Impact of Agricultural Research

Post-Green Revolution Evidence from India

Editors

P K Joshi • Suresh Pal • P S Birthal • M C S Bantilan

National Centre for Agricultural Economics and Policy Research

International Crops Research Institute for the Semi-Arid Tropics

Impact of Agricultural Research

NCAP

Impact of Agricultural Research
Post-Green Revolution Evidence from India

Editors

P K Joshi
Suresh Pal
P S Birthal
M C S Bantilan

भाकृअनुप
ICAR

National Centre for Agricultural Economics and Policy Research
New Delhi 110 012, India

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

Impact of Agricultural Research: Post-Green Revolution Evidence from India

Edited by
P K Joshi, Suresh Pal, P S Birthal and M C S Bantilan

Published by
Dr Ramesh Chand
Director, NCAP

Printed at
Chandu Press
D-97, Shakarpur
Delhi - 110 092

About the Editors

P K Joshi is Principal Scientist at the National Centre for Agricultural Economics and Policy Research, New Delhi, India (currently on deputation to the International Food Policy Research Institute, Washington, DC, USA).

Suresh Pal is Principal Scientist and Theme Leader, Technology Policy theme at the National Centre for Agricultural Economics and Policy Research, New Delhi, India.

P S Birthal is National Fellow at the National Centre for Agricultural Economics and Policy Research, New Delhi, India.

M C S Bantilan is Global Theme Leader of the ICRISAT Global Theme- Markets, Policy and Impacts.

Contents

Foreword v

Acknowledgement vii

Acronyms and abbreviations ix

1. Impact of Agricultural Research : An Overview 1
   P K Joshi, Suresh Pal, P S Birthal and M C S Bantilan

2. Agricultural Research Intensity in India 9
   Suresh Pal , A Kumar and A Singh

3. Total Factor Productivity in Indian Agriculture: Impact of Research 17
   P Ranjitha and Mruthyunjaya

4. Measurement of Total Factor Productivity Growth of Rice in India: Implications for Food Security and Trade 25
   P Kumar and D Jha

5. Hybrid Rice Research : Will it have an Impact on India's Rice Economy? 37
   A Janaiah and M Hossain

6. Total Factor Productivity and Sources of Growth of Wheat in India 57
   S Mittal and P Kumar

7. Impacts of Improved Sorghum Cultivars in India 69
   U K Deb, M C S Bantilan and B V S Reddy

8. Impacts of Improved Pearl Millet Cultivars in India 85
   U K Deb, M C S Bantilan and K N Rai

9. Adoption and Impact Assessment of Hybrid Maize Seed in India 101
   R P Singh and M L Morris

10. Chickpea in Nontraditional Areas: Evidence from Andhra Pradesh 115
    P K Joshi , M Asokan and M C S Bantilan

11.	Assessment of Varietal Preferences of Chickpea in Gujarat R L Shiyani , P K Joshi , M Asokan and M C S Bantilan	131
12.	Impacts of Improved Groundnut Varieties in India U K Deb, M C S Bantilan and S N Nigam	141
13.	Impact of Improved Varieties on Sugarcane Production in India: Relevant Issues and Constraints Jagdish Lal, L S Gangwar and A K Srivastava	153
14.	Socioeconomic Impact of Investments in Potato Research and Development in India P S Dahiya	165
15.	Impact Assessment of Watershed Technology in India Ram Babu and B L Dhyani	175
16.	Economic and Environmental Sustainability through Participatory Watershed Management Program in the Garhwal Himalayas B L Dhyani and R Babu	187
17.	Technological Options for Salinity Management in Agriculture: Scope and Prospects K K Datta	199
18.	Total Factor Productivity of the Livestock Sector in India A Kumar, D Jha and U K Pandey	205
19.	Assessment of Crossbreeding Technology in India: A Macro Perspective S Sirohi	217
20.	Meat Production and Productivity Trends: Some Issues for Research and Development P S Birthal and A Ravishankar	229
21.	Potential Benefits of Disease Prevention in Goats S Kumar, V S Vihan and P R Deoghare	241
22.	Impact of AICRP on Improvement in Production and Other Economic Traits of Pigs C B Tiwari and R L Arora	247

23. Technological Change in Arid Agriculture: A Case of Leguminous Crops from Rajasthan — 255
B Singh and B L Gajja

24. Economic Evaluation of Integrated Pest Management in Cotton — 261
P S Birthal, O P Sharma and S Kumar

25. Impact Assessment of Improved Management Practices for *Phytophthora* Foot Rot Disease in Black Pepper — 281
M S Madan, Y R Sarma, K V Peter, K Sivaraman, S Varma, V Srinivasan and P Singh

Abstracts of Other Selected Papers — 293

Foreword

Agricultural research systems all over the world are acclaimed for their significant contributions to food and nutritional security and poverty alleviation. There is empirical evidence of agricultural growth induced by the Green Revolution technologies having benefited the rural and urban poor through reduction in food prices. Although the impact in terms of poverty reduction has multiplied over the years and spread geographically, there is a need to accelerate these impacts in order to improve the livelihoods of the poorest of the poor and to achieve the Millennium Development Goals (MDGs).

India is one of the success stories of the Green Revolution. The Indian experience has convincingly proven that appropriate technologies, supported by facilitating public policies and efficient institutions, can transform smallholder agriculture. Umpteen studies have revealed that these three major sources of agricultural growth are highly interactive and dynamic. They evolve in the contextual realities of an agricultural sector and respond to internal and external developmental changes. However, the question now arises as to how modern technologies and institutions interact in the era of privatization and globalization. The ways and means of harmonizing national agricultural policies with international agreements on trade, exchange of resources, property rights, etc, should be evolved for accelerating the flow of technologies to millions of smallholders.

Research impacts are not uniform across different sub-sectors of agriculture owing to differences in the degree of market orientation, efficiency of input and service delivery systems, dominance of smallholders, etc. Sector-specific institutional and policy constraints need to be understood and addressed in order to enhance the flow of technology to farmers and to realize large-scale impacts. Similarly, greater attention should be paid to understanding institutional constraints to the dissemination and adoption of technologies promoting sustainable use of natural resources. The same holds true for the technologies for livestock, horticulture and agro-processing which are capital intensive.

The Indian Council of Agricultural Research (ICAR) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have a long tradition of research partnership in agricultural science. Both accord high priority to tracking adoption of technologies by farmers, assessing their impacts and learning from this experience. Social scientists from both the organizations have allocated considerable resources towards this work and brought out a number of publications. This volume is an addition to this series, wherein both macro- and micro-level studies pertaining to different sectors of Indian agriculture have been covered in detail, with evidence mostly stemming from the post-Green Revolution period.

We are sure that this volume would be of interest to researchers and policymakers alike.

Mangala Rai
Secretary
Department of Agricultural
Research and Education, and
Director General,
Indian Council of Agricultural Research
New Delhi 110 012, India

William D Dar
Director General
International Crops Research
Institute for the Semi-Arid
Tropics, Patancheru 502 324
Andhra Pradesh, India

July 2005

Acknowledgements

The editors of this book are indebted to many institutions and individuals. The institutions that generously co-organized the workshop that culminated in the publication of this volume are the National Centre for Agricultural Economics and Policy Research (NCAP) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), to whom we are grateful. The workshop drew from the expertise of Dr Mangala Rai, Secretary, Department of Agricultural Research and Education, and Director General, Indian Council of Agricultural Research (ICAR), and Dr William D Dar, Director General, ICRISAT, who spared their time to guide us through the deliberations and encouraged us to bring out this volume.

We extend our deep appreciation to Dr M V Rao, former special DG, ICAR, Dr Dayanatha Jha, National Professor, Dr Dyno Keatinge, Deputy DG, ICRISAT, Dr J P Mishra, Assistant Director General (Economics, Statistics and Marketing), ICAR, Dr Mruthyunjaya, Director, NCAP, and Dr CLL Gowda and Dr BVS Reddy of ICRISAT whose incisive inputs contributed much to the quality of the book.

A special thanks to the chairpersons and rapporteurs who ably conducted the workshop proceedings and summarized the discussions. The unstinted support and cooperation from the contributing authors, discussants, referees and participants of the workshop are acknowledged. We also thank the authors for revising their papers and responding to editorial queries.

We are grateful to the National Agricultural Technology Project (NATP) for providing funding support which allowed us to organize the workshop and bring out this volume. A word of appreciation also goes to Smitha Sitaraman and Dr B S Aggarwal for their patience in editing the volume and to the staff members of the ICRISAT Global Theme on Markets, Policy and Impacts for their valuable contributions during the preparation of this workshop.

