to being orthogonal to one another (Dunteman, 1989). Standardized PCA of all (untransformed) data are performed using SPSS package. PCs that receive high eigen values were assumed to best represent the variation in the system. Therefore only the PCs with eigen values e"1 (Kaiser, 1960) are examined. Additionally, PCs that explain e"5% of the variability in the soil data (Wander and Bollero, 1999) were included, when fewer than three PCs had eigen values e"1. Principal component analysis has been used for identifying the important indicators as well as under a particular PC, only the variables with high factor loading were retained for soil quality indexing. When more than one variable was retained under a single PC, correlation are employed to determine if the variables could be considered redundant and, therefore, eliminated from the SQI (Andrews *et al*., 2001). Among well-correlated variables, the variable with the highest factor loading (absolute value) was chosen for the SQI (Masto *et al.*, 2008). If the highly loaded factors are not correlated (assumed to be correlation coefficient < 0.80) then each was considered important, and thus, retained in the SQI. Each PC explained a certain amount of variation (%) in the total data set, this percentage provided the weight for variables chosen under a given PC. The final PCA based soil quality equation is as follows:

$$\text{Soil Quality Index (SQI)} = \sum_{i=1}^{n} Wi \times Si$$

(for both productivity and environmental protection goal)

Where, S is the score for the subscripted variable and W is the weighing factor derived from PCA. Here the assumption is that higher the index scores meant better soil quality or greater performance of soil function. Correlation of SQI thus developed is done with the yield of crops.

Management strategies to enhance soil quality

Cropping systems and crop rotation

Cropping systems play an important role in improving soil quality (Lal, 2013). In a narrow sense, "cropping system" implies a temporal sequence in which different crops are grown on the same land. In this context, the term cropping system is synonymous with "crop rotation." In a broad sense, however, cropping system implies both temporal sequences of crop and the management (soil and crop) practices adopted to grow them. Components of cropping systems that affect soil quality and agronomic productivity are tillage and residue management, drainage and irrigation, integrated nutrient management, cover crops and rotation, erosion control and integrated pest management (Lal, 2013). Some crops grown in rotation leave especially large quantities of residue, contributing greatly to the addition side of the gains-losses equation. Some crops, such as legumes, grasses, or grass-legume forage crops, supply a lot of root biomass, which can contribute to residue, whereas the lack of tillage and continuous soil cover of such crops decreases soil organic matter losses by soil food web respiration or by erosion. The quality of the crop residue also has an impact on soil organic matter in that higher nitrogen content of residue enhances the incorporation of carbon into stable soil organic matter. Compared with monoculture cropping practices, multi-crop rotations with two or three crops in a year can result in increased soil organic carbon contents which is considered as one of the important soil quality parameters. This is because of addition of large amount of above ground as well as underground biomass in soil. As compared to tomato inclusion of sunflower in Pearl millet-Potato cropping system enhanced SOC contents. The enhancement of soil organic carbon contents is further heightened due to introduction of leguminous green manuring crops like *Sesbania aculeate* L. in Pearl millet- wheat- *Sesbania aculeata* L. (Chander *et al.*, 1997), cowpea in sorghum-cowpea (Duriasami *et al.*, 2001) and clover in Rice-clover crop rotations (Batra andRao, 2004).

Conservation tillage

Soil quality can be enhanced by decreasing the intensity and frequency of mechanical disturbance to soil by tillage operations, and by increasing the amount of crop residues and biomass left on the soil surface (Lal, 2013). Conservation tillage implies any tillage method that reduces soil erosion and maintains at least 30% of the ground cover by returning crop residue on the soil surface (Uri,1999; Michalson *et al.*, 1999). Conservation agriculture in the form of conservation tillage (zero/reduced/bed planting) and incorporation of crop residues have been introduced in the irrigated regions of Indo-Gangetic Plains to reduce the cost of cultivation, saving the resources like water, fertilizers, energy and time, improve soil health and enhance system productivity (Mishra and Chatrath, 2009). No-till wheat can also benefit from the residual moisture by planting immediately after harvesting of rice without a pre-sowing irrigation. Long-term sites maintained at farmers' fields in Teek, Uchani, and Nangla villages in Haryana revealed an improvement in the organic matter considered as an important soil quality parameter with no-till (Kumar *et al.*, 2002). Organic C in bulk soil in Inceptisol from Meerut, Uttar Pradesh was significantly affected by tillage practices; the difference was significant in the 0- to 5-cm layer (Kumari *et al.*, 2011). In this layer, zero tillage (ZT) had significantly higher SOC of 7.37 and 7.86 g kg”1 in T5 (direct drill-seeded rice on permanent flat-beds) and T6 (conventional puddled-transplanted rice in zero till plots 21-day old rice seedlings), respectively than those of 5.81 and 6.14 g kg”1 in conventional tillage treatments T1 (conventional puddled-transplanted rice) and T2 (same as T1 except that irrigation withheld for about 1 month), respectively. Puddling and irrigating rice after three days of drainage and no tillage and two irrigations in wheat emerged as the promising management practices for higher soil quality (Bhaduri, 2010). Mohanty *et al.* (2007) reported that using zero tillage for wheat had a positive effect on soil quality. Multivariate analysis of

Balanced fertilization

Balanced fertilization

From the long-term fertilizer experiments clearly indicated that the balanced applications of NPK is crucial for improvement of important soil quality indicators. The balanced application of NPK (100% or 150% NPK) showed higher accumulation of soil organic C, over imbalanced use of fertilizers (100% N and 100% NP) in different cropping system (maize-wheat-cowpea, rice-wheat-jute, maize-wheat, soybean-wheat) over three decades under dissimilar climate and soil (Rudrappa *et al.*, 2006, Manna *et al.*, 2006, Subehia *et al.*, 2005, Bhattacharya *et al.*, 2004). There Total organic C content in entire 0-45 cm soil profile in maize-wheat-cowpea cropping system in Delhi followed the order: 100% NPK + FYM > 150% NPK > 100% NPK> 100% NP > 100% N = 50% NPK > control (Purakayastha *et al.*, 2008). There was deterioration of soil quality in terms of loss of native soil carbon and nitrogen in the 0-15 cm surface under N and NP plots of LTFEs at Barrackpore and Ranchi whereas impact of these treatments was positive at Akola (Manna *et al.*, 2006). In the imbalanced fertilizer plots (N and NP), soil microbial biomass carbon decreased about 1.1-3 folds compared to NPK+FYM in all the LTFE sites described above. The sustainable yield index correlated significantly with soil organic carbon, water stable aggregate, soil microbial biomass nitrogen and dehydrogenase activity (Manna *et al.*, 2006). Masto *et al.* (2006) developed the soil quality index (SQI) across various nutrient management in long-term fertilizer experiment and reported that the SQI ratings ranged from 0.552 (Unfertilized control) to 0.838 for the combined NPK fertilizer plus manure treatment. Comparisons among treatments indicated that SQI increases associated with the combined (NPK+manure) treatment were distributed as follows: N (1.7% increase), P (7.8%), K (14.4%), Zn (4.8%) and manure (15%). The control (-11.4%) and N alone (-5.1%) resulted in degradation compared to a reference soil (no fertilizer/manure, no crop) and NP alone or sub-optimal rates of NPK were on the verge of degradation. Chaudhury *et al.* (2005) reported from a LTFE of rice-wheat-jute cropping system that the mean weight diameter of aggregates contributed maximum to the soil quality index (42.2%)

followed by available P (29.6%), DHA (19.9%), and total N (8.3%), respectively. By considering 100% NPK + FYM as ideal treatment (SQI = 100), the relative soil quality explained that if there were exclusion of FYM, the soil quality would decline by 19.35%. Furthermore if FYM and potassium fertilizer were excluded, the SQ would decline to 25.81%: similarly if FYM, potash and phosphorus fertilizer were excluded, the SQ would decline by 56.68%. Multivariate assessment of soil quality indicated use of NT practices improved the biological and physical condition of the soil despite increased consolidation (Wander and Bollero. 1999). Application of chemical fertiliser with 2 t of rice straw compost gave a sustainable index of 1.75 (Kang *et al.*, 2005). Application of chemical fertilizer alone resulted in an unsustainable system due to low microbial (0.88) and crop (0.82) indices of soil.

Organic manuring

Application of organic amendments such as FYM, straw or green manure crops, tends to build up soil organic matter and soil quality in all rice-based cropping systems (Regmi *et al.*, 2002; Yadav *et al.*, 1999).Green manures incorporated in the soil before rice transplanting had residual effect on the succeeding wheat crop as evident from the grain yield. Such residual effects are often associated with the presence of more hydrolysable organic N in the soil (Chakraborty *et al.*, 1988). Results indicated that partial substitution of fertilizer NPK with Sesbania green leaf manuring in rice was as good as 100% recommended NPK through chemical fertilizers (Yadav *et al.*, 2000). As green manure is an organic material, incorporation of green plant material (Sesbania rostrata, Sesbania aculeata, Vigna radiata residues) obviously, increased the accumulation of soil organic matter and total nitrogen concentrations and overall soil quality during the growth period of rice and wheat. Incorporation of green manure improved the physical quality of soil by increasing total pore space, which in turn decreased bulk density of soil as well as an increase in hydraulic conductivity observed (Mandal *et al.*, 2003). Enhancement of both stable and labile organic matter content and microbial activity due to manure application to soils are considered to provide positive impacts on soil quality. The manure of high organic matter content is anticipated to be most beneficial in improving the physical condition of the soil (Schoenau *et al.*, 2002). Integrated use of fertilizer with farmyard manure significantly improved SOC contents as well as overall soil quality which are developed by encompassing different physical, chemical and biological properties of soil. Integrated nutrient management was helpful in greatly increase soil quality index (Singh, 2007). However, in a long-term fertilizer experiments Masto *et al.* (2007) reported significant improvement in soil quality vis-à-vis organic C due to long-term application of NPK plus FYM than only NPK, NP or N treatments. Ability to resist biochemical degradation was significantly higher with 100% NPK + FYM than for all other treatments. The SQI and soil function ratings were also increased with increasing rates of chemical fertilizers. Kang *et al.* (2005) reported that application of 8 t of rice straw compost for 4 years gave a sustainability index of 1.69 for the rice-wheat cropping system.

Residue management

The incorporation of residues has favourable effect on soil quality parameters (physical, chemical and biological properties) such as pH, organic carbon, and water holding capacity and bulk density of the soil (Singh *et al.*, 2005). In an 11 years field experiment on a loamy sand soil in Punjab, India the incorporation of residues of both the crops in the rice-wheat cropping system increased the total P, available P, and K contents in the soil over the removal of residue removal. In another study over a 5-year period on a silt loam soil at Palampur in Himachal Pradesh, India having a relatively cooler climate than Punjab, the incorporation of rice straw in wheat caused a slight increase in availability of P, Mn and Zn and a marked increase in the availability of K (Verma and Bhagat, 1992). The incorporation of crop residues on a long-term basis increased the DTPA-extractable Zn, Cu, Fe. The decrease in bulk density with straw addition definitely has a bearing on wheat yield in rice-wheat rotation, where soil aeration becomes a limiting factor. The incorporation of residue also prevents the leaching of nitrates. It adds a plenty of organic carbon and thus increases bacteria and fungi in the soil. In a rice-wheat rotation, Beri *et al.* (1992) and Sidhu *et al.* (1995) observed that soil treated with crop residues held 5-10 times more aerobic bacteria and 1.5 to 11 times more fungi than soil for which residues were either burned or removed. Due to increase in microbial population, the activity of soil enzymes responsible for conversion of unavailable to available form of nutrients also increases. Mohanty *et al.* (2007) reported as the puddling intensity for rice increased, sustainability without returning crop residues decreased from 6 to 1 year. When residue was returned, the time for sustainable productivity increased from 6 to 15 years for direct seeded rice, 5 to 11 years with low-intensity puddling and 1 to 8 years for high intensity puddling. For sustainability and productivity, the best practice for this or similar Vertisols in India would be direct seeding of rice with conventional tillage and residue returned.

Use of Biochar

There is currently great interest in the application of biochar to agricultural lands as a means of improving soil quality while sequestering carbon (C) in soils (Lehmann *et al.*, 2006; Laird, 2008). Biochar is a fine-grained, carbon rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350-600 oC) in an environment with little or no oxygen (Amonette and Joseph, 2009). It has been projected that in India about 309 million tons of biochar (eqv. to 154 million tons of biochar C) could be produced annually, the application of which might offset about 50% of C emission (292 tera gram C year-1) from fossil fuel (Lal, 2005). If these residues are converted for bioenergy production, biochar would be produced as a by-product which has lot of implications on soil organic carbon sequestration, improvement in soil quality and sustainable crop production. Purakaystha *et al.* (2011) reported that corn biochar prepared at 600 oC could be a useful biochar material for enhancing carbon storage in both Mollisol and Alfisol. The biochar amendments significantly increased total N (up to 7%), organic C (up to 69%), and Mehlich III extractable P, K, Mg and Ca but had no effect on Mehlich III extractable S, Cu, and Zn (Laird *et al.*, 2010). Because of higher stability of maize stover biochar due tothe presence of stronger structural surface functional groups includingaromatic C=C stretching, it might be having greater potential forlong-term C sequestration in soil (Purakayastha *et al.*, 2015). The results indicate that biochar amendments have the potential to substantially improve the quality and fertility status of Midwestern agricultural soils. Applying biochar to soils may cause a win-win situation resulting in C sequestration and soil fertility improvement (Peng *et al.*, 2011). The effect may be more evident in highly weathered and infertile tropical soils, but will be dependent on biochar quality.