Editors

Acronyms and Abbreviations

ACGR	:	Annual Compound Growth Rate
Ag GDP	:	Agricultural Gross Domestic Product
AICRP	:	All India Coordinated Research Project
AICRPDA	:	All India Coordinated Research Project for Dryland Agriculture
AOP	:	Active Operational Phase
APSSDC	:	Andhra Pradesh State Seeds Development Corporation
BC	:	Benefit Cost (Ratio)
CIRG	:	Central Institute for Research on Goats
CMIE	:	Centre for Monitoring Indian Economy
CPRI	:	Central Potato Research Institute
CPRs	:	Common Property Resources
CRIDA	:	Central Research Institute for Dryland Agriculture
CRS	:	Cotton Research Station
CSSRI	:	Central Soil Salinity Research Institute
CSWCRTI	:	Central Soil and Water Conservation Research and Training Institute
CSWRI	:	Central Sheep and Wool Research Institute
CV	:	Coefficient of Variation
DES	:	Directorate of Economics and Statistics
EMVP	:	Estimated Marginal Value Product
FAO	:	Food and Agriculture Organization of the United Nations
FSCs	:	Farmers Science Centers
FTCs	:	Farmers Training Centers
FWP	:	Financial Withdrawal Phase
FYM	:	Farmyard Manure
GA3	:	Gibberelic Acid
GDP	:	Gross Domestic Product
GOI	:	Government of India
HYV	:	High-yielding Varieties
IARCs	:	International Agricultural Research Centres
ICAR	:	Indian Council of Agricultural Research
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IISR	:	Indian Institute of Sugarcane Research
IPI	:	Input Price Index
IPM	:	Integrated Pest Management

IRR	:	Internal Rate of Return
IRRI	:	International Rice Research Institute
ISMA	:	Indian Sugar Mills Association
K	:	Potassium
Mha	:	Million Hectare
MIRR	:	Marginal Internal Rate of Return
Mt	:	Metric Ton
N	:	Nitrogen
NARS	:	National Agricultural Research System
NATP	:	National Agricultural Technology Project
NCIPM	:	National Center for Integrated Pest Management
NGOs	:	Non-Governmental Organizations
NSC	:	National Seeds Corporation
NSKE	:	Neem Seed Kernel Extract
OPVs	:	Open Pollinated Varieties
ORP	:	Operational Research Project
P	:	Phosphorus
PPP	:	Pre-Project Phase
PTM	:	Potato Tuber Moth
R&D	:	Research and Development
R&E	:	Research and Extension
RCP	:	Real Cost of Production
SAUs	:	State Agricultural Universities
SBI	:	Sugarcane Breeding Institute
SSD	:	Subsurface Drainage
T&V	:	Training and Visit
TE	:	Triennium Ending
TFP	:	Total Factor Productivity
TFPI	:	Total Factor Productivity Index
TII	:	Total Input Index
TOI	:	Total Output Index
TPS	:	True Potato Seed
UNDP	:	United Nations Development Programme
WALMI	:	Water and Land Management Institute
WTO	:	World Trade Organization

Units

Weight	:	Metric ton
Lakh	:	Hundred thousand
Crore	:	Ten million

1

Impact of Agricultural Research : An Overview

P K Joshi,[1] Suresh Pal,[1] P S Birthal[1] and M C S Bantilan[2]

Agricultural research in India is largely in the public sector domain. Research in the private sector is limited, and mostly confined to research foundations and in-house R&D in a few input industries such as the seed sector. Research investment in Indian agriculture is channeled through ICAR, the apex organization, which allocates resources for agricultural research, education, and frontline extension through a vast network of research institutes and SAUs. As a result of ICAR's continuous support to agricultural research and extension, and sustained efforts of the scientific community, a large number of improved technologies have been developed, contributing significantly in achieving growth in production. Though the contribution of agricultural research has been immense, it has not been well documented in the past. The information available is scattered and based on anecdotal evidence. As a result, investment in agricultural research is often questioned.

In order to document and synthesize the impacts of past and ongoing research investment in agriculture, a workshop was organized jointly by the National Centre for Agricultural Economics and Policy Research and the International Crops Research Institute for the Semi-Arid Tropics on 10-11 February 2000. Fifty-one papers were contributed in multiple areas like genetic enhancement of crops, resource management, integrated pest management, animal sciences, agricultural

Joshi, P.K., Pal, S., Birthal, P.S. and **M.C.S. Bantilan.** 2005**.** Impact of agricultural research: An overview. Pages 1-8 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

[2] International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

implements, etc. A cross-section of research managers, policymakers, economists, agricultural scientists, and representatives from the seed industry attended the workshop. The papers documented the contribution of the past efforts of agricultural R&D in terms of several socioeconomic indicators, including efficiency gains, employment generation, and conservation of natural resources. Following is a synthesis of the workshop proceedings.

Investment in agricultural research and education (at 1980-81 prices) went up from Rs 733 million in 1965-66 to Rs 2994 million in 1998-99. The share of agricultural research and education in total government expenditure on agriculture was about 3.6% in the IX Plan. Agricultural research intensity is expected to reach 0.52% in the IX Plan, which is too low compared to that prevailing in the developed countries (2.5%).

Impact of Research in Genetic Enhancement

The genetic enhancement of a majority of agricultural crops received highest priority amongst different disciplines. The research efforts yielded positive dividends. Several improved varieties of almost all crops were developed and widely adopted by farmers. Their contribution to Indian agriculture is enormous. At the aggregate level, two important impact indicators were addressed: Total Factor Productivity (TFP) and poverty alleviation. The TFP index for crop-livestock reached 290% in 1991-92 from the base year (1964-65 = 100). Research contributed 48% to the TFP growth. The marginal Internal Rate of Return (IRR) on research investment was 53% during this period. Another indicator related to poverty alleviation and agricultural research. The poverty ratio declined from 55% in 1973-74 to 36% in 1993-94. A strong and positive association between research outputs and poverty alleviation was noted. Harsh and fragile environments (e.g., rainfed regions and hilly and mountainous terrains) yielded few acceptable research outputs. However, it was reported that the better-endowed (i.e., irrigated) regions produced a large number of successful technologies, which significantly contributed to enhancing the food security of those regions as well as that of the fragile environments.

Cereal production has increased substantially during the past three decades – from 70 million tons (Mt) in 1960-61 to 188 Mt in 1988-99. Most of the growth in production was driven by yield growth. Rice research in India has been highly rewarding, with IRR in the range of 30-50%. There has been a reduction in the unit cost of production and real price of rice. Similarly, technical change contributed to an increase in wheat productivity ranging between 34 and 51%. About 98% of the area under wheat in the Indo-Gangetic irrigated regions is now covered by varieties having the dwarf gene, yields from which increased annually by about 48 kg ha^{-1} between 1966-67 and 1998-99.

With yields stagnating in the Green Revolution belt, new research opportunities were explored. Among others, hybrid rice was found to break the yield barrier. Rigorous research efforts on hybrid rice over the last decade have led to the release of 12 rice hybrids by the public sector, and 7-8 hybrids were marketed by the private seed sector. The average yield gain of hybrids over that of popular inbred varieties was 16%. The major constraints to hybrid rice production are related to its relatively poor grain quality and high cost of seed production.

In the case of sorghum and pearl millet, adoption of improved varieties resulted in significant yield gains, reduction in unit cost of production, and yield stability. About 182 improved cultivars with multiple traits were developed from 1962 to 1998. Sorghum production fluctuated around 10 Mt but yield increased from 533 kg ha^{-1} in 1960-61 to 956 kg ha^{-1} in 1996-97. In the case of pearl millet, production rose to 8 Mt in 1997-98 from 3.3 Mt in 1960-61. Yields increased from less than 300 kg ha^{-1} in 1960-61 to 800 kg ha^{-1} in 1997-98. Farm-level evidence suggests that more than 90% adoption of improved pearl millet cultivars took place in Maharashtra and Gujarat. It is nearing 85% in Haryana, 80% in Tamil Nadu, and 30% in Rajasthan. It was noted that the average cost of pearl millet production per ton declined by 35% in Gujarat, 42% in Haryana, and 59% in Rajasthan in 1992-94 over 1972-74.

Maize production has been spectacular, surpassing 10 Mt in 1997-98. Much of the growth in maize production was due to the adoption of new seed-fertilizer-based technology. Hybrid maize is now moving to nontraditional areas because of its high-yield potential. Yields from hybrids were significantly higher than reported for OPVs. In the absence of hybrids, maize production in the major maize-producing states would have been about 1 Mt lower during 1994-95 than what was attained. Winter maize has shown considerable potential in flood-prone regions. Farm-level evidence has shown that due to the adoption of winter maize production technology, yield has increased three to four times more than in the case of rainy-season maize. The cost of production too has declined by

50%. The technology empowered women farmers as they got more fuel in the form of maize stalk stubble and maize stone on their farms. It also fulfilled the feed and fodder needs of farm animals, leading to higher livestock production, particularly of milk and poultry products.

The production of pulses too increased, though not as impressively as that of cereals. In the case of pulses, the increase was led by yield enhancement. However, a major concern was the decline in area being sown to pulses. Research in pulses contributed to improved varieties which were spreading in nontraditional areas. For instance, chickpea being sown in the hot and dry climates is now contributing more than 70% of the total chickpea production in the country. In Andhra Pradesh, chickpea area has increased rapidly since 1990-91. A large part of the area expansion was from areas released by either postrainy-season sorghum or postrainy-season fallow or both. This was possible due to higher output prices and the availability of improved, high-yielding, short-duration, and disease-resistant chickpea varieties in comparison to local varieties. In Gujarat, a majority of farmers still grows the local chickpea variety ‘Dahod Yellow’. An improved chickpea variety (ICCC 4) is finding niches in Jamnagar district, where it was adopted in about 25% of the chickpea area. The benefits were in the form of higher yields, more income, decline in unit cost of production, and higher employment generation.

In the case of pigeonpea, improved varieties (Bahar, Narendra Arhar-1, Pusa-9, and Amar) covered about 40% of the area in few selected locations in the eastern part of Uttar Pradesh. The major constraints to adoption of improved technologies included lack of information about them, and nonavailability of quality seeds of improved varieties.

Moth bean and cluster bean are important crops in the arid regions. India, which ranked first in cluster bean export in the world market in the past, is now ranked second. The introduction of high-yielding varieties of cluster bean led to higher yields even when rainfall was low and erratic. The unit cost of production too declined substantially as a result of HYVs.

Oilseed production too has shown substantial increase after the government-sponsored Oilseeds and Pulses Mission was launched in 1987. Groundnut research has shown benefits in terms of a significant increase in yield and yield stability. Groundnut production in the country rose from 4.8 Mt in 1960-61 to 9.2 Mt in 1998-99. The adoption rate of improved varieties rose from 6% in 1989 to 84% in 1994 in Maharashtra and Gujarat.

This resulted in yield gains of 53% and a decline in the cost of production by 20%.

Sugarcane is an important cash crop. India is one of the largest producers of sugar in the world, with a global share of about 13%. Sugarcane production increased from 110 Mt in 1960-61 to 296 Mt in 1998-99.

Research programs on sugarcane began at the Sugarcane Breeding Institute, Coimbatore, in 1912. Since then, several varieties have been developed. As a result, average sugarcane productivity increased from 35 t ha^{-1} in the 1930s to 67 t ha^{-1} in the 1990s. Studies have revealed that 50 to 70% of the increase in productivity has been due to HYVs. The increase in sugarcane acreage and sugar factories clearly indicates the contribution of varieties and inputs. Research efforts addressed the issue of improving the efficiency of sugar production through early-maturing varieties. The improved varieties (Co 281) not only yielded considerable benefits in India, but also brought about major changes in the sugar industry in South Africa. Tropical India witnessed a 50% improvement in sugarcane yield. Sucrose production too improved (0.9%). Early-maturing varieties occupied only 14% of the total sugarcane area in the country. In Punjab (Co J 64), Gujarat, Tamil Nadu, and Andhra Pradesh (Co C 671), the benefits of early varieties were fully exploited.

Potato research is another success story. Potato production in the country went up from 3 Mt in 1960-61 to about 23 Mt in 1998-99. More than 35 HYVs and improved technologies for potato production were developed. Annual potato production increased by about 5.8% during 1949-50 and 1997-98. During this period, the area sown to potato increased by about 3.62% annually, and yields by 2.07%. The impact of research on potato and seed production systems has been obtained in terms of (i) self-sufficiency in potato, (ii) higher cropping intensity, and (iii) employment generation.

Impact of Natural Resource Management Research

The Indian research program also focussed its efforts on improving resource-use efficiency, conserving natural resources, particularly soil and water, and rehabilitating degraded soils. The management of degraded lands posed an important challenge. Land degradation in the form of soil erosion, salinity/alkalinity, and waterlogging are posing serious threats to sustainable agricultural development. Research efforts were made by ICAR and IARCs like ICRISAT to overcome these problems. In this context, research papers have shown the impact of various technologies (e.g., watershed research, reclamation of salt-affected soils, and vertisol technology). Research outputs of watershed programs were found appropriate in solving the problems of about 65% of the total cultivated area. Watershed programs have shown several benefits in various target domains, documented in the form of higher incomes, crop diversification, increase in irrigated area and fodder availability, and soil and water conservation. The problem of women migration was also addressed through it. The studies also reported that out-migration was checked to a large extent. Controlling soil erosion was found to benefit sustainable agricultural production in rainfed areas. Runoff declined from 42 to 15% and soil loss from 12 to 2 t $ha^{-1}year^{-1}$ in select locations.

Vertisol technology was developed to overcome the problem of about 12 million hectares of rainfed area. It increased agricultural production and prevented the degradation of soil and water resources. It was observed that there was maximum adoption of different technology components when rainfall was about 1000 mm. The benefits of adopting vertisol technology were documented as easy cultivation, effective pest management, higher production, less labor time and cost, higher income, increase in food and fodder security, lower cost of seed and nutrients, better soil and water conservation, prevention of soil erosion, and effective use of rain water.

Another problem which has emerged in surface-irrigated areas is related to soil salinity/alkalinity and waterlogging. Several technological and policy options were developed and widely adopted in the trans-Gangetic region. Chemical amelioration of alkaline soils has led to numerous benefits which include higher income, employment generation, stronger intersectoral linkages, reduced income disparities, more effective and efficient conservation of rain water, etc. Reclamation of alkaline soils has contributed significantly to increased foodgrain production. Making provisions for subsurface drainage has led to the perfect management of saline soils, and it has shown considerable potential. The large-scale adoption of the technology is constrained by its indivisible nature, which calls for collective action. Conflicting objectives among beneficiaries and the problem of free riders are the other constraints.

To increase the resource-use efficiency of perennial crops, research efforts developed several Perennial Crop Based Farming System Models (PCBFS models). It was observed that the PCBFS was more suited to medium and large farmers. Factors like high plant density and underplanting of the main crop, lack of irrigation facilities, the capital-intensive nature of the technology, lack of skilled labor, and the nonavailability of capital were the major constraints to its adoption.

Impact of Livestock and Farm Machinery Research

The livestock sector is complementary to agriculture. Its share in the agricultural gross domestic product was about 26% in 1996-97. Livestock output at the national level grew at an annual rate of 2.6% during 1950-51 and 1995-96. National-level evidence shows that output as well as TFP growth of the livestock sector picked up in the eighties when output growth touched nearly 4% per year and TFP growth jumped to nearly 1.8%, contributing about 45% to total output growth. One of the success areas was milk production, which increased from 20 Mt in 1960-61 to 70 Mt in 1997-98. Crossbreeding technology contributed to a 11% increase in milk production at the national level, and 57% in Kerala. Micro-level evidence revealed that the average milk yield of crossbred lactating cows and graded Murrah buffaloes was significantly higher than that of lactating non-descript cows and local buffaloes. Lack of awareness, poor accessibility to technologies, and lack of financial resources were the major constraints to adopting improved dairy technologies.

Small ruminants are important enterprises with resource-poor households in rural areas. Research efforts were made to raise their production and productivity. It was estimated that as a result of various diseases in goats, their mortality ranged from 5 to 25% in adults and 10 to 40% in kids. An *ex ante* assessment predicted that if the suggested health calendar for prophylactic measures in goats is adopted, the huge losses incurred by goat farmers would be reduced by about 70%. Another important small ruminant of poor farmers is the pig. It was reported that crossbred pigs showed higher litter productivity, growth rates, efficiency in feed utilization, and had thick lower back fat and higher lean cuts in their carcass than indigenous pigs.

The public sector too allocated research resources to develop simple and low-cost tools and implements, especially for resource-poor farmers. In the past, several implements have been designed and adopted by resource-poor farmers. A paper in these proceedings discusses three implements — the animal-drawn integral toolbar, pre-germinated paddy seeder, and khurpa-cum-sickle. It was observed that these performed better than traditional ones in terms of saving costs and improving labor efficiency.

Impact of Research on Integrated Pest Management

Pest management research has received high priority since the 1980s. Pests are heavily damaging various crops. After attaining self-sufficiency in food, the attention shifted to research on crop protection. With the passage of time, the indiscriminate use of chemicals in agriculture caused several undesirable externalities. Cotton, which covers only 5% of the total cropped area, receives as high as 55% of total pesticides. To overcome the problems of pesticide overuse, environmental degradation, and management of innocuous pests and diseases, Integrated Pest Management (IPM) was developed. As a result of IPM in cotton, mustard, and Basmati rice, pesticide use declined, yield increased, and natural fauna was protected. Similarly, the impact of controlling *Phytophthora* foot rot disease, caused by *Phytophthora capsici* in black pepper was quite rewarding. The adoption of cultural and chemical control measures was about 78 and 67%, respectively. The positive impact of the technology was reflected by decreased incidence levels, improvement in productivity, and a high cost-benefit ratio.