Alternate land use

Alternate land use systems, viz., agro-forestry, agro-horticulture and agro-silviculture are more remunerative for SOC restoration as compared to sole cropping system. Das and Intal (1994) reported that organic C content was about double in agro-horticultural and agro-forestry systems as compared to sole cropping. Purakayastha *et al.* (2007) reported that vegetable growing plots exhibited similar SOC contents as rice-wheat growing plots. Soil organic C and microbial biomass C in agro-forestry was significantly higher than in either of the two systems reported above. Dhaliwal (2003) showed higher soil organic C and microbial biomass C in natural forest system followed by cultivated and pasture ecosystem.

Soil quality and environmental quality

Improvement in soil quality has a direct influence on improving the environmental quality. The environmental quality can be measured in the changes in soil environment as well as atmosphere. It is a well-known fact that improvement in soil quality is well associated with improvement in soil biodiversity and better cycling of nutrients. The change in soil quality is reported to increase the release of greenhouse gases. As for example, positive changes is soil organic carbon which is considered as one of the powerful soil quality indicators might increase the emission of greenhouse gases. It was reported that increasing the mulch rate increased the soil organic C as well as global warming potential (Mg CO_2e-C $ha^{-1}yr^{-1}$) and it was more in presence of fertilizer than without fertilizer (Lenka and Lal, 2013). There was no difference in CO_2 emission between conventional tillage and reduced tillage while N_2O emission was significantly higher in latter tillage management than the former tillage management (Abdalla *et al.*, 2014).

Conclusion

The concept and framework have strong scientific base for development of soil quality indices. With change in management goal the supporting soil functions would also change. The major challenge before development of soil quality indices is development of appropriate scoring functions for scoring the data. The weightage for individual soil quality indicator in a particular soil function or all the soil functions integrated into unified soil quality indices is determined by existing published literature and expert opinion.

The management goal, the supporting soil functions describing the goal and the indicators describing the soil functions are the new paradigm to develop soil quality indices. Thus the protocol which is used to develop soil quality indices is a powerful tool to assess the management induced changes in soil quality. The soil management and assessment framework could identify the sensitive soil quality indicators limiting the crop productivity and other ecosystem services. There is distinct promising land, soil and crop management practices which could be implemented for enhancing soil quality and sustainable crop productivity. The adoption appropriate management strategies e.g., conservation tillage, balanced fertilization, organic manuring, integrated nutrient management, appropriate crop rotation, residue retention and incorporation, biochar application and alternate land use etc. are promising for maintaining or enhancing soil quality, sustainable crop productivity. Improving soil quality through judicious management can reduce dependence on fertilizers and other chemicals. In addition to enhancing productivity, choice of appropriate cropping systems improves soil quality, sequesters C and improves environment, and sustains agronomic productivity. Overall the improvement in soil quality could result in soil environment as well as above ground environment.

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12

HOMA Therapy: An Effective Tool in Mitigating Soil, Water and Environmental Crises

R.K. Pathak and Ulrich Berk

Environmental degradation or pollution has acquired the global dimensions. Each component of the environment (lithosphere, hydrosphere, atmosphere, extra -atmosphere or space and surrounding flora and fauna or biosphere) has been affected adversely. Unthoughtful exploitation of nature, rapid development of science and technology, exponential growth of industrial sectors and mechanized agriculture, out flow of liquid, solid and gaseous waste products in the environment, enormous increase in number of automobiles causing gaseous and noise pollution, blind deforestation, killing animals, indiscriminate use agro-chemicals in agriculture, perforation in ozone layers on the upper part of atmosphere allowing radiation pollution in atmosphere are the chief sources of environmental degradation. Thus, environment has been badly oppressed, tangled and raped by the human activities and its deeds.

To sustain the ecobalance in nature and maintain the health of biosphere, it is inevitable that “Science and religion” should develop parallel. There must be coordination between science and religion. It has been rightly emphasized by the Great Scientist Sir Albert Einstein that “**Science without religion is lame and religion without science is dumb**”. Incidentally, Homa Therapy with Agnihotra as its basic tool has wide-reaching beneficial effects on soil, water resources and the atmosphere. It is pertinent to mention that environmental pollution is creating all these crises on planet earth. In fact, the food which we consume, water which we drink and the environment in which we live, all are polluted and problem is becoming alarming every day. This calls for introspection and change in the mindset of every individual and organisations associated with these basic issues. Interesting Homa Organic Farming, an ancient technology, provides an alternative in resolving these crises. As on today, it is being implement in more than 71 countries in all continents by thousands of people particularly under guidance of volunteers of Five Fold Path Mission and few other organizations.

Agnihotra is a gift to humanity from ancient- most Vedic Sciences of bio energy, medicine, agriculture and climate engineering. It the basic fire in HOMA THRAPY. It is the process of purification of the atmosphere through the agency of fire, prepared in the copper pyramid and tuned to the biorhythm of sunrise/ sunset. Basically it is science of pyramidology, biorhythum of nature, burning of organic substances, sonic power of chanting special mantras and its electro magnetic effects which is extended to a larger area by establishing resonance point. Agnihotra is also a process of fumigation which affects the intensity of pathogenic bacteria. It gives nourishment to plant life. Agnihotra atmosphere results in better absorption of sun's rays by the water resources on earth. Thus the energy cycle of planet is kept in rhythm (Paranjpe, 1976).

By practice of Agnihotra, one can notice that the tension of mind disappears and one begins to experience peace. The mind is reshaped so nicely, so delicately, so effortlessly by simply sitting in the Agnihotra atmosphere.

Tremendous amounts of energy are gathered around the Agnihotra copper pyramid just at Agnihotra time. A magnetic type field is created, one which neutralizes negative energies and reinforces positive energies. Therefore, a positive energy pattern is created by one who does perform regular Agnihotra.

When Agnihotra is performed, Agnihotra smoke gathers practices of harmful radiation from the atmosphere and on very subtle level neutralizes their radioactive effect. Nothing is destroyed, merely changed from one form to another.

When Agnihotra fire is burnt there is not just energy from the fire, but subtle energies are generated and thrust into the atmosphere by the fire. The quality of materials burnt is an important prerequisite to its full healing effect. Much healing energy emanates from the Agnihotra pyramid. Salient features of impact of this healing fire associated with soil, water and environment have been dealt.

Soil

Soil is the most important production factor for crops and at the same time also most influenced by the farmer. In recent decades, there has been heavy pressure on land because of indiscriminate use of agro chemicals, urbanization and other non farm uses; diversion takes place not only from wastelands but also from ecologically important areas, such as forests or pasture land, lakes and ponds and even land suitable for agriculture production. According to broad estimates, about 120 million ha of land in India is suffering from one or other regions (NAAS, 2010 quoted in Singh, 2011). Imbalanced fertilizer application, unscientific ways of water use and land preparation have affected vast stretches of once fertile land. Soils are very diverse and complex systems full of life. The soil itself can be viewed as a living organism, because it is a habitat for plants, animals and micro-organisms which are all interlinked with each other.

Some Facts Regarding Soil

A teaspoon of active soil is the habitat of millions of soil organisms. Some are of animal origin, some are of plant origin. The organisms vary greatly in size. Some are visible to the naked eye, such as earthworms, mites, spring-tails or termites. Most of them, however, or so small that they can only be seen with a microscope, thus they are called micro-organisms. The most important microorganisms are bacteria, fungus and protozoa. Microorganisms are the key elements to the quality and fertility of soils, but for humans, they do their work invisibly. The greater the variety of species and higher their number, the natural fertility of soil will be better. The same has been summarized.

- Soil is dynamic and living system and therefore is in a continuous process of transformation.
- It grows fast and vanishes very fast by erosion if someone does not respect her.
- Without soil organisms, soil is dead.
- Not all microbes are hostile.
- Most soil microbes are very important helpers of the farmers.
- *Soils acts as natural resource on whose proper use depends on life support system and social and economic development of any country.*
- *As on today soil is deteriorating rapidly in most part of the region.*

Lesson to remember

"The soil humus losses on planet might become ecologically dangerous if not arrested now, because humus is the major accumulator of solar energy at the earth surface at present and the guardian of soil productivity, guaranteeing ecological stability of the biosphere".

Rozanov (1990) from Moscow cautioned

- Humus retains nutrients & moisture and releases slowly;
- It also captures humidity from dew and capture subtle energy from planets, retains it;
- It also transmutate nutrients as plants need it;
- If the soil is deficient in humus content, subtle energy coming from planets are radiated back in atmosphere.

So for we have abused the soil with cocktail of chemicals, and many other human activities, therefore she has started in showing her discomfort through incidence of number of pest, diseases, weeds and soil erosion. If not arrested now, survival of humanity at planet earth will face crises in every sphere of life.

Current Status of Indian Soil

- Organic carbon content in most of soils is less than (>0.5%).
- Large parts of India's soils are deficient in three or more critical nutrients.
- Soils of Punjab, Haryana, UP, Bihar which produce 50 percent of grain and feed 40 percent population are seeing multiple nutrient deficiencies.
- N-deficient in Punjab, Haryana, UP, Rajasthan, Gujarat, Maharashtra, parts of Bihar, Jharkhand, MP, AP and Tamil Nadu.

Measures to Improve Soil Fertility

- Adoption of farming system approach.
- Crop rotation mixed cropping, multistoried cropping.
- Inclusion of legumes in the system as green manure, inter/cover crops.
- Regular addition of organic manure and other measures such as mulching, use of enriched compost and regular use of Bio enhancers.
- Integration with Homa Organic Farming and use Agnihotra ash and Biosol special bio enhancer has good impact in improving soil fertility.

Reports on HOMA Impact Shows that

Earth is ailing -almost beyond repair- was clear enough as early as 1912 to Nobel Prize winner, Dr. Alexis Carrel. He warned that since *soil is the basis of all human life* our only hope for a healthy world rests on reestablishing the harmony in the soil which we have disrupted by the modern methods of agronomy. All of life will be either healthy or unhealthy, said Carrel, according to the fertility of the soil. Directly or indirectly, all foods comes from soil.

The fertility of the earth is contained in the thin layer of topsoil which supports all plant life, and which is, in turn, protected by plants. Today, the soils of India are dying, and the most fertile among them are dying because of the indiscriminate use of agro-chemicals over 5-6 decades. This has adversely affected soil fertility, crop productivity, produce quality, water and the environment.

The emerging red, yellow, blue colours of the flame resulting from the burning of the oblations also has unifying link with Agnihotra mantra. Thus, all beneficial qualities of chromatography too are present in the Agnihotra mantra (Potdar, 1999).

> There are two basic energy systems in the physical world: Heat and Sound. In performing Agnihotra, these two energies namely, the heat of the fire and the sound of chanting Mantras are combined to achieve the desired physical, psychological and spiritual benefits (Narang, 2007).

A Western Scientist from Poland has said that Agnihotra is a wonder weapon to counter pollution. Agnihotra heals the atmosphere. Modric (2004) is of view that in Agnihotra, it is the role of special vessel made of copper, its ziggurat shape, a form related to the horn antennas used in high frequency transmission. The ash which is available after Agnihotra is disinfectant, anticoagulant, and tissue contracting was well established. He agreed that ash had pesiticidal and fungicidal properties. He was of the firm view that he was dealing with a complex problem that could potentially affect the whole environment, countring the toxins of modern technology developed over the last century by the industrial revolution, and that the process might have enormous implications for our existence. He claimed that Agnihotra ceremony was energetically quite complex, involving at least three energitic aspects, or field phenomenon, having to do with fire and the ash, with radiation of an undefined nature, and with ESP, or psychism. He said that there is possibility of electromagnetic radiation during the ceremony. He asked that lot of systematic research is needed to provide scientific explanations for exciting impact which has been claimed in agriculture, animals and human health.

In fact as on today the soil needs to be rejuvenated first by Homa Therapy. Tremendous amounts of energy are gathered around the Agnihotra copper pyramid just at Agnihotra time. A magnetic type field is created, one which neutralizes negative energies and reinforces positive energies (Narang, 2007). Therefore, a positive energy pattern is created by one who does perform regular Agnihotra.

In rejuvenated soil different types of microorganisms, starting from level of viruses, bacteria, fungi and algae thrive better. Thus a healthy micro-flora and micro-fauna is created. This gives rise to micro environment or micro-system which is comparatively less toxic to the growing plant. The soil which has now become a living soil because of presence of micro organisms has all the chemical components useful for life in the form of carbon, hydrogen and oxygen. According to the modern theory, these three together form life in the form of bacteria. The soils have nitrogen fixing bacteria also bacteria working on phosphorus content of soil (Ulrich, 2009). There is large number of reports which indicates impact of Homa in resolving soil pollution and improving its fertility.