Conclusions

The workshop revealed the significant contribution that agricultural research has made in the agricultural and nonagricultural sectors. Yet, more systematic research is needed to empirically measure the research impact on social welfare and conservation of natural resources. It was realized that an appropriate policy environment, infrastructure, and institutions were preconditions for a greater impact of agricultural research. It was also stressed that appropriate policies were necessary for the distribution of research benefits to society.

2

Agricultural Research Intensity in India

Suresh Pal,[1] A Kumar[1] and A Singh[2]

Introduction

The government of India has allocated a significant proportion of its resources to agricultural research and education, resulting in an extensive network of institutions in the country. This was made possible through committed and continued political support to agricultural research, and the ability of research managers to visualize research challenges and evolve appropriate institutional responses to them. This research system is now entering a new phase; it is diversifying and evolving as a mature national agricultural research system, which should be capable of addressing new and complex research challenges. The system has to address issues of sustainability, environment, trade and balanced regional development, besides maintaining food security and alleviating poverty. Therefore, it is imperative to look at current research efforts and their adequacy in order to address emerging national research needs. This paper examines the trends in government expenditure on agricultural research and its allocation pattern across regions, and raises some issues regarding efficient use of available research resources.

Pal, S., Kumar, A. and **Singh, A.** 2005**.** Agricultural research intensity in India. Pages 9-15 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P. K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

[2] Division of Agricultural Economics, Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India.

Agricultural Research System

Although agriculture is a state subject under the Indian Constitution, the Union Government is responsible for supporting agricultural research. At the helm of affairs is the Indian Council of Agricultural Research (ICAR), which plans, executes, and coordinates the country's agricultural research with its network of institutions, most of which are either commodity based or resource (soil and water) based. While some of these bodies are mandated to undertake upstream research, others are engaged in applied research. A few institutes have been established to explore, characterize, and conserve genetic resources.

Funded totally by the Union Government, a large chunk of ICAR funds is utilized to support research, manpower training, and frontline extension in its network of institutions. ICAR also uses a part of its funds to support State Agricultural Universities (SAUs) through grants and sponsorship of research schemes. There are currently three such schemes. Firstly, ICAR sponsors a number of All India Coordinated Research Projects — multidisciplinary projects to conduct research on a commodity, resource or theme. Many centers of these projects are located on SAU campuses and are funded by ICAR. Secondly, all SAUs participate in research programs of the National Agricultural Technology Project (NATP), initiated with financial support from the World Bank. Thirdly, ICAR has established competitive research funds (the AP Cess Fund Scheme and the Competitive Grant Programme of NATP), for which any research institution, including a private one, can compete.

The state governments fund their respective SAUs, which are mandated to agricultural education and state- or region-specific applied and adaptive research. All SAUs have set up zonal agricultural research stations in the states or regions of their jurisdiction to undertake location-specific research. Some of them have more than one campus engaged in education and research.

The private sector's entry into agricultural research is of comparatively recent origin and, therefore, constitutes a small proportion of national research efforts. A few research foundations and input companies like large seed companies are currently undertaking research activities. However, with the growth of commercial agriculture and enabling government regulations, private sector's participation in research is expected to increase rapidly. Efforts are underway to foster an effective interface between the public and private sectors for the development, commercialization, and dissemination of technologies (Mruthyunjaya et al. 2000).

Agricultural Research Intensity[3]

There are three main sources of funding to agricultural research: the Union Government, state governments, and the private sector. Since estimates of private expenditure on research are not readily available, this paper discusses only government expenditure. Although agricultural research expenditure is met from both revenue and capital accounts of the government, most of it comes from the former.

Unlike in other countries and international organizations, public expenditure on agricultural research (including education) in India in real terms has steadily increased. Research intensity measured as research expenditure as percentage of agricultural gross domestic product (AgGDP), has shown appreciable growth (Table 1). The intensity increased from 0.31% during the V Plan period (1974-79) to 0.42% during the VI Plan (1980-85). It further increased to 0.48% during the VII Plan period (1985-90) and remained almost the same (0.49%) during the VIII Plan (1992-97). It may be noted that research intensity has increased because of the hike in

Table 1. Intensity of public expenditure on agricultural research and education in India.

Plan period	Annual research expenditure (million Rs at 1993 prices)	Research expenditure as percentage of AgGDP	Share of plan outlay in the total research expenditure (%)
V Plan (1974-79)	4,305	0.31	46.18
VI Plan (1980-85)	5,426	0.42	53.77
VII Plan (1985-90)	7,242	0.48	31.43
VIII Plan (1992-97)	9,799	0.49	37.41
IX Plan (1997-2002)*	12,350	0.52	48.02

*Based on two-year data.

[3] The data up to 1994-95 are from Pal and Singh (1997) and have thereafter been updated. Research expenditure includes expenditure on research, education, and frontline extension. In case research expenditure is used against education or extension expenditure, it indicates pure research efforts, excluding education and extension.

expenditure made by the Union and state governments. Currently, their share is almost equal in the national expenditure.

A comparison of agricultural research intensity in India with that in developed countries reveals two distinct differences. First, research intensity is much lower in India than in developed countries (2.5%). Secondly, about half the total research expenditure in developed countries comes from the private sector, whereas in India most of it comes from governments, with private research expenditure being marginal (15% of the total) (Pal and Singh 1997). Although private research expenditure is rising rapidly in India, it is unlikely to bridge the gap in the near future. It is therefore essential to increase public expenditure so that research intensity is raised to the commonly prescribed level of 1% of AgGDP.

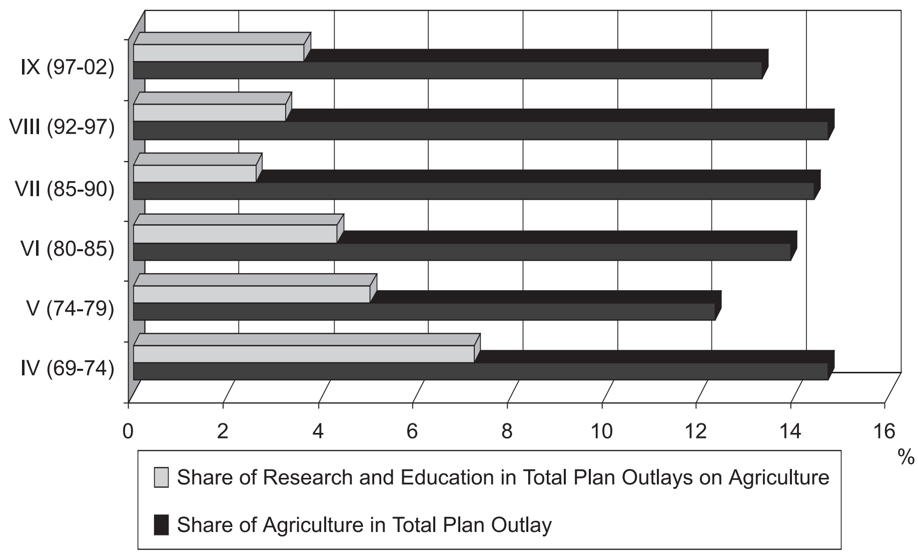
Plan Allocation to Agricultural Research

Government funding to agricultural research is in the form of plan and nonplan funds. Nonplan funds are meant for maintaining ongoing government activities, and usually include staff salaries and other establishment costs. The share of plan funds not only indicates further expansion of activities but also affects factor shares in the total expenditure. For instance, the share of plan funds decreased sharply in the VII and VIII Plans. This resulted in a sharp decline in the share of operating expenses in the total expenditure. It was found that the share of operating expenses in the ICAR budget dropped from 38% in the early 1980s to 23% in the early 1990s (Pal and Singh 1997). The shortage of operational funds constraints the efficiency of the research system in two ways: it results in the suboptimal use of other resources including scientific manpower, and nonplan research activities may not be subjected to a rigorous monitoring and evaluation exercise, and could thereby result in a wastage of resources or duplication of efforts. The research system, particularly ICAR, has taken steps to address these problems. The NATP largely supports operational expenses, and there is no provision for additional manpower. The NATP also places high priority on institutionalization of improved priority assessment, monitoring, and evaluation in the research system (Pal and Joshi 1999). These measures are expected to have a far-reaching impact on research efficiency.

Trends in plan allocation reveal the government's priority for agricultural research, which unfortunately seems to be declining. For instance, although the share of agriculture in the total plan outlays varied between 12 and 15%

since the IV Plan, the share of research expenditure in total outlays for agriculture decreased drastically from 7.2% in the IV Plan to 2.6% in the VII Plan. However, it improved and is expected to remain around 3.6% in the IX Plan (Fig.1). In view of the low research intensity, it is essential to accord high priority to agricultural research in the allocation of Plan funds.

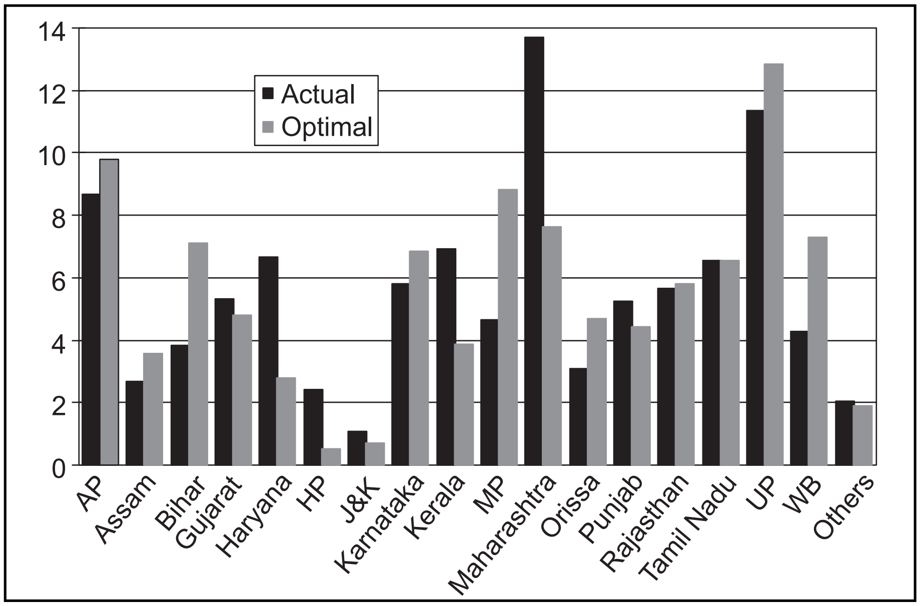
Figure 1. Plan allocation to agricultural research (1969-74 to 1997-2002).



Sectoral and Regional Allocations

An all-India picture of the allocation of research resources across various sectors of agriculture is difficult to obtain since sectoral allocations at the state or university level are not readily available. However, the allocation of ICAR funds is rather simple, mainly because of the commodity and resource set-up of its institutions. There are several studies analyzing trends in sectoral allocation of ICAR resources. Jha et al. (1995) observed undue high allocation of resources to extension at the cost of education and research, and also that allocations to horticultural and livestock research were not commensurate with their economic significance and expected contribution to equity, sustainability, and exports. Similarly, Pal and Singh (1997) observed gaps between actual and normative allocation of resources across states, and suggested that more resources be

Figure 2. Resource allocation across states.



Source: Pal and Singh (1997).

allocated to the eastern states and other less developed states like Madhya Pradesh (Fig. 2).

Gaps in resource allocation across commodities or regions are expected given the magnitude of the Indian research system and the absence of a formal priority assessment analysis. Allocation of research resources used to be largely based on historical trends. This process must now change and a structured and transparent mechanism should be in place to rationalize resource allocation. The new mechanism should derive directions from national policy goals and link priorities with farm-level constraints and opportunities. Such a mechanism, which draws lessons from other countries and international organizations, is being experimented under the NATP (Pal and Joshi 2000), and it is expected to be institutionalized in the entire research system over a period of time.

Conclusions

Since India's research funding for agricultural research is quite low, there is a need to accelerate public as well as private resources. At the same time, it is important to address institutional constraints in the efficient allocation and use of scarce resources. This calls for a three-pronged strategy: mandatory priority assessment and evaluation (concurrent and ex-post) in all institutions and research programs; decentralization of the system for greater autonomy and accountability, and encouraging innovations in research management; and exploiting the synergies of interinstitutional collaboration within the public sector and public-private sector interface for higher research productivity.

References

Jha, D., Kumar, P., Mruthyunjaya, Pal, Suresh, Selvarajan, S. and **Singh Alka.** 1995. Research priorities in Indian agriculture. NCAP Policy Paper No. 3. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 84 p.

Mruthyunjaya, Pal, Suresh, and **Bawa, A.K.** (eds.) 2000. ICAR-industry interface in agricultural research. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 35 p.

Pal, Suresh, and **Joshi, P.K.** (eds.) 1999. New paradigms for agricultural research management. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 103 p.

Pal, Suresh, and **Joshi, P.K.** (eds.) 2000. Priority setting, monitoring and evaluation in agricultural research — Selected readings. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 120 p.

Pal, Suresh, and **Singh, Alka.** 1997. Agricultural research and extension in India: Institutional structure and investments. NCAP Policy Paper No. 7. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 63 p.

3

Total Factor Productivity in Indian Agriculture: Impact of Research

P Ranjitha[1] and Mruthyunjaya[2]

Introduction

Measuring productivity is essential in order to account for economic growth. The efficiency change analysis of total factor productivity (TFP) attempts to measure the increase in total output which is not accounted for by increase in total inputs. In the production function framework, TFP growth indicates technical progress, which represents shifts in the production function over time. In the Indian context, technical progress measures the impact of shifts in production technology on account of irrigation, high-yielding varieties (HYVs), modern agricultural equipment, fertilizers, pesticides, etc. It also captures the effects of improved labor quality, better management practices, and intensive use of resources which lead to increased crop intensity, changes in cropping pattern in favor of high value-added crops, etc.

Research has been the prime mover of agricultural growth in India. In the post-Green Revolution period, productivity growth was sustained through increased input use. Lately, this has been done through input efficiency-enhancing technical change. The Indian National Agricultural Research System (NARS) is one of the largest in the world, investing about 0.3% of national agricultural gross domestic product (GDP) in the same.

Ranjitha, P. and **Mruthyunjaya.** 2005**.** Total factor productivity in Indian agriculture: Impact of research. Pages 17-24 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P. K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Indian Grassland and Fodder Research Institute, Jhansi, India.

[2] Indian Council of Agricultural Research, Krishi Bhavan, New Delhi 110 001, India.

This paper assesses the contribution of agricultural research in India to increases in productivity. The TFP decomposition method was used to estimate returns to investment in agricultural research between 1964 and 1992. A double-log regression framework was used to estimate the contribution of various factors — research, extension, infrastructure, human capital, and weather — to TFP growth. Research and extension stocks were constructed with appropriate lags.

The Research System

Institutions

India has one of the largest and institutionally complex agricultural research systems in the world. Its effective functioning in close association with education and extension systems has significantly contributed to the rapid growth of agricultural production. Historically, the Indian NARS is a culmination of a process which began in the previous century and resulted in the establishment of the Imperial (now Indian) Council of Agricultural Research on the recommendations of the Royal Commission on Agriculture in 1929. State Agricultural Universities (SAUs) came into being during the 1960s as a significant component of NARS. While ICAR is the national-level body responsible for coordinating, directing, and promoting agricultural research, extension, and education in the country, the SAUs are the counterparts at the state level. At present, ICAR has a network of four multidisciplinary national institutes (deemed-to-be universities) among its 49 institutes, while the other 45 are central research institutes with commodity/ agroecological focus (Table 1). The 28 (currently 34) SAUs and one Central Agricultural University operate through over 300 research stations. The All-India Coordinated Research Projects (AICRPs) are the main link between ICAR and SAUs.

Investment

Table 2 reveals the regionwise trend in agricultural research investment in India. During 1965-68, about Rs 307 million year^{-1} (at 1980-81 prices[3]) were invested in agricultural research. This figure rose to Rs 1704 million year^{-1} during

3 The consumer price index (CPI) for urban nonmanual employees was used as the deflator to construct a constant expenditure series.

Table 1. Growth of agricultural research institutions in India.

Institutions	1973-74	1980-85	1992-97
ICAR institutions	23	39	49
National research centers	0	11	30
Project directorates	0	5	10
AICRP/network projects	69	63	84
Others	0	8	17
Total	92	120	190
SAUs	17	23	28

Source: Mruthyunjaya and Ranjitha (1998).

Table 2. Regionwise investment (in million Rs) in agricultural research as per 1980-81 prices.

Region[1]	1965-68	1971-74	1977-80	1983-86	1989-92
Northern	338	630	779	995	1381
Southern	127	340	729	1027	1404
Central	149	292	473	717	958
Western	180	374	601	752	1079
Eastern	126	245	337	429	590
All-India	920	1881	2929	3920	5112

[1] Northern region: States of Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, and Delhi; Southern region: States of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu; Central region: States of Uttar Pradesh and Madhya Pradesh; Western region: States of Gujarat, Maharashtra, Rajasthan, and Goa; Eastern region: States of Assam, Bihar, West Bengal, Orissa, and North-eastern states.

Source: Ranjitha (1996).