- Acidic soil was brought back to normal-Soil with a pH of 4.4 was brought back to normal by organic farming methods like composting and mulching and Homa Therapy including the use of Agnihotra ash (Poland). The soil which was not suitable for crop production, now large number of fruits, vegetable, medicial harbs are grown and the place has become paradise (Bizberg, 2009, www. terapiahoma.com.pl).
- High sodicity in soil could be brought back to normal by Homa atmosphere and by adding some Agnihotra ash. Some preliminary observation at one of the KVK in Unnao district with ameluration of sodic soil has shown interesting results (Johnson and Karin, 2009).
- As there are large areas in India of previously fertile land which now are lying barren because of high sodicity/ salinity Homa Therapy could give a solution to a big problem.
- The soil improves through Homa Organic Farming Technology even in difficult climatic conditions like acid rain:
- At Tapovan Homa Farm of about seven acres in Ratnapimpri, Taluka: Parola, District: Jalgaon, Maharashtra, India, where Agnihotra and other Homas are practiced since 2001. The soil was very poor. Always there is a water problem in that area as wells dry up in summer. After one year of practicing 24 hours fire, there was a total change and the soil received much nutrition

and soil fertility has improved with respect to physico, chemical and biological properties at this Homa farm (www.homa1com; www.homatherapyindia.com; tapovan3@yahoo.com).

- In the surrounding area, it looks like all deserts and only these HOMA acres are lush, shining green and full of biodiversity. The crops are highest per acre. Fruits and vegetables have exquisite taste and aroma; they are resistant to disease. The soil has been nourished by the effect of the 24 hours HOMA fire in the atmosphere (Johnson and Karin, 2009).
- Soil in resonance atmosphere holds moisture better than any soil, due largely to the feedback of Homa on the atmosphere. When the nutritional rain comes due to the practice of Homa healing fires of Homa Organic Farming Technology, (Agnihotra and Om Tryambakam Homa), the nutrients and moisture are sustained as a unit in the soil. This makes for better quality vegetation. Agnihotra Homa and Agnihotra ash, when put in the soil, help stabilize the amount of nitrogen and potassium present (Paranjpe, 2005).

It has been observed that when "***Agnihotra* Ash**" is added to the normal soil it increases the water soluble phosphate content of the soil (Kartz, 2007 and Lai 2007) and nutrients are absorbed readily by the root hairs of the plants. Solubility of Phospate as influenced by incorporation of Agnihotra ash is evident from the following table.

Table 1: Showing Solubility of Phosphate

Soil used	Phosphate % per g of soil Non homa Homa	Phosphate % per g ash Non-Homa Homa
No soil -Only ash		3.40 8.90
Weld Loam	0.42 1.72	21.00 86.00
Red Feather Loamy Sand	0.23 1.15	11.50 57.50

In Homa atmosphere the metabolic process of plants is speeded up. It is the ghee used in Agnihotra process that is the catalytic factor and on a more subtle level the mantras interacting with the combined effect of the burnt ghee and rice. This combination enters the soil after returning from the solar range. It enters the plant by, one might say, attaching itself to minerals and water absorbed by the root system of the plants. The ghee acts as a catalyst, creating a chemical reaction with the plant, aiding in enzyme and vitamin production and encouraging and increasing the cyclic rate. In other words plants mature faster, taste better and better just by performance of Homa in the garden.

- Water solubility of phosphorus will be increased by adding Agnihotra ash to the soil. This has been shown in institutes both in U.S. as well as recently in Germany (Lai, 2007 and Kratz and Schnug, 2007).
- Aeration of the soil is increased by Agnihotra.

- Agnihotra enhances soil microbial activities including earthworms.
- Moisture holding capacity of soil is increases in Homa atmosphere.

Water Resources

Water is an important natural resource made available in plenty by the Mother Nature. It is one of the critical inputs, which is essentially required for survival of huminity. Agriculture uses nearly 70- 80 percent of the water resources in the country. According to IWMI study, food crops alone use 74 percent of total consumptive water use. As for supply is concerned, the ground water component is declining rapidly in most part of the country. Progressively larger blocks are being declared 'dark zones'. The situation is all the more worrisome because of the low water use efficiency. As in case of land, quality of water resources is also, deteriorating. Salinity and alkanity is continuously increasing and damaging agricultural land, especially in areas irrigated by ground water sources, while water logging is a major problem in the areas irrigated by surface irrigation particularly through canals.

In recent years, water, is becoming one of the major constraints for the welfare of human beings. In future, water shortages are likely to be widespread. Our current concerns are over the long-term sustainability of water infrastructure, and its ability to sustain future food, water requirements to human being and other activities. The public water infrastructure are showing signs of crumbling, and is impacting the land, and water resource quality base of agriculture, affecting crop productivity. Indiscriminate over exploitation of ground water resources is shrinking the total resource-base itself, as wells fail because of fall in water tables beyond acceptable limit.

Some Facts Current Water Resources

Shree Paranjpe, strong promoter of Homa technology stated in an article written in Nov 2002 that If Homa is practiced on a large scale, the atmosphere is healed and the water resources get purified, leading to better absorption of sun's rays'. He believes that this is a clue as to how Homa brings water resources back into a healthy condition.

Shree Paranjpe explains further that, 'Water resources on earth are finding it difficult to absorb energy from the sun (due to pollution). This will result in depletion of marine life and imbalance in nature. Water pollution now takes its toll in rich as well as poorer countries. No water is relatively safe to drink now (Paranjpe, 2005.

In rivers like Ganga, industrial pollution and most alarming is affluent discharge of untreated human wastes, symbolized by the raw sewage that pours into the river along the major cities are creating pollution. The blue and black slime that oozes from the tanneries is one of the nastiest forms of pollution, laden with chromium sulfate, sodium sulfide, and a score of other toxic acids, fats, dyes and synthetic chemicals. It is alarming that presence of fecal coliform bacteria levels as much as 3,000 times higher than the limit set by the WHO. This situation becomes further alarming owing to contamination all along Ganges because of conventional agriculture, and contaminations of arsenic from city garbage and thousands of corpses, both animal and human, and tons of cremation ashes (Times of India, June, 15th, 2014). In fact almost all rivers in the country are facing the similar problem.

HOMA Therapy and Agnihotra ash Improve the Quality of Water and Make it Potable.'

Soil in Homa atmosphere holds moisture better than any soil. It is due to ghee and the feedback of Homa atmosphere. When nutritional rain comes due to practice of Homa organic farming, the nutrients and moisture are sustained as a unit in the soil. This makes for better quality vegetation.

Report Indicates the De-Polluting Effect of Agnihotra Ash on Water

Dr. Masuru Emoto-JAPAN did pioneer work on water quality and dedicated his life to research on water and human health; he was of the view that human body consists of 75 percent and brain itself has 69 percent of water, which is crucial for sound health. This fact realization created idea how can water affect out wellbeing? Can we heal ourselves through water? Yes! Water is a vital healing agent. He developed a technology by quick freezing of water and through advance photography it gives wonderful results of crystal formation depending upon its purity. He was of the view that it was typical case of subtle enery as enumerated below.

Subtle Energy www.rh4.info

§ Emoto- photos show difference in water patterns after you utter mantras.

§ Same with adding Agnihotra ash.

§ Water is not just H_2O;

- In order to fully understand how Agnihotra and Homa Therapy work, we probably have to go one step deeper to level of subtle energies generated during Agnihotra.
- He took water from rivers of Japan, Germany and London, in all the rivers water observed to be polluted and showed hazy photographs;
- Wonderful crystal formation was noticed from water collected from springs from Japan;
- He got similar photographs from the polluted water by placing Agnihotra ash.
- He was of the view that regular performance of Agnihotra and placement of

Ash in water bodies may be helpful in resolving water crises in the country.

The following report indicates the de-polluting effect of Agnihotra ash on water and on biotic life when industrial effluent was present in the water.

HOMA Therapy and Agnihotra ash improve the quality of water and make it potable. Agnihotra ash is extremely medicinal and has a powerful purifying effect on water.

It was suggested (Satsang, volume 13. Number 22 and 23) that addition of Agnihotra ash to a fish tank would enhance the process of purification of the water by retarding the process of multiplication of harmful bacteria and algae in the water freshening through by absorbing odours. The observations clearly indicated that Agnihotra ash does, indeed affect the quality of water and the growth of algae in the medium. The ecosystem wherein we live, Agnihotra ash treatment of polluted and acidified lakes and streams need to be researched upon and promoted as there are some positive response.

- A Bio assay test was carried out to study the effect of Agnihotra ash on biotic life. Different concentrations of effluents were prepared. Ash dose was given and fish were kept under observation for 48 hours. The effluent was collected from textile process industry. Biotic life was possible in concentrations of 15 percent effluent with 0.5 gm/liter ash and 20 percent effluent with 2 gm/liter ash. Whereas biotic life was absent in 20 percent effluent with 0.5gm/liter ash and 15 percent effluent with no ash.
- The Chemical Oxygen Demand (COD) of the effluent before and after Agnihotra ash treatment was compared.
- The study revealed concentration of COD after Agnihotra ash treatment is reduced which indicates Agnihotra ash helps to purify the water.

Ground water quality is controlled by geological factors (arsenic, iron, fluoride etc), overdraft, fertilizers and pesticides use, and saline water intrusion in the coastal regions. The current status of water can be viewed from the following statement.

- High levels fluorides have been reported in several pockets of 200 districts in West Bengal, Bihar, Chhattisgarh, Assam and in certain pockets of Uttar Pradesh.
- The problem of arsenic is very serious in West Bengal, where the first case of arsenicosis was reported in early 1980s.
- In a joint research Indo-British study by University of Manchester and CSIR-Indian Institute of Chemical Bilogy in Kolkata derived serious consequences on human health.
- Study revealed that people in rural Bengal eating rice as a staple with greater than 0.2 mg/kg arsenic showed higher frequency of micronuclei than those

consuming rice with less than this concentration of arsenic.

- Increased frequency of these micronuclei has been shown by researchers to be linked to the development of cancers.
- High concentrations of iron in ground water have been reported in Assam, West Bengal, Orissa, Chhattisgarh and Karnataka.
- Nitrate pollution has been reported in intensively irrigated and high agricultural productivity regions, and in urban areas due to improper and inadequate sewage disposal.
- Punjab and Haryana consumes N fertilizers more than 100 kg/ha and have the highest nitrate pollution in their waters.
- High nitrate concentrations (more than 45mg/ l) have been found in many districts of AP, Bihar, Delhi, Haryana, Punjab, Himachal Pradesh, Karnataka, Kerala, MP, Maharashtra, Orissa, Tamil Nadu, Rajasthan etc.
- The trend in N fertilizer consumptions in MP, AP, West Bengal, Karnataka, points to nitrate pollution becoming a major threat to their sustainable water -resource development.
- Nitrate pollution (above the WHO permissible limit) also occurs at several locations in Gujarat, Maharashtra and Orissa.
- About two lakh square km has been estimated to be affected by saline water of EC in excess of 4dS/m. In several places in Haryana and Rajasthan the EC values greater than 10dS/m make water non-potable.
- Coastal salinity, caused by excessive withdrawal of fresh ground water, has been observed in Tamil Nadu, Saurashtra, and in an 8-10 km wide belt near coast of Subarnrekha, Salandi, and Brahmani rivers.
- Several reports show that by performing Agnihotra and putting Agnihotra ash in the well, the water quality improves considerably. Non-potable water become good drinking water - in one case the pH came down from 9.5 to 7.2, and the salinity from 1150 ppm to 720 ppm (Frits and Lee, 2009; www.agnihotra.com.au).
- On one farm in Austria, officials closed one well as the water was not even good enough for the animals to drink owing to arsenic contamination. With Homa and putting Agnihotra ash to the well after only two months another inspection was done and they found out now it was good quality drinking water.
- A simple experiment shows that if you put Agnihotra ash in a container with putrid water within a few days the water becomes clear again.
- One experiment done in a Polish institute for Environmental Biology, showed that by adding Agnihotra ash to water with some decomposing plant matter the beneficial microorganisms grew much better than in the control environment.

Environment

Our way of life has intensified the quantum of pollution. In fact no place can be called safe from pollution. What varies is the type of pollutant and degree of pollution. Pollution is of various types such as i) Gaseous pollution, ii) water pollution, iii) food pollution, iv) radioactive pollution and so on.

Human activities are changing the composition as well as behaviour of the atmosphere at an unprecedental rate. The changes contribute to green house gases. Carbon dioxide is the most common and important greenhouse gas, which makes up for more than 99 percent of the air pollutants. It is estimated that doubling of atmospheric carbon dioxide will cause a temperature rise of nearly three degrees Celsious. This is expected to cause an increase in floods, infectious diseases and water borne diseases as well as disrupt the entre ecosystem.

Concentration levels of air pollutants such as Sulphur dioxide, ammonia, and suspended particulates in the air in city like Mumbai is higher that the CPCB standards. These are posing serious health concerns.

In recent years microbial pollution is the most important type of pollution for people in medical and paramedical fields. There are mainly two types of microbes i.e. pathogenic (disease causing) and saprophytic (harmless not causing and disease). Micro organisms like *Salmonelle* or *Vibrios* contamine water, etables, milk and milk products. When contaminated eatables are consumed the individual suffers from typhoid, bacillary dysentery or cholera. Similarly organisms like *Staphyloccoi* cause food poising by increasing toxins in food. This also causes wound infection with pus formation. *Streptococci* infect the respiratory tract after inhalation of the droplet nuclei on which they are settled. Regular practice ‘of Agnihotra and application of its ash on infected portion has impressive impact in control of any infection.

In recent years problem of radio activity is becoming alarming. In fact impact of Agnihotra in resolving radio activity came in the knowledge of scientific community after Chenobyl nuclear accident in 1986. Due to leakage, radio activity covered large area all around the nuclear plant and all the commodities got infected with nuclear radiation. Incidentally on of dairy farm near Graz in Austria which was being managed by Homa Organic farming techniques does not have any radio active trace in cow milk and fodder being raised (Karin, 2009). With this basic information now the same technique is being attempted to resolve radio activity.

For the first time in the history of mankind Homa Therapy is being acknowledged by modern holistic science. It is the complete revelation of the procedure for healing and cleansing the atmosphere. Its origin lies in the oldest sources of human knowledge - the Vedas.

Heal the atmosphere and the healed atmosphere will heal you. This is the basic principle of Homa Therapy- Shree Vasant, P. Paranjpe, 2005.

According to the ancient Science of VRUKSHA AYURVEDA, (VRUKSHA means TREE) which is now presented as Homa Organic Farming Technology, atmosphere is the biggest single factor which affects plant kingdom, soil and water quality. So now, let Science investigate if, in effect, Agnihotra is an efficient way to make ATMOSPHERE MORE NUTRITIOUS AND FRAGRANT and thus improve soil quality and water resources.

When cowdung is burnt along with rice and ghee by chanting mantras the disinfectant effect goes to the atmosphere and the atmosphere is disinfected, purified. The impact is radiated to a larger area by establishing Resonance Point. It is claimed that up to 60 hectares polluted area. The statement get support with following statements.

- Experiments done with Agnihotra showed that indoor microbial pollution is greatly reduced.
- Regular practise of Agnihotra controls pathogenic bacteria in an area where resonance has been established.
- The concentration of negative ions is an important indicator of atmospheric pollution: The more negative ions in the air, the less pollution.
- Normally smoke particles are charged positive. This can be easily tested if we blow cigarette smoke towards an instrument measuring the electric charge of the air. It will show that the concentration of negative ions is getting less.
- But if you perform Agnihotra and place the same device above the pyramid, the smoke of the Agnihotra fire shows a higher content of negative ions.
- Agnihotra is thus purifying the air in an area around the pyramid.

Systematic research on Agnihotra was initiated at CSK, Himachal Pradesh. Enhancement of environment gets support from the following statement (Rameshwar *et.al;* 2009)

- Spread of white clover (*Trifolium repens*) a legume & Kikyun (*Penisetum clandestinum*) - soil binder increased at Homa farm;
- Weeds problem a little bit suppressed.
- Frequency of occurrence of brahmi (*Centella asiatica*) naturally in farm.
- Birds diversity and their frequency of visit has been increased.
- Friendly insects occurrence has been enhanced.
- Robust health of plant, animals and microbes.

Polluted planet is in a denatured state, i.e. nature is thrown out of balance due to rampant pollution through human activities. This renders nature unable to perform properly and this is a very serious situation in relation to nature’s capacity to provide food. Already we are seeing food shortage on a planetary scale. Homa Organic farming needs to be implemented worldwide to bring nature back into balance so that we have quality food for all and peaceful natural surroundings to enjoy quality of life. This can be achieved by simply accepting regular practice of Agnihotra. Since environmental pollution is becoming alarming, hence it becomes imperative by every citizen of the universe to undertake this in day to day life. Lesson can be learnt from the following statement.

Help for the Environment

- The principles of life must be restated now on the planet earth.
- Everyone must be made aware that HOMA is necessary for survival of humanity on planet earth.
- We withdraw nutrients from the environment.
- They must be some how replaced, HOMA is the means.
- When Agnihotra is performed there is a turbulence of electricity's and ethers created by the combination of mantras and fire that extends all the way to the solar range. This turbulence leads to a quick upheaval of the nutrient structure in the area.
- By regular practice of Agnihotra and other Homas, one can play an unique role in mitigating soil, water and environmental crises which are becoming beyond control by the conventional approaches.
- More people should begin to perform Agnihotra under a tree. This makes the tree happy and the tree dances and sings. Also the birds are much attracted to Agnihotra. It is healing to them.
- Similarly regular performance of Agnihotra and placement of its ash in water bodies say rivers, ponds and well will have great impact in improving its quality.

Conclusion

Homa Therapy is ancient environmental practice from Vedas which is having remarkable results in today's poluted environment, where farming practices including Apiculture is struglinggling to obtain desired results. Needless to say environmental degradation world wise is the cause of poor results and disappearance of honey bees necessary for pollination and thus food supply.

Homa Therapy and Homa Organic farming employ methods that neutralize and regenerate environment through daily practice of Homa Organic farming methods, a biosphere is built in the area that is full of micro nutrients and vitality, ultimately purifying soil, water and air of pollution and bringing balance and proper functioning of the ecosystem. It is pertinent to mention here that the aforesaid experiences on soil, water and environment of merely Homa Organic Farming. Most of these experiences are from Agnihotra practinors from different parts of the world. For its acceptance by policy makers and particularly by the farming community, systematic research duly supported by data required to be generated by the concern institutions. It is also pertinent to mention that in Homa Jaivik Krishi, there are other components like Habitat management through greening of area by plantation, inclusion of legumes in system, crop rotation, water conservation, use of enriched compost, enhancement of humus content in soil, all these factors will be helpful in addition to Homa Organic farming. Thus, there is need to understand the complete package and try in few specific areas and after getting fully satisfied need for assertive promotion.

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- www.agnihotra.info
- www.fivefoldpathmission.info
- www.agnihotraindia.com
- www.shivpuri.org
- www.homa1.com
- www.homatherapyindia.com
- tapovan3@yahoo.com

13

Impact of HOMA Organic Farming in Mitigating Soil, Water and Other Environmental Crises

ULRICH BERK

Farmers are the first to suffer from climate change and from environmental pollution and deterioration. And if farmers suffer, ultimately all of us do in terms of quality and cost of produce. Homa Therapy counteracts pollution of atmosphere, soil and water resources and helps to restore balance of Nature and create a kind of microclimate around the farm which is beneficial to plants, animals and humans in that area. Homa Therapy is the science of healing the atmosphere through pyramid fires to eliminate pollution and contamination. The basis of Homa Therapy is Agnihotra, the smallest Homa healing fire tuned to the specific biorhythm of sunrise/sunset. It comes from the ancient most Vedic sciences of Bioenergy, Medicine, Agriculture and Climate Engineering.

Why is it so important to keep exact timings of Agnihotra? Vedic Knowledge states about sunrise:

"At sunrise the many fires, electricities, ethers and more subtle energies emanating from the sun extend all the way to the Earth and produce a flood effect at those coordinates where the sun is said to rise. It is awesome. The flood enlivens and purifies everything in its path, destroying what is impure in its wake. This torrent of life-sustaining energies causes all life to rejoice. At sunrise that music can be heard. The morning Agnihotra Mantra is the essence of that music. It is the quintessential sound of that flood. At sunset the flood recedes."

As this effect is there only for a short time band, Agnihotra has to be done at the exact time. A special software has been developed in Germany which gives a timetable for the whole year after entering the coordinates of the place (or even just the address). If you go to a different place even in the same town, the timings will be different, and also they change from year to year.

This flood of energies is said to carry a subtle music, the Agnihotra mantras being the quint essential sound of that music. That leads to a kind of resonance effect - and therefore the mantras have to be uttered in correct way; and of course using a different language from Sanskrit would not have the effect. But anyway, Sanskrit is the mother or may be grand mother of all our languages. Therefore, uttering Sanskrit mantras means just going back to the roots of our own civilization.

Effects of Homa Therapy on Water

We have a lot of observations on the effect of Homa Therapy on the environment - water, soil and atmosphere. Regarding water, purification can be seen when Agnihotra Ash is added and/or when Agnihotra is performed next to the water sample: Pathogenic bacteria are reduced; pH comes back to normal; beneficial microorganisms thrive.

Purification of Water from Pathogenic Bacteria

Dr. John Matlander, a physician from Ecuador, sent the following report: An experience was with a gallon of infected water that I had for several weeks. Before using it, I requested a doctor to analyze it with a potent microscope. He told me that water was a cultivation containing fungi, staphylococcus and streptococci. Before throwing it away, I put some of this water in a 200 ml glass and added two teaspoons of Agnihotra Ash. I mixed it well and left it for 3 days.

Then I returned it to the doctor and asked for another checkup with the microscope and he said: "Completely pure water." So I told him that this was the same water he had analyzed 3 days ago and the doctor thought that this was impossible, completely impossible. But it happened this way, the Agnihotra Ash had made this water completely pure.

Purification of Industrial Effluent

In year 2000 a study was made in Mumbai on the effect of Agnihotra Ash on water and biotic life when industrial effluent from textile process industry was present in the water. Different concentrations of effluents were prepared. Ash dose was given and fish were kept under observation for 48 hours. Biotic life was absent in 15% effluent. But if 0.5 g/litre Agnihotra Ash was added to the concentration of 15% effluent, biotic life was possible again. For a concentration of 20% effluent 2 g/litre Agnihotra Ash had to be added in order to make biotic life possible. The Chemical Oxygen Demand (COD) of the effluent before and after Agnihotra Ash treatment was compared.

The study revealed concentration of COD after Agnihotra Ash treatment is reduced which indicates Agnihotra Ash helps to purify the water.

	Effluent Concentration	Treatment	COD mg/litre
1.	15% effluent in 1 litre of water	filter	573.0
2.	15% effluent in 1 litre of water	+0.5 gram ash filter	270.9

Agnihotra Ash and Salinity- India

In year 2002 we were involved in outreach programs with farmers in the Khargone district, Madhya Pradesh, India. One particular farmer told us his well from which he irrigated his crops had water with salinity problems. We told him of our experience and suggested that he regularly perform Agnihotra by the well and to put Agnihotra Ash into the well regularly as well. A few months later we received a surprise visit from this particular farmer who happily informed us that he had done what we had recommended and had water samples laboratory tested once a month. With each successive test the water became less and less saline.

Wells Remain Active-India

Also in year 2002 Homa Therapy volunteers were working with a farm near Indore owned by Prestige Feed Mills. The workers on the farm were instructed to perform twice daily Agnihotra and some Om Tryambakam Homa as well as ash application in their irrigation well and in the soil. After approximately 3 months of ongoing Homa Therapy at this farm we visited again. The area was in severe drought but to our surprise locals were lining up at the well. We asked what was happening and were informed that this was the only well in the area that had not dried up and indeed was supplying water for others without water.

Salinity and alkalinity of borewell water neutralized -Australia

We had a bore well drilled, despite indications that there were no underground streams on our farm. Sub-artesian water was found at forty meters (130 Feet). It was laboratory tested and found to be highly saline and alkaline.

The pH was 9.5 and the salinity measured 1150 ppm. So, we performed Agnihotra near the bore well and regularly placed Agnihotra Ash into the bore well. The State Department of Water Resources was conducting regular tests on the bore wells in our area and we were all amazed to see that the salinity and alkalinity reduced with each lab report until finally after about 6 months we had potable drinking water.

Now the pH is constant at 7.2 which is neutral and the salinity is 720 ppm, within the standards laid down by the World Health Organization for potable water.

	pH	Salinity
First analysis	9.5	1150 ppm
After 6 months	7.2	720 ppm

Neutralization of genotoxic effect by Agnihotra Ash

Colchicine was added to water

Left side: Without Ash Right side: With Agnihotra Ash

Effect of Agnihotra Atmosphere on Water Purification

Several reports show that Agnihotra Ash helps to purify water (Gerlecka 1988, Matlander, 2013). When you add Agnihotra Ash, you have a combination of chemical and of physical effects which lead to the effect of purification. Would Agnihotra itself have a similar effect also - no Agnihotra Ash added, and no contact to the fumes of Agnihotra? Is there some kind of 'energy field' around Agnihotra which has some effect on water? Would this 'energy field' be of electromagnetic type?

The following experiment was designed to examine the effects of Agnihotra on water only in terms of physics and exclude any effects of possible chemical reactions of Agnihotra Ash or Agnihotra smoke with water. Therefore, we decided to keep polluted water from the Narmada River in glass bottles in an Agnihotra room (where Agnihotra has been performed since several years regularly at sunrise and sunset and where apart from the mantras related to Agnihotra no word is spoken). A preliminary experiment showed that after a period of five days the count of coliform bacteria was reduced by more than 50% compared to control (same water kept in the laboratory during these five days). No Agnihotra Ash was added to the water, and the bottles containing the water were tightly closed so that no Agnihotra smoke could enter, thus ruling out a chemical explanation by some effect of particles produced by the Agnihotra procedure. What else could lead to such an effect?

The most obvious guess would be that regular performance of Agnihotra creates some kind of energy field which helps to purify water. But this guess does not help much unless we know which kind of energy field we are talking about. In our everyday life the most common energy fields are electromagnetic fields. Could it be that electromagnetic fields lead to the purificational effect of Agnihotra on water? In order to find this out we designed the following experiment. We know that Faraday cages shield electromagnetic waves. Therefore, if the effects of Agnihotra on water are (partly) based on some electromagnetic waves, then there would be no (less) change in the parameters of water quality if this water is kept in such Faraday cages. Water was taken from the Narmada River and filled in bottles. Three each of the bottles filled with water were put in containers made of stainless steel, copper, and aluminum, respectively. Then the metal containers were closed with a tightly fitting lid in order to get Faraday cages. In addition to these nine water bottles enclosed in metal containers for comparison we also used eight bottles without metal containers (filled with the same water from Narmada river). All these bottles were placed in the Agnihotra Shala at Maheshwar Homa Therapy Goshala where Agnihotra is being performed regularly exactly at sunrise and sunset.

For control three water bottles were kept in a lab.

After five days all water samples were examined for DO (dissolved oxygen), pH, COD (chemical oxygen demand), hardness, and count of coliform bacteria.