1989-92. The southern region experienced the highest growth in research investment during the study period. Of the country's total research expenditure during 1989-92, however, the northern region received the highest share (25%), followed by the southern (23%), western (22%), central (19%), and eastern (11%) regions.

Table 3 gives the commodity orientation of research investment in the country. These estimates were arrived at by allocating research investment according to the share of a commodity in the total number of research publications (Ranjitha 1996). The crop sector accounted for the major share of research expenditure (66.5%), followed by livestock (27.9%), fisheries (3.03%), and forestry (2.51%). The most rapid gain was made by the livestock sector; its share rose from 22% in 1965-68 to 28% in 1989-92.

Among cereals, rice occupied the first place followed by wheat. While sugarcane, tobacco, beverages, fruits and vegetables, and fibrous crops registered a decline in their shares, an increase was observed in the shares of spices, oilseeds, medicinal plants, and pulses.

A statewise distribution of the priorities of a commodity reveals that more than half of the cereal research (52%) was done in the states of Andhra Pradesh, Madhya Pradesh, Maharashtra, Orissa, and Punjab. In the case of pulses, the research was conducted mainly (>60%) in the states of Andhra Pradesh, Madhya Pradesh, Maharashtra, and Rajasthan. Research on oilseeds was concentrated (60%) in the states of Gujarat, Kerala, Madhya Pradesh, Maharashtra, and Uttar Pradesh.

Table 3. The share of commodities (%) in the total research expenditure in India.

Commodities	1965-68	1977-80	1989-92
Wheat	1.46	5.15	1.88
Maize	1.18	1.60	1.43
Millets	2.79	4.89	4.06
Rice	7.07	5.91	6.08
Cotton	3.49	2.25	2.50
Jute	1.06	0.92	0.68
Sugarcane	5.68	1.30	1.45
Tobacco	1.52	1.23	0.60
Tea and coffee	1.67	0.98	0.36
Spices	1.52	1.94	2.43
Oilseeds	4.25	4.91	5.31
Medicinal plants	2.16	2.43	2.27
Pulses	1.79	4.74	8.35
Fruits and vegetables	13.42	15.63	12.97
Livestock	21.86	20.55	27.94
Fisheries	2.67	2.30	3.03
Forestry	3.25	1.46	2.51

Source: Ranjitha (1996).

Table 4. Share (%) of ICAR research expenditure (1989-92) in non-commodity areas.

Areas	Share (%)
Research management	0.89
Soil and water management	7.37
Area-specific research [e.g. CAZRI, ICAR Complex (Goa)]	6.68
Agricultural engineering	2.07
Total	17.01

Source: Mruthyunjaya et al. (1995).

Table 4 gives the share of ICAR research expenditure in non-commodity areas. These were arrived at by compiling information on budgets on research management, soil and water management, and areas of specific research carried out at natural resource management institutions and those related to agricultural engineering. Non-crop research expenditure was about 17% of total research expenditure. A large share of it went towards managing soil and water resources, and rehabilitating degraded soils.

Total Factor Productivity

The TFP decomposition method was used to estimate returns to investment in agricultural research and extension. The TFP indices were constructed based on Dholakia and Dholakia (1993). A double-log regression framework was used to estimate the contribution of various factors to TFP growth. Variables representing research, extension, infrastructure, human capital, and weather were included as regressors in the model. Stocks of research and extension (R&E) were constructed assuming that expenditures on R&E will have a minor impact on productivity in the current year but that their impact would peak over time and then taper. Stepwise regression was used to preclude problems of multicollinearity. Marginal product for investment in research was calculated from the estimated stock elasticities and the ratios of annual expenditures to product values. Marginal products are the values of increased output when the time weight equals one from one unit of investment.

Impact of Research

The TFP analysis measures the increase in total output not accounted for by increases in total inputs. The TFP index measures the growth in net output per unit of factor input. In the production function framework, TFP growth indicates technological progress which represents shifts in the production function over time. Table 5 gives the changes in TFP indices over time.

There were fluctuations in TFP indices during the study period. There was a fall in TFP index corresponding to the years of natural calamities. The growth rate of TFP has been falling over the years. Assuming no innovations, there will be a minimum natural rate of TFP growth. A higher growth rate can only come about through technological change. However, a decline in TFP growth is a logical process as population pressures increase, marginal lands are brought under cultivation, available technology becomes obsolete, and there are no additions to the technology pool. At one time, a low TFP growth could sustain production and meet the demands as the population growth was below 1% and there was no scarcity of land. Thus, indigenous technology sufficed.

The 2-3% jumps in TFP growth rates experienced in Europe, Japan, and the USA are one-time events, and have eventually tapered off. A long-term growth rate of 1% should cause no alarm, but ways and means to sustain it, if not increase it, should be thought of.

A decomposition of TFP was attempted to estimate the contribution of variables like research, extension, infrastructure, human capital, and weather. In the final regression, only two variables — number of regulated markets and research — appeared in the equations as significant determinants of TFP growth. The estimated equation explained 97% of the variation in TFP. The estimates are indicating a declining returns to scale. Both markets and research were found to be positively related to productivity growth (Table 6).

Table 5. Changes in output, input, and TFP indices of Indian crops and the livestock sector.

Year	Output index	Input index	TFP index
1964-65	100.00	100.11	99.89
1971-72	171.71	117.41	146.25
1978-79	314.50	152.24	206.57
1985-86	336.43	247.64	267.90
1991-92	1104.38	381.73	289.31

Source: Ranjitha (1996).

Table 6. Estimated parameters of TFP decomposition for Indian crops and the livestock sector, 1964-92.

Variable	Parameter estimate	Standard error	't'-ratio
Markets	0.3096 *	0.07229	4.283
Research	0.1143 *	0.03169	3.606
Constant	1.7095 *	0.03192	5.355
R^2	0.97		
Adjusted R^2	0.97		

* Coefficient is significant at 5% level. The dependent variable is the natural logarithm of the TFP index.

All variables are specified in logarithms.

Source: Ranjitha (1996).

Table 7 gives the sources of growth and the contribution of each of these significant factors to TFP growth. In the total variation explained by these factors, assuming it to be 100%, research contributed almost 48%; regulated markets contributed the rest.

Table 7. Sources of TFP growth in Indian crops and the livestock sector, 1964-65 to 1991-92.

Sources	Annual growth	Elasticity of TFP	Share of TFP growth explained (%)
Research	17.50	0.1143	47.64
Markets	7.10	0.3096	52.36

Source: Ranjitha (1996).

The stream of marginal output generated from investments was computed using the estimated parameters from the TFP decomposition equation and the lag structure of the research variable. An investment of one rupee in agricultural research will yield a return of Rs 10.43 over a 17-year period. The annual stream of benefits was then related to their associated annual stream of in-country research costs. The marginal rate of return (MRR) was computed to be 53%.

Lessons for Future Research

The TFP growth rate has been falling over the years. Such a fall is natural assuming there have been no innovations. Declining productivity trends can be directly associated with ecological consequences of intensive cultivation systems, such as a build-up of salinity and waterlogging, declining soil-nutrient status, increased soil toxicity, and pest build-up. Longer time gains in productivity may be more dependent on sources of technical change, stemming both from research within and outside the agricultural sector, greater input-use efficiency related to increased human capital in agriculture, and possibly, infrastructural development. A constant R&D effort is the most effective way of sustaining productivity growth.

The need of the hour is context-based, client-oriented, problem-focussed research in a system perspective to improve its efficiency and efficacy. Till now, qualitative and informed judgements have formed the basis of problem definition. However, more concrete socioeconomic data are required to make a judicious research plan. Sustainability of natural resources should therefore be the major goal of any research.

References

Dholakia, R. H. and **Dholakia, B. H.** 1993. Growth of total factor productivity in Indian agriculture. *Indian Economic Review* 28(1):25-40.

Mruthyunjaya, and **Ranjitha, P.** 1998. The Indian agricultural research system: Structure, current policy issues and future orientation. *World Development* 26(6):1089-1101.

Mruthyunjaya, Ranjitha, P. and **Selvarajan, S.** 1995. Congruency analysis of resource allocation in Indian agricultural research system. Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi, India.

Ranjitha, P. 1996. An analysis of investment in agricultural research and extension in India. Ph.D. thesis, Indian Agricultural Research Institute, New Delhi, India.