Percentage changes as compared to control:

	DO Average	pH Average	C.O.D. Average	Hardness Average	Coliform/100ml Average
Average all	195%	-21%	-63%	-52%	-69%
Average (Stainless Steel)	233%	-21%	-62%	-50%	-68%
Average (Copper)	173%	-23%	-66%	-53%	-69%
Average (Aluminum)	158%	-17%	-66%	-51%	-70%
Average (All Metals)	188%	-20%	-65%	-51%	-69%
Average (All glasses)	203%	-22%	-60%	-52%	-69%

There was a general improvement of water quality in all the parameters measured as compared to control. These changes are consistent through all three replications. Although there was some difference between the water samples kept in metal containers and the samples kept in bottles regarding DO, pH, and COD, this difference was rather small compared to the difference with control. Also there were some differences between the different kinds of metal containers - but again these differences were small compared to the difference with control. Further experiments could look deeper into these differences.

But the main results with all three replications and all parameters of water quality are that

a) Agnihotra atmosphere helps to purify water

b) This effect of purification is there whether or not the water samples are kept in Faraday cages.

The conclusion seems natural that there is some kind of energy field around Agnihotra which is not of the known electromagnetic type and which is not shielded by Faraday cages. If you have some alternative explanation we would be interested to hear about that.

River Purification with Homa Therapy

Preliminary report from Dr. Shailendra Sharma about water quality of the Narmada River in Madhya Pradesh. Various parameters were studied to determine the quality of the water. Water samples were taken at monthly intervals from four sites along the river - Omkareshwar, Mandaleshwar, Barwani and Homa Therapy Goshala, near Maheshwar.

This experiment demonstrates the effect of Homa Therapy, based on the ancient science of Vedas, which offers solutions to reduce the pollution in our environment and of the water resources.

Parameters	WHOMax. allowed	Omkareshwar	Mandleshwar	Maheshwar (Homa Therapy)	Barwani
pH	6.5-9.2	8.0	8.2	7.5	8.0
Total Solids	1500	1090	1256	650	1225
Total Hardness	500	555	620	475	650
Chlorides	600	550	520	250	652
Nitrate	45	15.5	20.5	12	22.5
Sulphate	1000	450	375	250	350
Coliform count	100ML	500 ML	600 ML	100 ML	700 ML

Water Crystals

Chemically speaking pure water is H_2O. But in many countries people talk about water from certain springs which is said to have healing properties. Still, a chemical analysis will just show H_2O. Is it superstition to assume differences in such spring water and water coming from the tap?

Recently Dr. Emoto from Japan developed a method which does show a difference. Water drops were put on small glass plates and then inserted in a freezer compartment with very low temperatures. Immediately ice crystals formed - if the water was from wells etc. Otherwise, no crystallization took place. See the following photos which show different qualities of water.

Physics still has to interprete these results - cluster formation may help to understand the different patterns - but at least this seems to be one first step to detect differences in what till now was just seen as H_2O.

Tokyo (Japan): This picture of tap water in Tokyo does not show any crystallization. This indicates dead water the fate of city water.

A source of water at Saijo, Distt: Hirosh: This Mountain region is well known for its pure water quality. Beautiful crystal formation.

Agnihotra Ash Water Crystal

Effects of Homa Therapy on Soil

- Aeration increased.
- Moisture holding capacity increased.
- Both acidity and alkalinity controlled.
- Salinity removed.
- Beneficial microbes prosper.
- Earthworms multiply at a higher rate.

Water Retention in Soil (India)

Out of curiosity we asked someone to dig a hole in the cultivating area on the farm to see how deep he would have to go before finding moisture. It was approximately 0.5 meter. He then went to a couple of neighboring farms and obtained permission to dig a hole in their cultivating areas and to our surprise we had to dig approximately one meter before finding moisture in the soil. This observation suggests that regular performance of Homa Therapy increases the soil ability to retain moisture. A controlled experiment would be interesting.

Acidic Soil (Poland)

The soil of one Homa farm in Poland (Jordanow, South of Cracow) was officially tested by the agricultural laboratory. The soil in the vegetable garden was the worst, with a pH of 4.4. The officials told that nothing will grow there. Agnihotra and Agnihotra Ash have improved the quality of the soil and there is a good yield of vegetables and the taste, texture, weight and quality are superior. A recent test showed a soil pH of 7.2.

Improvement of Sodic Soil (India)

In year 2006 a trial was taken at Virendra Kumar Singh Krishi Vignan Kendra, Virendra Nagar, Dhaura, Distt. Unnao, U.P.

Wheat was planted in 3 plots:

1. with agro-chemicals
2. with vermicompost
3. with vermicompost + Agnihotra Ash

Soil pH was tested after harvesting the wheat crop.

Soil Treatment	pH
with agro-chemicals	9.86
with Vermicompost	9.06
with Vermicompost + Agnihotra Ash	7.67

The field which was treated with Vermicompost + Agnihotra Ash showed significantly lower pH. Potash and phosphorus were also found in more abundant quantities in this plot. For a replication of this experiment it would be good to have one more plot with Control Ash in order to see whether the effect comes about just by ash or actually by the special properties of Agnihotra Ash.

Solubility of Phosphate

All growing plants need phosphorus. However, regardless of how much phosphate is added to the soil, only the water soluble portion can be utilized by the plant. Dr. Tung Ming Lai, Denver, Colorado, USA did an experiment and showed that Agnihotra Ash helps to increase the water solubility of phosphorus in soil.

Solubility of Phosphate

Soil used	Phosphate & per gram of soil		Phosphate & per gram of ash	
	Non-Homa	Homa	Non-Homa	Homa
No Soil - Only Ash			3,40%	8,90%
Weld Loam	0,42%	1,72%	21,00%	86,00%
Red Feather Loamy Sand	0,23%	1,15%	11,50%	57,50%

Effects of Homa Therapy on the Atmosphere

- Pathogenic bacteria are reduced.
- Concentration of negative ions increases.

This indicates that atmospheric pollution decreases. (Agnihotra smoke has a different effect from any other normal smoke).

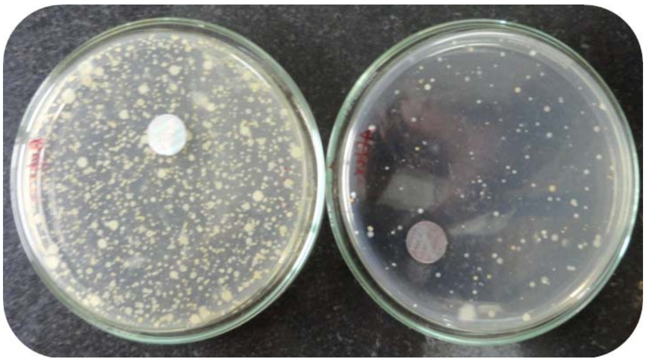
Pathogenic Micro-organisms

Dr. Arvind G. Mondkar M.Sc., Ph.D., Practising Microbiologist, Mumbai. Studies showed that Agnihotra fumes are rich in substances which have inhibitory effects on micro-organisms like staphylococci, salmonellae, etc.

Dr. B.R. Gupta, Associate Professor of Microbiology, CSA University of Agriculture, Kanpur, Studies showed that bacterial colony count in Agnihotra atmosphere was 80% less than that in non-Agnihotra atmosphere.

Wg. Cdr. D.V.K. Rao, Classified Specialist, Pathology, Defence Institute of Physiology and Allied Sciences, Delhi studies showed that Agnihotra Ash has a bacteriosatic effect and controls the growth rate of various types of pathogenic bacteria.

Recently the following experiment was done at Fergusson College, Pune. Medium plates were open in room before and after Agnihotra, and incubated for 24 hours to grow bacterial colony.



Before Agnihotra After Agnihotra

As per results obtained, Agnihotra fumes decreases microbial load in air.

Further Experiments were done to see the effects of Agnihotra Ash on bacteria. Following results could be shown:

- Loss of capsule formation with *Klebsiella pneumoniae;*
- Loss of haemolytic activity with *staphylococcus aureus* and *klebsiella pneumonia;*
- Decreased resistance to phagocytosis with *klebsiella pneumonia*, *staphylococcus aureus*, and *pseudomonas aeruginosa*.

These results show that the pathogenic bacteria examined show a reduced virulence when in contact with Agnihotra Ash.

Negative Ions in Air

Negative ions are known to be an indicator for fresh air. Lack of negative ions indicates polluted air. Normally, smoke reduces the amount of negative ions. But an experiment done in Germany showed that the amount of negative ions increased, opposite to what was expected. That would be a good experiment to replicate.

Nutrition through Atmosphere

Modern science speaks only of soil analysis and water analysis but not about the atmosphere. Ancient science of Homa Therapy states that more than 75% of nutrition to plants and soil comes through the atmosphere. So if you make the atmosphere more nutritious and fragrant by Homa, a type of protective coating comes on plants and diseases, fungi, pests, etc. do not thrive. Plants' capacity to breathe increases and the toxic effect of choking to death due to atmospheric toxins is eliminated.

Effects of Agnihotra and Agnihotra Ashon Germination and on Plant Growth

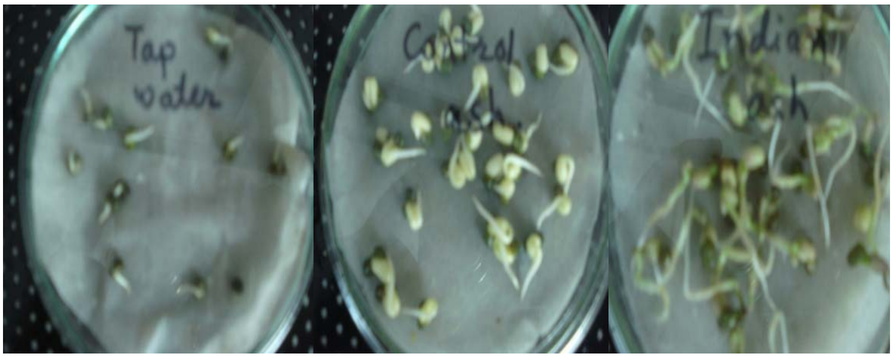
The following two experiments were done in Fergusson College, Pune. First was to study the effect of Agnihotra Ash on the germination of seeds. For watering, three types of water was used:

a. tap water,

b. Control Ash water and

c. Agnihotra Ash water

Seeds of *Vigna aconitifolia* and *Vigna unguiculata* were taken as experimental material. Seeds were allowed to germinate and germination was observed after 24 hrs.



Tap water control ash Agnihotra Ash

From results obtained it can be concluded that Agnihotra Ash promoted the process of germination probably by increasing its nutrient content and hence can be used as fertilizer.

The second experiment was about plant growth in Agnihotra Atmosphere. Two plants were maintained providing same amount of water, light and other environmental conditions. One is kept in separate room where Agnihotra is performed and another is kept in normal room where Agnihotra is not performed.

Control **Test**

In Agnihotra Atmosphere plant growth increased. More information on the effect of Agnihotra on plants and in agriculture/horticulture is collected in Berk/ Johnson 2009**.**

Recent reports are posted on www.homafarming.com.

Effects of Homa on Human Health

In the night of December 2, 1984 Methyl Isocynate (MIC) gas leaked from Union Carbide Factory in Bhopal causing great havoc. This is still one of the biggest industrial catastrophies worldwide. Thousands of people died and many thousands more were seriously injured. However, all those performing daily Agnihotra in Bhopal were safe. Agnihotra proved a very protective armour for all of them. Volunteer Agnihotris actively served in the MIC gas affected colonies after the accident. They formed 8 to 10 groups of Agnihotris at different places where about 40-50 affected people used to gather for morning and evening Agnihotra. Also small packets of Agnihotra Ash were distributed. Eye-drops used to be put in the eyes of the affected people. The result of the treatment with Agnihotra eye-drops was wonderful as it gave immense relief to the patients. Conventional medicines did not give much relief to the patients. Agnihotra Ash and Agnihotra atmosphere helped and provided inner peace to those who suffered from loss of dear ones. This is the experience of about 400-500 people of both Hindu and Muslim communities. Those 15-20 Agnihotra volunteers who performed daily morning-evening Agnihotra in the group of assembled suffering people did so regularly for about 2 months. Thereafter they inspired these people to perform Agnihotra themselves.

Reports on healings with Agnihotra and Agnihotra Ash are posted on www.homahealth.com.

Effect of Agnihotra on the Atmosphere

The indoor pollution quite often is even worse, as tests in Germany have shown. Poisonous gases from furniture are one main factor, also from any other things we bring into our houses like clothes, toys, and of course from the chemicals we use in the household. Chemical analysis can identify what are these pollutants and whether and to which extent they are reduced in Agnihotra atmosphere.

Homa-Effect on Atmosphere

Folling a quote from Tompkins/Bird 1989:

Mr. Modric, an expert in electromagnetic fields, believed Agnihotra could potentially affect the whole environment, countering the toxins of modern technology developed over the last century by the industrial revolution & that the process might have enormous implications for our very existence. He added that Agnihotra performed at various specifically spaced points on earth, if done exactly at sunrise & sunset, could affect an energy associated with the earth, one such as described by Steiner and Reich, the enhancement of which would have a healing effect on the environment. He said, "We believe we can establish the fact of an electromagnetic radiation during the ceremony, but we are in an area of informational transfer through intermolecular & inter-atomic processes mediated by ultraviolet photons. It's logical to conclude that some kind of energetic mechanism is being activated which can be translated into physical meaning linked to concrete information systems that are as yet unknown but connected to systems of resonance".

Effects of Homa Therapy on Radioactive Pollution

Neutralizing harmful radiation

When Agnihotra is performed, the Agnihotra smoke gathers particles of harmful radiation in the atmosphere and, on a very subtle level, neutralizes their radioactive effect. Nothing is destroyed, merely changed (Paranjpe, 1989). Radioactivity is an increasing problem all over the world.

A few weeks after the Fukushima accident higher levels of radioactivity were found in Western USA. Levels of cancer rose and thyroid problems increased all over the world because of radioactive iodine.

Agnihotra Ash and Radioactivity - an Experiment

Agnihotra Ash is said to neutralize radioactivity in food. In order to test this hypothesis an experiment was carried out at the Institute of Physics, Academy of Sciences, Kiev/Ukraine (former Soviet Union). Scientists of this institute had developed a instrument to measure radioactivity in food samples with great accuracy within a few minutes. People from Japan came after the Fukushima accident to test the equipment and they bought several units. For testing the Japanese scientists had brought radioactive rice, 200 Bq per kg. This rice was put in water to which a spoonful of Agnihotra Ash was added. Each day radioactivity level was measured. After two days radioactivity came down and after ten days the radioactivity of the rice was totally neutralized.

Energy Field of Agnihotra

The experiment mentioned above about water purification in Agnihotra Atmosphere showed that a Faraday Cage does not prevent Agnihotra from affecting water positively. This leads to the conclusion that there must be some energy field created by Agnihotra which is beyond the electromagnetic range. Traditional Vedic Knowledge talks about Prana energy, and in many ancient cultures a similar kind of subtle energy is mentioned by different names like Ki or Chi, Orgone, etc.

Modern science has not yet been able to measure such subtle energies but hopefully will be able to do so in near future. Kirlian photography and the recent improvement by the Russian physicist Prof. Korotkov called GDV (Gas Discharge Visualization) show something which could be interpreted as an aura energy field around living matter (like leaves, hands, or the whole body of a person). Also the technique developed by Dr. Emoto mentioned above shows some subtle energy differences. Interesting enough Dr. Emoto could show that our thoughts have a great impact on water samples: When people hold a water bottle in their hands and send love to the water, nice crystals then can be seen. But if they instead concentrate on negative emotions like hatred, very disharmonious patterns appear.

This result suggests that our thoughts do have an impact on matter, although subtle. Similar experiments have been done with plants (Backster, 2003).

Ancient Vedic Knowledge states that the worst form of pollution is thought pollution, and that Agnihotra also helps to remove this root cause of most other forms of pollution. Is it possible that Agnihotra creates a positive energy field on the level of thought energy? This would be an interesting hypothesis to be examined by a further development of modern physics.

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14

Use of Metaphysical Energy in Crop Production: A Concept

B.K. Chandrashekhar

There are three powers in the universe: God, Soul, and Nature. Souls receive the Spiritual Energy from God and maintain their physical and mental health. After controlling their physical and mental health, they become able to control their inner and outer nature. We all know that human nature consists of five virtue: Power, Purity, Happiness, Love and Peace. These five virtue are connected with the five elements Earth, Water, Fire, Air and Space of the Universe respectively. Psycho Neurobics is an art of cleaning and balancing our inner nature and Rajyoga Meditation is an art of creating a harmony with outer nature. So, Psycho Neurobics and Rajyoga Meditation are now recognized as a valuable component in the treatment of many illnesses and as a means of achieving holistic health. If we will be able to enjoy our holistic health, then it will be easy for us to be in tune with outer nature. Now it is the time of using this amazing technique in crop production. The Rajyoga Meditation and Psycho Neurobics involve creating the awareness of being the subtle conscious being rather than the physical body and then directing thought energy (Peace, Love and Bliss) from the Divine Source to the crops at any stage of growth or to the seeds before planting. With the help of both these techniques, we can purify the five elements of the universe and also empower them. If the five elements of our universe will pure and powerful then everything in this universe will pure and powerful. In this wonderful situation, each and every plant of the earth will get abundant energy which is the root of all development.

The great scientific minds of this world are accepting slowly that a great mistake has been done. The main reason behind this situation is their very desire to be powerful against nature. In the 20th century with the bursting of atom into pieces through particle physics, faith in the Vedic science has also grown stronger. We accept that atom is no longer inert and has unsuspected vitality. Vedas had already mentioned about it 4 to 5 thousands years ago. We forgot this great phenomena with the passage of time. The ecology of the earth has been destroyed by our misdeeds. In Vedic era, the rhythm of life was natural both internally and externally. They were completely healthy and happy because of the deep harmony with nature. The existing society is rediscovering religious fervour, values, scriptures and culture as a panacea of all ills.

Most of the Vedic hymns end with the prayer "*OM shanti shanti shanti.*" It is a prayer to the universal Lord - the formless supreme Reality, to help mankind in creating peace, peace, peace all rounds. Three times, reference to the word *shanti* relates to peace on the earth, over the earth in the firmament and below the earth in the deep oceans and waters. It is only possible when there is no pollution and environmental hazards on the earth, atmosphere and in all rivers, lakes, sea and oceans.

If we think minutely on the above para, we will certainly find that hymns and sounds were very important in Vedic era. Chanting of hymns was the key of creating an environment of harmony all around. Many instances of our Vedic scriptures remind us that people in Vedic era were able to call God on the earth through their harmonious hymns and sounds.

Now we will discuss about the reason behind this great power. Sound is a form of energy. What is moving to make sound energy? Molecules. Molecules are vibrating back and forth at fairly high rates of speed, creating waves. Energy moves from place to place by waves. The molecules vibrate back and forth, crashing into the molecules next to them, causing them to vibrate, and so on and so forth. All sounds come from vibrations. So, Sound is nothing more than vibrating molecules.

Through the 19902 s, Dr. Masaru Emoto performed a series of experiments observing the physical effect of words, prayers, music and environment on the crystalline structure of water. Emoto hired photographers to take pictures of water after being exposed to the different variables and subsequently frozen so that they would form crystalline structures. The results were nothing short of remarkable.

For Example:

Water before Prayer **Water after Prayer**

Fig. 1: Experiment of Thought Energy on Water

Let us imagine a situation of our day to day life. When we are happy we create a vibration of happiness both internally and externally. These happy vibrations are able to provide us optimum health. Think for a while when every particle of this universe will able to produce happy vibrations our whole environment will be healthy automatically. We have discovered Resonance Field Imaging (RFI) which is based on MRI technology. Through this instrument, we can measure the energy vibrations of particles.

What is Energy Field or "Aura"?

RFI, and the presumption of the existence of the Aura, is based upon the principle that all mental activity is electromagnetic. While some medical theorists argue that mental activity is chemical, because of the chemical neurotransmitters involved, the fact is that neurotransmitters are created only when electrical impulses induce a voltage in a neuron that exceeds its firing threshold. In addition, EEG (electroencephalogram) technology shows that mental activity can be effectively analyzed and monitored entirely by electromagnetic principles.

In electrical engineering, it is an established principle that all electrical currents produce surrounding electromagnetic fields. Accordingly, our psychological and emotional activities are sent throughout the body as electrical impulses, radiating electromagnetic fields outside the body, which are characteristic of the mental activity that generated them.

What is RFI?

RFI is an experimental electromagnetic feedback and imaging process. This new technology gives detailed scientific information and objective interpretations for all Auras and bioenergy fields, and identifies the type and function of all bioenergies present in specific regions of the human brain.

In particular, RFI generates complete psychological profiles that fully reveal the role of a patient's psychology in their health condition. While it is not intended for medical diagnosis of specific illnesses, RFI does give comprehensive information about a patient's health conditions, and provides a detailed and technical level of information that trained medical doctors can use as a factor in their professional decisions.

Perhaps most interestingly, RFI is the first Aura imaging technology that can create full colour bioenergy charts of objects, plants, animals, and even ambient bioenergy or brainwaves in the air, so its use is unlimited.

Aura imaging using RFI gives one a tangible objective starting point to psychological analysis. When we are able to measure the bioenergy charts of living and non living objects. Now we should think about the techniques of creating a harmonious vibrations in order to create a healthy and happy atmosphere. Psycho Neurobics combining Rajyoga Meditation provide a complete solution. By increasing our mind power with these two, we can do wonders in this world.

Do Plants Have Feelings and Emotions?

Sir Jagadish Chandra Bose is one of the most prominent Indian scientists (from Bengal) who proved by experimentation that both animals and plants share much in common. He demonstrated that plants are also sensitive to heat, cold, light, noise and various other external stimuli. Bose invented a very sophisticated instrument called Crescograph which could record and observe the minute responses because of external stimulants. He did many experiments on plants and recorded responses with this instrument.

Nearly a hundred years ago, based on his analysis of the nature of variation of the cell membrane potential of plants under different circumstances, J. C. Bose believed that plants can "feel pain, understand affection etc." and suggested that a plant treated with care and affection receive a different signal than a plant subjected to torture and give response accordingly.

He found that every plant and every part of a plant appears to have a sensitive nervous system and responds to shock by a spasm just as an animal muscle does. In addition Bose found that plants grow more quickly amidst pleasant music and more slowly amidst loud noise or harsh sounds.

Suppose someone feel like pulling out a leaf of a flower plant to feel it. We think that the plant does not suffer like us. But the plant does suffer. In fact the pulsation of the plant stops where the leaf was plucked. In a short time the pulsation again begins at the spot, but this time very slowly and then it completely stops. That spot is as good as dead for the plant.

Most of us have seen a peculiar kind of plant called the Mimosa (touch-me-not', in Hindi *Chhuyi-muyi*). This plant has very small leaves. It is extremely sensitive. If we just touch it, the leaves nearby all fold up. The whole row of leaves of the branch can be made to fold like this by touching it with a little greater force. We wonder to see such response of Mimosa plant! Bose wondered, too. And he went on to find out. He found that other plants also react to a man's touch in the same way. The only difference is that we cannot see the reaction of other plants but we can see the reaction of the mimosa.

Bose showed his experiment in Cambridge and Oxford. The scientists were fascinated by the extreme sensitivity of plants; they were also filled with wonder when they saw the excellent instruments Jagadish Chandra Bose himself had made. No one had done work of this kind in biology. It was news that plants could also experience different sensations like us.

Bose chose a plant that was cautiously dipped up to its stem in a vessel holding the bromide solution. The salts of hydrobromic acid are considered a poison. He plugged in his instrument with the plant and viewed the lighted spot on a screen showing the movements of the plant, as its pulse beat, and the spot began to and fro movement similar to a pendulum. Within minutes, the spot vibrated in a violent manner and finally came to an abrupt stop. The whole thing was almost like a poisoned rat fighting against death. The plant had died due to the exposure to the poisonous bromide solution.

That plants are living matters is established and accepted fact for Bose. He also proved that plants had finer senses like responding to melodious music and harsh noise. He showed that with the former the plants grow faster while with the latter their growth is stunted. Using the Crescograph, he further researched the response of the plants to fertilizers, light rays and wireless waves. The instrument received wide spread acclaim, particularly from the Path Congress of Science in 1900. Many physiologists also supported his findings later on, using more advanced instruments.

After seeing these amazing facts, we can reach on a conclusion that plants do have feelings and emotions. As we know that we have positive feelings and emotions using our mind power in a positive way.

All the forms of natural physical energy, or forces, known as light, heat, electricity, magnetism, etc., are held by science to be forms of energy arising from the *vibration of the particles of matter*. Now what causes the vibration? Motion of the particles, of course! And what causes the particles to move? Just this, the attraction and repulsion existing between them! And what causes the particles to exhibit this attraction and repulsion toward each other? Now here is where we get to the heart of the matter; listen well! We have seen that the particles are attracted to, or repelled by, each other-in the matter of "likes and dislikes"; "love and hates"; or "pleasure or revulsion"; or "comfortable and uncomfortable experiences related, however distant, to sensation," etc. And these attractions and repulsions are held to result from "capacity to experience sensations" and the power to "respond to sensations." And both the power to receive and experience "sensations," and to respond thereto, *are manifestations of mentality*, which Haeckel has compared to "desire" and "will." And if mentality is the cause of the sensations and of the response there; and the latter are the causes of the attractions and repulsions; and the latter are the causes of the motion, to and fro, of the particles of matter; and the latter, in turn is the cause of the vibrations; and the vibrations are the causes of the manifestations of light, heat, electricity, magnetism, etc.,-then is it not justified in claiming *that mind and Mind Power are the motive force of all physical energy*?

Research on Plant Consciousness

Plant consciousness is the process of bio-communication in plant cells, which has come to mean that plants are sentient life forms that feel, know, and **arse** conscious. The scientific field of neurobiology has been effective in demonstrating plant consciousness. Consciousness exists in everything, but manifests itself in different ways. With the reality that all matter is energy vibrating at different frequencies, it is reasonable to say that all matter has consciousness in its unique way, since all matter comes from the same source and is comprised at its basics level of the same building blocks. This can be seen in DNA consciousness as well. This would be a universal principle that would be true for any state of energy, be it a solid, liquid, gas, plasma and then as crystalline, plant, animal, human, and higher dimension life forms. Plants communicate just through feelings. They are purely feeling beings, they do not even know what "thinking" is (**except to the extent that they can get a taste of what "thinking" means when they connect with a human)**. You have to get in touch with your own feelings in the moment in order to communicate with a plant. You have to be there in the moment and be aware of what you are feeling right then when you are in contact with the plant. Not the feelings about what is going on yesterday and tomorrow, but the feelings of now, in the present moment. It is one of the things that plants can teach you. Not just **entheogens,** but any plant who shares your life with you. Each species has a distinct personality that you can get to know just by being open to "feeling" it.