4

Measurement of Total Factor Productivity Growth of Rice in India: Implications for Food Security and Trade

P Kumar[1] and D Jha[2]

Introduction

The Green Revolution phase in India was characterized by the widespread adoption of improved varieties, boosting productivity and resulting in a steady growth of food and nonfood crops. The first post-Green Revolution phase saw continued growth in returns to land through intensified use of chemical and labor inputs per hectare. The second phase began when input use was high, and further gains in productivity were largely dependent on increased efficiency of input use. Increasing the use of inputs, to a certain extent, allows the agricultural sector to move up along the production surface by increasing yield per unit of land. Their efficient use may also induce an upward shift in the production function to the extent that a technological change is embodied in them. It has been recognized that partial productivity measures such as output per unit of individual inputs have limited use as indicators of real change in productivity, as defined by a shift in production function. The Total Factor Productivity (TFP)

Kumar, P. and **Jha, D.** 2005**.** Measurement of total factor productivity growth of rice in India: Implications for food security and trade. Pages 25-35 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P. K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Division of Agricultural Economics, Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India.

[2] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

concept, which implies an index of output per unit of total factor inputs, measures these shifts or increases in output, holding all inputs constant.

During the past two decades or so, several studies on agricultural productivity in India have been conducted (Evenson and Jha 1973; Rosegrant and Evenson 1992), focusing on the estimate of the effect of technological change on agriculture as a whole or on total crop production. Owing to the nonavailability of input allocation data on individual crops, this may overestimate or underestimate the TFP for the crop sector to the extent that rates of technical change differ from crop to crop. Recent studies (Sidhu and Byerlee 1992; Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; Kumar et al. 1998) sought to measure TFP for individual crops, mainly rice and wheat. These studies showed that wherever growth in crop production had occurred, it had been driven by growth in yield. TFP growth is declining and future growth in production is input-based in many regions of the country. There has also been a reduction in unit cost of production and real prices. Agricultural research has contributed significantly to these trends, and returns to agricultural research have remained both stable and high since the 1970s. Significant inter-regional variations in TFP growth have been observed as Indian agriculture has undergone technological change across regions and among different crops. Rice, which is produced and consumed throughout the country, is an important crop which contributes 43% of the total foodgrain and also to exports.

This paper, which seeks to build on an earlier study on rice (Kumar and Rosegrant 1994), presents a more disaggregated perspective on changes in TFP across states in India. This perspective is valuable since the states are the units of development and policy action in India. The study also examines how changes in TFP will affect the possibility of generating an exportable surplus of rice.

Data and Methodology

Various methods have been used to compute TFP index (Christensen 1975). This study uses the Divisia-Tornqvist index to compute total output, total input, TFP, and input price indices for crop by state, using state averages of cost of cultivation data for principal crops, collected under the Comprehensive Scheme for the Study of Cost of Cultivation, Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. Grain and straw (byproducts) from the crop are included in the output index. Total output, total input, TFP, and input price indices are calculated as:

Total output index (TOI)

$$TOI_t / TOI_{t-1} = \pi_j (O_{jt}/Q_{jt-1})^{(R_{jt} + R_{jt-1})^{1/2}}$$

Total input index (TII)

$$TII_t / TII_{t-1} = \pi_i (X_{it}/X_{it-1})^{(S_{it}+S_{it-1})^{1/2}}$$

Total Factor Productivity index

$$TFP_t = (TOI_t / TII_t)$$

Input price index (IPI)

$$IPI_t / IPI_{t-l} = P_i (p_{it}/p_{it-1})^{(S_{it} + S_{it-1})^{1/2}}$$

where R_{jt} is the share of output j in total revenue, Q_{jt} is the value of output j, S_{it} is the share of input i in total input cost, X_{it} is input i and p_{it} is price of input i, all in period t (1981-82).

These equations provide the indices of total output, total input, TFP, and input price for the specified period 't'. The real cost of crop production was computed by deflating the cost of production by input price index.

Trends in TFP

Kumar and Rosegant (1994) reveal that for the country as a whole, TFP has been growing at about 1% since 1976. In general, the eastern states drag the national average down (Tables 1 and 2). While Bihar and Madhya Pradesh have recorded negative TFP growth, the figures for Orissa and West Bengal are significantly lower than the national average. Among the southern states, Karnataka lags behind. In the north, Haryana's performance is in sharp contrast to that of Uttar Pradesh or adjoining Punjab. Thus while the national estimate of about 1% TFP growth is respectable, there are substantial areas where technical change has not made much headway.

Table 1. Trends in indices of Total Factor Productivity (TFP) of rice in India.

State	1970	1980	1990	Growth	
Andhra Pradesh					
Input index	65.5	100.2	128.8	2.72	
Output index	63.8	99.7	143.4	4.16	
TFP	97.2	99.4	111.2	1.44	(34.6[1])
Assam					
Input index	88.0	96.7	106.3	1.28	
Output index	84.5	107.9	111.1	2.36	
TFP	96.3	112.0	104.2	1.08	(45.9)
Bihar					
Input index	84.0	100.2	106.4	1.28	
Output index	74.1	93.1	86.1	0.72	
TFP	88.1	92.9	80.9	-0.58	
Haryana					
Input index	-	99.9	151.0	3.24	
Output index		109.9	135.3	2.12	
TFP	-	110.4	89.4	-1.14	
Karnataka					
Input index	92.6	96.7	90.8	0.98	
Output index	102.2	92.3	101.7	1.28	
TFP	108.4	95.3	112.1	0.30	(23.6)
Madhya Pradesh					
Input index	86.5	99.5	135.9	2.43	
Output index	77.4	88.6	97.9	0.99	
TFP	89.3	88.9	72.2	-1.42	
Orissa					
Input index	93.1	99.9	111.7	1.11	
Output index	109.0	104.0	126.7	1.61	
TFP	117.1	104.0	113.6	0.49	(30.2)
Punjab					
Input index	45.5	91.4	160.8	7.53	
Output index	34.9	87.0	153.5	8.98	
TFP	76.5	95.2	95.6	1.45	(16.1)

Contd.

Table 1 — Contd.

Tamil Nadu					
Input index	91.1	97.2	-	2.05	
Output index	70.1	95.3		5.70	
TFP	77.2	97.6	-	3.62	(63.5)
Uttar Pradesh					
Input index	86.1	98.4	109.4	1.28	
Output index	89.4	103.6	139.1	3.38	
TFP	104.0	105.3	126.7	2.09	(68.8)
West Bengal					
Input index	73.7	91.1	123.6	2.51	
Output index	79.3	95.4	149.9	3.12	
TFP	107.2	104.7	121.3	0.61	(18.8)

[1] Figures in parentheses are shares of TFP in output growth.

Table 2. Annual TFP rate of growth (%) for rice, India.

State	1971-80	1980-91	1971-91
Andhra Pradesh	-0.45	1.85	1.44
Assam	3.37	-1.67	1.08
Bihar	-0.53	-0.74	-0.58
Haryana	5.75	-2.14	-1.14
Karnataka	-3.29	3.30	0.30
Madhya Pradesh	-2.79	-1.28	-1.42
Orissa	-0.67	1.67	0.49
Punjab	2.38	0.39	1.45
Tamil Nadu	3.62	-	-
Uttar Pradesh	1.91	2.77	2.32
West Bengal	0.13	1.58	0.60

Though it is hazardous to attempt an interpretation of short-term trends in TFP series, nevertheless Table 2 shows some important trends between the 1970s and the 1980s. For example, growth in TFP improved in some states (Andhra Pradesh, Karnataka, Orissa, Uttar Pradesh, and West Bengal) and deteriorated in others (Bihar, Haryana, and Punjab). These trends highlight two points. Firstly, that research challenges remain with there being no scope for complacency. The high growth in Punjab and Haryana in the past may not be sustained if further technological improvements do not occur. Secondly, it is essential for a country as diverse as India to cover a varied research portfolio.

Impact on Real Costs of Production

Table 3 shows impact in terms of changes in real cost of production in selected states. In Andhra Pradesh, Punjab, Uttar Pradesh, and West Bengal, costs have been declining at 2% or more per year. Bihar, Haryana, and Madhya Pradesh have been problematic states where costs have been rising. Significant changes have taken place over time. States like Bihar, Karnataka, Madhya Pradesh, Orissa, and West Bengal too started showing a decline in cost in the 1980s. These results are along expected lines and support earlier results.

Returns to Research

Research is an important determinant of productivity change. Table 4, which shows the impact of research in different states using results from Kumar and Rosegrant (1994), indicates high payoffs to research in all states. The marginal internal rate of return (MIRR) varies from about 32 % in Karnataka to 74% in Uttar Pradesh.

Table 3. Annual growth rate (%) of rice production in India in real cost (at 1981-82 prices).

State	1971-80	1980-91	1971-91
Andhra Pradesh	-0.48	-2.80	-1.97
Assam	-3.45	1.09	-1.12
Bihar	2.51	-1.20	0.50
Haryana	-5.67	1.43	0.40
Karnataka	3.19	-4.69	-1.80
Madhya Pradesh	2.81	-0.53	0.13
Orissa	1.40	2.88	-1.77
Punjab	-2.68	-1.28	-2.45
Tamil Nadu	-4.55	-	-
Uttar Pradesh	-5.33	-2.67	-2.61
West Bengal	0.54	-3.39	-1.74

Table 4. Estimated marginal value product (EMVP) and marginal internal rate of return (MIRR) to investment in rice research, India.