Scientific Evidences of Plant Consciousness

Although it is not commonly discussed for various socio-political reasons, there is an ample amount of scientific evidence that has proven that plants do indeed have some sort of consciousness. An enormous amount of research was provided in the revolutionary book on this subject entitled ***The Secret Life of Plants*** **by Peter Tompkins and Christopher Bird.**

Plant Nervous System

Each root apex harbors a unit of nervous system of plants. The number of root **apices** in the plant body is high and all brain-units are interconnected via vascular strands (plant nerves) with their polarly-transported auxin (plant neurotransmitter), to form a serial (parallel) nervous system of plants. The computational and informational capacity of this nervous system based on interconnected parallel units is predicted to be higher than that of the diffuse nervous system of lower animals, or the central nervous system of higher animals/ humans.

Plant Pain

In the research of **Jagadish Chandra Bose**, in plant stimuli, he showed with the help of his newly invented crescograph that plants responded to various stimuli as if they had nervous systems like that of animals. He therefore found a parallelism between animal and plant tissues. His experiments showed that plants grow faster in pleasant music and its growth retards in noise or harsh sound.

His major contribution in the field of biophysics was the demonstration of the electrical nature of the conduction of various stimuli (wounds, chemical agents) in plants, which were earlier thought to be of chemical in nature. He claimed that plants can "feel pain, understand affection etc.," from the analysis of the nature of variation of the cell membrane potential of plants, under different circumstances. According to him a plant treated with care and affection gives out a different vibration compared to a plant subjected to torture."

Plant Thinking and Memory

Recent research has **unveiled** that plants transmit information about light intensity and quality from leaf to leaf in a very similar way to the nervous system of human beings. In the experiment that found this, scientists showed that light shone on to one leaf caused the whole plant to respond and the response, which took the form of light-induced chemical reactions in the leaves, continued in the dark.

This showed that the plant remembered the information encoded in light. Plants seem to be able to perform a sort of biological light computation, using information contained in the light to immunize themselves against diseases. These "electro-chemical signals" are carried by cells that act as "nerves" of the plants.

Now, we can say that there is no life without mind and Mind Power-and no Mind Power, or mind, without life. And, further, we can claim that there is nothing without life in the universe-nothing lifeless there, or anywhere. The universe is alive, and has mind and Mind Power in every part and particle of itself. So, now we want to use this amazing power of mind in the field of agriculture.

Rajyoga and Psycho Neurobis Help a Lot

Combining Rajyoga with Psycho Neurobics is an ultimate way of connecting ourselves with the Supreme Soul. Regular practice of these exercises is very helpful in order to enhance our mind power. We give practical demonstration of this process. At first, we check the chakras and aura of a person. After that, we give them the charged water, charged with mind power, to drink. After drinking the water, you can see instant effect in the situation of chakras and aura. So, with the help of Rajyoga and Psycho Neurobics, our mind, body and spirit vibrate at correct frequencies. This keeps our all chakras active and in proper function.

If we check the bioenergy field of plants with the help of RFI technology.

Fig. 2: People Doing Meditation in Crop Field
(Photo Courtesy: www.yogickheti.com/photos.html)

We will be able to know the metaphysical energy circulation and growth process of plants. We can use our mind power during the whole agriculture process practically like concentrated mind power at the time of seeding. We can irrigate the crops with charged water. We can also ensure the natural growth of plants without any fertilizers by giving them vibrations through mind power. You can imagine about the quality of yields grown by these ways.

These are the benefits of mind power in agriculture field. Several scientific studies are done in this regard. We all should think about this great technique, a technique of agriculture with the help of metaphysical energy, very seriously.

15

Metaphysical Energy (BK RYM): A Zero Budget Technology for Seed Invigoration

OMVATI VERMA AND SUNITA T. PANDEY

Now-a-days the acceptance and recognition of thought power and healing techniques are increasing worldwide. There are many healing techniques which are known and are in use from the ancient time to cure the problem of body, diseases and mental disorders. The idea that thoughts can affect the matter is not new. In the lives of our ancestors, there was a inherent connection between two living systems, the living system of human thoughts, feelings and the living system of the natural world, a connection that scientific researches continues to affirm. In modern context, it has been stated that thought, words and feelings affect the molecular structure of water and thus thought also have an effect on human body and plants as both contain water in plenty. In view of above theory and facts, a laboratory study was carried out on wheat and chickpea seeds in Department of Agronomy, College of Agriculture to assess the effect of metaphysical energy on seed germination, seedling vigour and dehydrogenase enzymes during storage. Seeds of wheat variety UP-2565 and chickpea variety PG 114 were obtained from the Breeder Seed Production Centre, Pantnagar and treated with Meta physical energy through BK-Raj Yog Meditation (BK-RYM) for 2 hour and 4 hours in wheat and in chickpea. Thereafter, invigorated seeds were stored in poly-lined cloth bag at 10% moisture content (for wheat) and 8% moisture content (for chickpea) under ambient condition from June to October, 2012 up to next planting season. Results revealed that all the seedling vigour parameters decreased as the storage period advanced but in both the crops, metaphysical energy treated seeds showed higher seedling vigour and enzyme activity. Over a period of 6 months of storage, Alpha (á) amylase activity was 2.4 times higher in BK-RYM for 4 hours treated wheat seeds over control seeds. Whereas, in case of chickpea protease activity was 2.0 times higher in BK-RYM treated seeds for 2 hours duration, than that of untreated control seeds. This increase in enzyme activity resulted in enhanced seedling growth parameters and seedling vigour in wheat as well as in chickpea seeds.

Seed vigour is one of the important parameters of seed quality which can potentially influence crop yield through affecting seedling growth and its establishment, particularly when low vigour seeds sown under less favorable condition. Seed vigour is maximum at physiological maturity thereafter begin to deteriorate on the mother plant or during storage. The rate of seed deterioration is positively related to initial seed quality and storage management practices like temperature, relative humidity, type of container and seed mois-ture content (Ellis and Roberts, 1981).Membrane disruption is one of the main reasons of seed deterioration. The major causes of membrane disruption are increase in free fatty acid level and free radicals production. Free radicals have potential to damage membrane, enzymes, protein, DNA and ultimately cellular repair mechanism (Wilson and McDonald, 1986).

Seed deterioration may be improved by seed quality enhancement treatments. These-days researchers around the world try to find out eco friendly seed quality enhancement techniques based on meta-physical or bio-electromagnetic energy treatments to increase the germination and vigour of seed. It has long been known that activities of cells and tissues in human body generate electrical fields that can be detected on the skin surface. Subsequently, it has been discovered that all tissues and organs produce specific magnetic pulsations, which have come to be known as biomagnetic fields/metaphysical energy (Rubik, 2002a). However, no agreement has been reached in the scientific community on the definition of the biofield. Various approaches have been submitted by Rubik (1993, 2002b) and other authors Tiller (1993); and Zhang (1996)]. One of the mystery is that living organisms respond to extremely low-level non-ionizing electromagnetic fields, displaying a variety of effects ranging from cellular and sub-cellular scales to the level of brain, emotions and behavior. This metaphysical energy is utilized by mind through brain in the form of thoughts.

The idea that thoughts affect the matter is not new. In the lives of our ancestors, there was a inherent connection between two living systems, the living system of human thoughts, feelings and the living system of the natural world, a connection that scientific researches continues to affirm. In modern context, it has been stated that thought, words and feelings affect the molecular structure of water and thus thought also have an effect on human body and plants as both contain water in plenty. Water stores thought energy and this energy impacts whoever and whatever use it. The positive thoughts subjected to water have been found to form beautiful crystals and water exposed to negative thoughts form either no crystal or deformed ones (Emoto Masaru, 2004). Many of these modalities challenge the dominant biomedical paradigm because they cannot be explained by the usual biochemical mechanisms. One possible influence of metaphysical phenomena is that they may act directly on molecular structures, changing the conformation of molecules in functionally significant ways. Another influence is that they may transfer bio-information carried by very small energy signals interacting directly with the energy fields of life, which is more recently known as the *biofield* (Rubik, 2002a).

Thus, healing with thought power may be a zero budget technology or non-monitory input for improving crop establishment of crops. This type of healing has been practiced on farms and the intended crops grew faster with least diseases (Yiji, 1991). A very little information is available on influence of metaphysical energy on seed germination and seedling vigour during storage. Therefore, present study was carried out to find out the influence of positive thoughts on seedling growth and biochemical enzyme activities of wheat and chick pea seeds.

The present experiment was conducted to find out the effect of metaphysical energy healing on seedling growth and biochemical enzyme activities during germination of seed. Seeds of wheat variety UP-2565 and chickpea variety PG-114 were obtained from the Breeder Seed Production Centre, Pantnagar. The experiment consisted of three treatments viz. control and bio-electromagnetic energy treatment through Brahma Kumari's-Raj Yoga Meditation (BK-RYM) for 2 hour, BK-RYM for 4 hour. For giving **BK-RYM** treatment seeds were sent to International head quarter of Brahma Kumaris World Spiritual University, Mount Abu. The duration of meditation was 2 and 4 hours. The methodology for treated seeds was applied as described by Brahma Kumaris World Spiritual University (Anonymous, 2009). This method includes understanding the self as a soul (bio electromagnetic energy healing), managing the energy of mind, becoming cognizant of the relationship between thought and behavior, maintaining a thought union with the divine and experiencing transcendental states that fill the mind and character with positive strength. Thereafter invigorated seeds of wheat and chickpea were stored in poly-lined cloth bag at 10%and 8% moisture content respectively under ambient condition from April to October, 2012. The observations on germination, seedling vigour and enzyme activities were recorded bimonthly interval up to October to determine the length of time that invigorated seeds will remain viable under ambient storage conditions. Germination test was conducted in four replications as per standard procedure for germination as described in International Rules for Seed Testing (ISTA, 1993). For measuring root length, shoot length, seedling length, root dry weight, shoot dry weight, and seedling dry weight, ten normal seedlings from each replicate were taken at random from germination test (final count) and after separating root and shoots; their lengths were measured in centimeters and averaged. Seedling length was computed by adding length of roots and shoots in centimeters and averaged. After taking length, the roots and shoots of ten seedlings from each replication were separately dried in an air oven at 72±2°C for 72 hours and their dry weights (mg) were recorded and averaged. Seedling dry weight was obtained by adding dry weights of roots and shoots and averaged. Seedling vigour index-I and seedling vigour index-II was computed as per the formula suggested by Abdul Baki and Anderson (1973):

SVI-I= Germination percentage X Seedling length (cm/seedling)

SVI-II= Germination percentage X seedling dry weight (mg/seedling)

For recording electrical conductivity of seed, 5 g seeds were surface sterilized with 0.1% mercuric chloride ($HgCl_2$) solution for about 5-10 minutes. The seeds were taken out, washed with distilled water and soaked in 50 ml distilled water in a beaker for 17 hours kept in an incubator maintained at 25±1°C. After this, the seeds were removed from the water with the help of a clean forcep and the solution left in the beaker was referred to as leachate. Electrical conductivity of seed leachate was measured with the help of an electric conductivity meter and mean was expressed as µS cm^{-1} g^{-1} of seed. The electrical conductivity of distilled water was also recorded. Dehydrogenase enzyme activity was measured following the method described by Kittock and Law (1968). Alpha amylase and protease enzyme activity was measured following the method described by Majumdar and Majumdar (2003). The study was set up in Completely Randomized Block Design with four replications and the data was analyzed by using STPR-2 Programme, designed and developed by Department of Mathematics and Statistics of College of Basic Science and Humanities, Pantnagar. Standard error of means (S.Em.±) was computed and critical differences (CD) at 5% level of probability were worked out for comparing treatments in case of significant 'F' test (Gomez and Gomez, 1984).

Effect of Metaphysical Energy on Seedling Growth

As the storage period advances, the seedling vigour parameters in all the treatments in both wheat and chickpea seeds decreased over a period of 6 months of storage with control seeds showing greater reduction in seedling growth than invigorated seeds. The difference in germination per cent was non-significant in wheat.

The seedling vigour is important for establishment of a good stand under field conditions. Seeds having higher vigour are known to germinate faster and establish themselves quicker in the field. In the present experiment, metaphysical seed quality enhancement treatments significantly influenced, seedling length, seedling dry weight, seedling vigour index-I and seedling vigour index-II in the month of June and August whereas in the month of October except seedling length the effect of metaphysical energy on above measured parameters was found non-significant. The highest seeding length, seedling dry weight, seedling vigour index-I and seedling vigour index-II was recorded with 2 hours BK RYM metaphysical energy treatment which was as par with 4 hours BK RYM treatment (Table 1). The higher seedling length and seedling dry weight consequently resulted in increased seedling vigour index-I and seedling vigour index-II with metaphysical energy treated seeds over untreated seeds. The lowest values of seedling length, seedling dry weight and SVI were observed in untreated seeds. At the end of storage period, seedling length, seedling dry weight, SVI-I and SVI-II with metaphysical energy treated seeds were respectively 14.7%, 12.2%, 16.9% and 12.6% higher over untreated seeds.

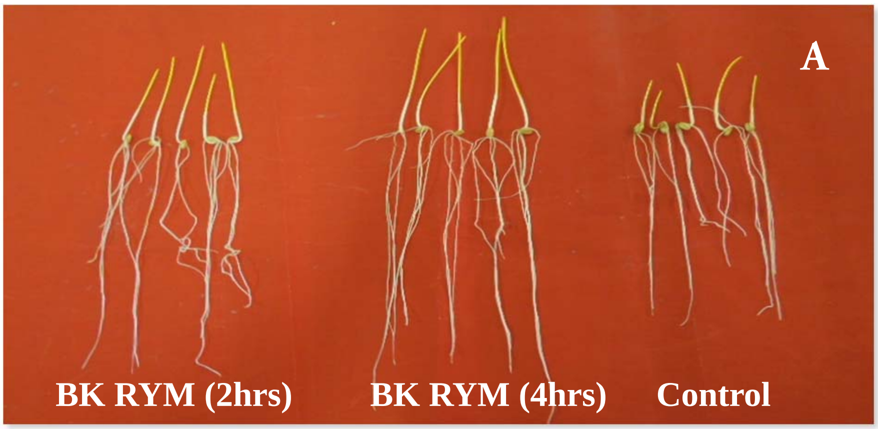
The loss of plasma membrane integrity is characteristic of aged seeds. The results of present study revealed that biochemical vigour parameters were significantly higher in metaphysical energy treated seeds. At the end of storage, BK RYM energy treated seeds than that of untreated seeds (Fig. 1A). This loss was particularly pronounced in untreated seeds, probably because of higher leachate of organic acid and electrolytes induced by aging. The lowest value of EC was recorded in BK-RYM treated seeds for 4 hours 31.0 µS/cm /g of seed)

Table 1. Effect of seed invigoration treatments on germination (%), speed of germination (SG), shoot length and root length of wheat seed during storage

Treatments	Germination (%)			Seedling length (cm)			SVI-I			Seedling dry weight (mg/seedling)			SVI-II		
	Storage period (months)			Storage period (months)			Storage period (months)			Storage period (months)			Storage period (months)		
	2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
Control	97.8	99.0	98.0	24.3	14.7	14.7	2384	1455	1436	15.6	12.9	13.1	1523	1277	1284
BK-RYM (2 hr)	98.0	98.5	98.5	27.6	16.5	16.3	2699	1629	1602	17.4	14.8	14.7	1701	1456	1446
BK-RYM (4 hr)	98.0	98.5	98.5	27.6	16.9	16.9	2722	1676	1678	18.1	14.4	14.3	1788	1435	1425
S.Em.±	98.8	99.5	99.5	0.24	0.40	0.52	25	39	108	0.40	0.39	0.42	43	40	42
CD (5%)	NS	NS	NS	0.7	1.2	1.5	73	111	NS	1.2	1.1	NS	123	115	NS

Table 2. Effect of seed invigoration treatments on germination (%), speed of germination (SG), shoot length and root length of chickpea seed during storage

Treatments	Germination (%)			Seedling length (cm)			SVI-I			Seedling dry weight (mg/seedling)			SVI-II		
	Storage period (months)			Storage period (months)			Storage period (months)			Storage period (months)			Storage period (months)		
	2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
Control	92.3	94.0	68.0	8.82	9.36	7.26	816	879	503	10.46	12.13	6.87	9.65	11.44	4.68
BK-RYM (2 hr)	94.3	93.5	83.5	10.24	13.00	10.41	951	1219	867	15.65	16.57	7.15	14.71	15.43	5.91
BK-RYM (4 hr)	90.5	93.0	71.5	9.06	10.27	8.27	825	958	597	11.51	12.96	7.02	10.51	12.03	5.02
S.Em.±	1.78	1.01	1.47	0.34	0.54	0.43	40.6	53.6	33.75	0.30	0.52	0.26	0.38	0.55	0.16
CD (5%)	NS	NS	4.24	0.98	1.57	1.26	116.9	154.6	97.10	0.87	1.52	NS	1.09	1.60	0.47



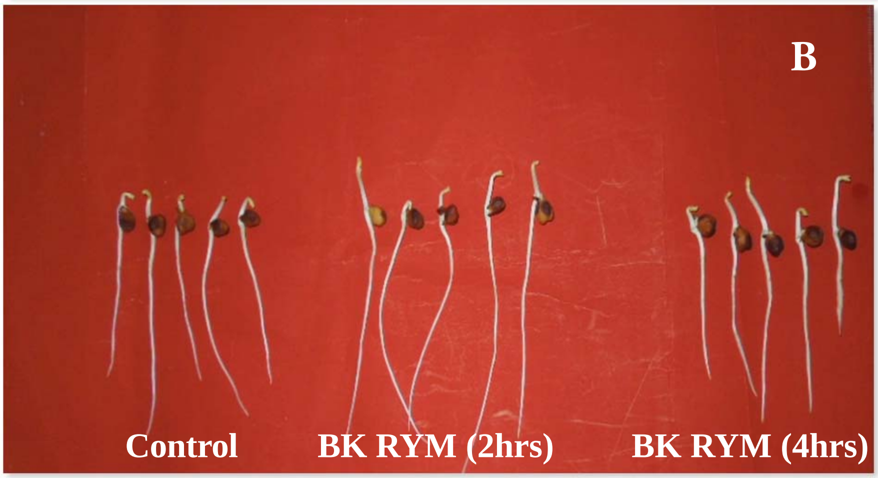


Plate 1: Seedling Seedling Growth of wheat (A) and chickpea (B) seeds as influenced by different metaphysical energy (BK RYM) treatments

which indicate better membrane stability by indicating less leachate of electrolytes. However, it was par with BK-RYM treated seeds for 2 hours (31.3 µS/cm /g of seed) and differ significantly with untreated seeds which recorded highest value of EC of seed leachate (34.5 µS/cm /g of seed).

In case of chickpea seed enhancement treatments had non- significant effect on germination per cent in all the months during storage except in October. Highest germination was recorded in BKRYM treat seeds for 2 hours (83.5%) which was significantly different from BK RYM 4 hour treatment (71.5%). Lowest value of germination was observed in untreated seeds (68%) which were significantly lower than other treatments (Table 2). The present one year study revealed that, BK-RYM treatments significantly influenced, seedling length, seedling dry weight, seedling vigour index -I and seedling vigour index-II in the month of June, August and October. The highest seeding length, seedling dry

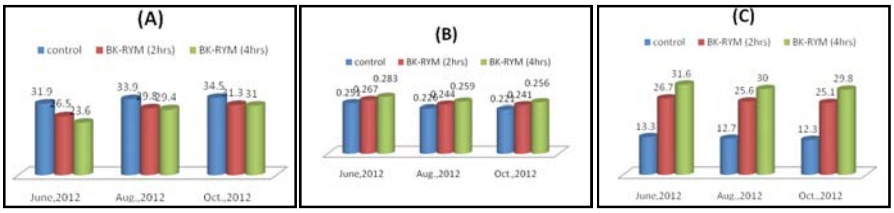


Fig. 1: Effect of metaphysical energy treatments on electrical conductivity (A), dehydrogenase enzyme (O.D./10 seeds) (B) and α amylase enzyme (mg of starch hydrolysed/g of seed) (C) of wheat seeds during storage

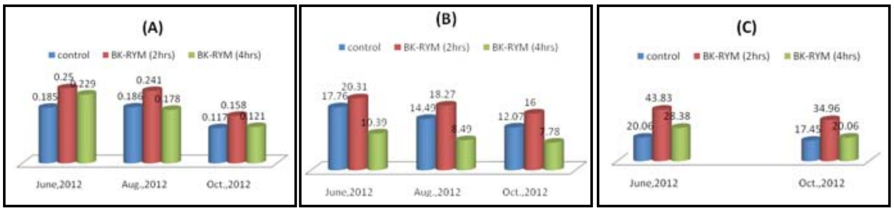


Fig. 2: Effect of metaphysical energy treatments on dehydrogenase enzyme (O.D./10 seeds) (A) α amylase (mg of starch hydrolysed/g of seed) (B) and protease (mg/g of fresh seeds) (C) of chickpea seeds during storage

weight, seedling vigour index -I and seedling vigour index-II was recorded with 2 hours BK RYM metaphysical energy treatment which was significantly higher than 4 hours BK RYM treatment. In case of chickpea, when exposure period of metaphysical energy treatment was increased, there was a decrease in germination, seeding length, seedling dry weight, seedling vigour index -I and seedling vigour index-II was observed. The increase in seedling vigour indices may be as a result in increase in seedling length and seedling dry weight with metaphysical energy treated seeds over untreated seeds. The lowest values of seedling length, seedling dry weight and SVI were observed in untreated seeds. At the end of storage period, germination, seedling length, seedling dry weight, SVI-I and SVI-II with metaphysical energy treated seeds were respectively 22%, 43%, 4%, 72% and 26% higher over untreated seeds.

The results of above studies are in agreement with the results observed by Du Charme Laurene (2007). He reported that after giving intentional thought to seeds, there is an increase in seed weight and germination and seedling length. Debra Williams (1999) in his article cited that, Dr. Franklin Loehr, conducted an experiment on germinating seeds and reported that positive prayer enhanced germination and produced more vigorous plants. Prayers on negative energy actually halted germination in some plants and suppressed growth in others. Creath and Schwartz (2004) reported that seeds treated with healing energy germinated faster than the untreated seeds. Thoughts also affect the molecular structure of water as reported by Emoto Masaru, (2004).Grad (1963) reported that water treated by the thought power of healer had minor shifts in its molecular structure and decreased hydrogen bonding between the molecules. Thus thought did affect the germination because seeds like other living organism, a living entity. However, the differences in germination per cent were non-significant.

Effect of Metaphysical Energy on Enzyme Activity

Seed enhancement treatments significantly influenced dehydrogenate and alpha (á) amylase enzyme activity during entire period of storage (Fig. 1 & Fig. 2). After 6 month of storage, the highest dehydrogenase activity was noticed with BK-RYM treated seeds for 4 hours (0.256 O.D. /10 seeds) and the lowest (0.251 O.D. /10 seeds) was noticed in untreated seeds (Fig. 1 A). In the month of June, August and October, alpha (á) amylase enzyme activity was highest with BK-RYM treated seeds for 4 hours duration which was significantly higher than BK-RYM energy treated seeds for 2 hours duration (Fig. 1B). The lowest value of mg of starch hydrolyzed per gram of seed was observed with untreated seeds (Fig. 1C). The increase in seedling growth parameters was the result of increased enzyme activities in treated seeds. Alpha (á) amylase activity was 2.0 -2.4 times higher over untreated seeds throughout the storage period. Amylases are key enzymes that play a vital role in hydrolysing the seed starch reserve, thereby supplying sugars to the developing embryo. Grad (1963) reported that healing energy increased plant growth and enzyme activities. In case of chickpea among the different seed enhancement treatments enzymes activity recorded during course of investigation was significant. The highest dehydrogenate, alpha amylase and protease activity was noticed with BK RYM metaphysical energy treated seeds for 2 hours (Fig. 2 A, B & C). Protease activity was 2.0 times higher in BK-RYM treated seeds for 2 hours duration, than that of untreated control seeds. This increase in enzyme activity resulted in enhanced seedling growth parameters and seedling vigour in chickpea seeds.

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Recommendations

1. Soil health cards need to be promoted among the farming community.
2. Site specific and differential tillage is pre-requisite for enhancing the productivity and efficiency of applied inputs in different cropping systems.
3. Precise nutrient management, use of customized fertilizers, differential rate of fertilizer placement need to be followed for improving nutrient use efficiency.
4. Site specific nutrient management tools like green seeker, LCC, Chlorophyll meter, senor based application technology, and use of SPAD are required to increase the output/input ratio.
5. IFS is the key for holistic and best approach to manage all adversities in present agriculture scenario to ensure sustainable productivity, profitability, efficiency and resilience of farming community.
6. The concept of resource decoupling and impact decupling may be an important strategy to achieve second green revolution by improving resource efficiency and reducing ill environment impacts.
7. Rain water harvesting, recharge and rejuvenations of sub-surface flow system, protection of terrace riser using good forage grasses, and fruit trees should be promoted to practice.
8. The focus of high-tech and cost effective interventions should be on the small farmers.
9. Bio based plant protection products should be launched to make Indian agriculture productive, remunerative, ecologically safe and secured.
10. Decision making shall be in accordance with the farmers status, as for small farmers, decision making is resource and need driven, while for resource rich farmers, it is science driven.
11. Global shift towards metaphysical energy need to be further experimented, for betterment of agriculture as it is a pivotal pre-requisite for developed economy and social structures.
12. To get the proper energy flow from Pancha Mahabhuta (land, water, air, fire, cosmos) and its transformation into chemically active energies is the task of high importance, and be experimented.
13. Nano particles like nano gypsum, nano rockphosphate, nano zeolite and other may help to boost crop production and nutrient use efficiency.
14. Advanced weather forecasts shall be utilized for planning and executive agricultural activities.

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About the Book:

This book contain 15 chapters covering various thematic areas (High tech interventions and input use efficiency including nanotechnology in agriculture, Biotic and a biotic stress mitigation, Innovation in input management for enhancing crop production & quality, Intervention for improving environment and soil quality). Through this book, the editors have made sincere efforts to put forth the emerging issues to be tackled for enhancing the input use efficiencies of production system to make agriculture profitable & sustainable. It is our belief that this publication will prove worthy to policy makers, planners, researchers, teachers, students, development agencies, NGOs & entrepreneurs.