State	EMVP (Rs)	MIRR (%)
Andhra Pradesh	17.9	55.2
Assam	28.7	63.3
Karnataka	3.2	31.7
Orissa	9.1	44.8
Punjab	7.8	42.8
Tamil Nadu	22.5	59.0
Uttar Pradesh	50.2	74.0
West Bengal	16.8	54.2

Supply-Demand Analysis

Supply of Rice

Based on an integrated dynamic supply model, Kumar and Rosegrant (1997) projected the supply of rice under two extreme scenarios of TFP growth: (i) continuing growth in TFP at a constant (historical) rate (1.3%), and (ii) future decline in TFP as observed in the recent past. As seen in Table 5, in the year 2020, domestic supply of rice is estimated to reach 121-134 Mt. Loss in rice supply will be of about 14 Mt in 2020 due to deceleration in TFP.

Table 5. Domestic supply of rice at domestic prices, India.

Year	Constant growth in TFP (million tons)	Deceleration in growth in TFP (million tons)	Loss in supply due to deceleration in TFP (%)
1995	79.8	79.5	0.4
2000	89.1	87.5	1.8
2005	98.7	94.7	4.1
2010	109.3	102.5	6.2
2020	134.0	120.5	10.1
Annual growth in rice supply (%), 1995-2020	2.1	1.7	

Source: Kumar and Rosegrant (1997).

Demand for Rice

Recently, Kumar (1998) made projections for rice demand using a food characteristic demand system by accounting for urbanization, regional variations in consumption patterns, shifts in dietary patterns and income distribution, limit on energy requirement, and changes in consumer tastes and preferences for food. The projections were made assuming that: (i) total income grows at 4 or 5 or 7% per year; (ii) population grows at 2% per year between 1991 and 1995, 1.9% between 1995 and 2000, 1.8% between 2000 and 2010, and 1.7% between 2010 and 2020; and (iii) the pace of urbanization will be consistent with recent historical trends. Apart from its demand for direct human consumption, rice is an increasingly important component required for feed, seed, industrial use, and wastage. The total domestic demand for rice is derived after adding these requirements to human consumption. The projections for domestic rice demand corresponding to the three scenarios of growth in GDP at constant prices are given in Table 6. In the year 2020, domestic demand for rice will be about 122 Mt. During 1995-2020, domestic demand for rice will grow at an annual compound growth rate of 1.9%.

Table 6. Projected domestic demand for rice in India.

Income growth (%)	Demand (Mt)				Growth during 1995-2020 (%)
	1995	2000	2010	2020	
4	76.8	85.4	103.7	122.4	1.88
5	76.9	85.4	103.6	122.1	1.87
7	77.0	85.6	103.7	121.9	1.85

Source: Kumar (1998).

Supply-Demand Gap

Looking at the supply and demand scenario (Table 7), it appears that the demand for rice will be met with an annual surplus of about 3.7 Mt by 2005. This will be so if TFP growth is maintained at 1.03%. In case of a deceleration in TFP, the demand for rice will exceed domestic production between 2010 and 2020. However, in an open world trade policy environment, the surplus is estimated at about 2 Mt annually during 1995-2010, given a deceleration in TFP growth. In view of this, there is a need to strengthen efforts to increase production by maintaining or increasing productivity.

Table 7. Supply-demand gap (in million tons) for rice in India.

	Domestic scenario			World scenario		
Year	**Supply**	**Demand**	**Gap**	**Supply**	**Demand**	**Gap**
Scenario: Constant growth in TFP						
1995	79.8	77.0	2.8	79.6	77.0	2.6
2000	89.1	85.6	3.5	90.2	85.6	4.6
2005	98.7	95.0	3.7	104.1	95.0	9.1
2010	109.3	103.7	5.6	117.0	103.7	13.3
2020	134.0	121.9	12.1	147.8	121.9	25.9
Scenario: Deceleration in TFP growth						
1995	79.5	77.0	2.5	79.6	77.0	2.6
2000	87.5	85.6	1.9	87.6	85.6	2.0
2005	94.7	95.0	-0.3	96.2	95.0	1.2
2010	102.5	103.7	-1.2	105.5	103.7	1.8
2020	120.5	121.9	-1.4	126.9	121.9	5.0

Source: Kumar (1998).

Conclusions and Research Issues

It is clear that despite the respectable national estimate of more than 1% growth in TFP, there has not been much technical change in marginal areas. Deceleration in TFP growth has been observed. Substantial trade in rice can take place from India only if TFP growth is maintained at about 1%, for which increased research investments are needed in several areas. Three issues should receive high priority in rice research: greater focus on rice productivity in eastern India, which essentially means rainfed (upland and lowland) rice, sustainability of irrigated rice production (in the rainy as well as postrainy season), and improving input-use efficiency in rice production. Greater emphasis should be laid on export markets. The extent to which these issues receive attention could very well determine the extent of growth in rice production in India.

The results of this study reiterate the need for greater investment in rice research. However, several complex conceptual issues have not been adequately captured by the kind of econometric analysis used in the study. For example, agricultural research has contributed to breaking the seasonal barrier in rice production and to a great extent the shift in rice area (in northwestern India or postrainy-season rice) has been driven by research. Secondly, a great deal of stability has been achieved in rice production by providing varieties tolerant to biotic and abiotic stresses. Finally, quality improvement has added to the value of production. All these contributions are subsumed under a residual TFP measure. It would be worthwhile to capture these impacts explicitly, which would lead to a more realistic assessment of research on productivity of rice. A more detailed analysis of rice production in different environments using disaggregated data may be a useful starting point.

References

Christensen, L.R. 1975. Concepts and measurement of agricultural productivity. *American Journal of Agricultural Economics* 57:910-915.

Evenson, R.E. and **Jha, D.** 1973. The contribution of agricultural research system to agricultural production in India. *Indian Journal of Agricultural Economics* 28(4):212-230.

Kumar, P. 1998. Food demand and supply projections for India.Agricultural Economics Policy Paper 98-01. New Delhi, India: Indian Agricultural Research Institute. 141 pp.

Kumar, P., Joshi, P.K., Johansen, C. and **Asokan, M.** 1998. Sustainability of rice-wheat-based cropping system in India. *Economic and Political Weekly* 33(53):A152-158.

Kumar, P. and **Mruthyunjaya.** 1992. Measurement and analysis of total factor productivity growth in wheat. *Indian Journal of Agricultural Economics* 47(3): 451-458.

Kumar, P. and **Rosegrant, M.W.** 1994. Productivity and sources of growth for rice in India. *Economic and Political Weekly* 29(53):A183-188.

Kumar, P. and **Rosegrant, M.W.** 1997. Dynamic supply response of rice and other major food crops in India. *Agricultural Economics Research Review* 10(1):1-27.

Rosegrant, M.W. and **Evenson, R.E.** 1992. Agricultural productivity and sources of growth in south Asia. *American Journal of Agricultural Economics* 74 (August):757-761.

Sidhu, D.S. and **Byerlee, D.** 1992. Technical change and wheat productivity in the Indian Punjab in the post-Green Revolution period. Working Paper 92-02, Economics. Mexico: Centro Internacional de Mejoramiento de Maíz y Trigo.

5

Hybrid Rice Research: Will it have an Impact on India's Rice Economy?

A Janaiah and M Hossain[1]

Background

Rice research has contributed substantially to achieving food security in India. Several studies have indicated high payoffs from it in India (Evenson and Mckinsey 1991; Evenson 1993; as quoted in Pingali and Hossain 1999; Kumar and Rosegrant 1994; Pal and Jha 1996; and Pingali et al. 1997). Growth in rice output was 3% per year during 1966-96, with the highest rate of growth (4.4%) achieved during the 1980s. Yield improvement was the major source of this growth, largely due to the widespread adoption of modern rice varieties in favorable irrigated environments (Barker and Herdt 1985; David and Otsuka 1994; Hossain 1996; Pingali et al. 1997). However, the demand-supply balance disappeared during the early 1990s when it was visualized that yield advances in rice, achieved through the Green Revolution, started eroding in the intensive irrigated rice systems. With the universal adoption of HYVs (Fig.1), the economically exploitable yield of the existing HYVs of rice has almost reached the technical optimum in irrigated rice systems.

Janaiah, A. and **Hossain, M.** 2005**.** Hybrid rice research: Will it have an impact on India's rice economy? Pages 37-55 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Social Science Division, International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines. This paper is based on the first author's Ph.D. (Janaiah 1995) and his subsequent work on socioeconomic evaluation of hybrid rice in India conducted at the Directorate of Rice Research.

Figure 1. Rice-paddy yield and adoption of HYVs in irrigated rice system in India (1970-95).

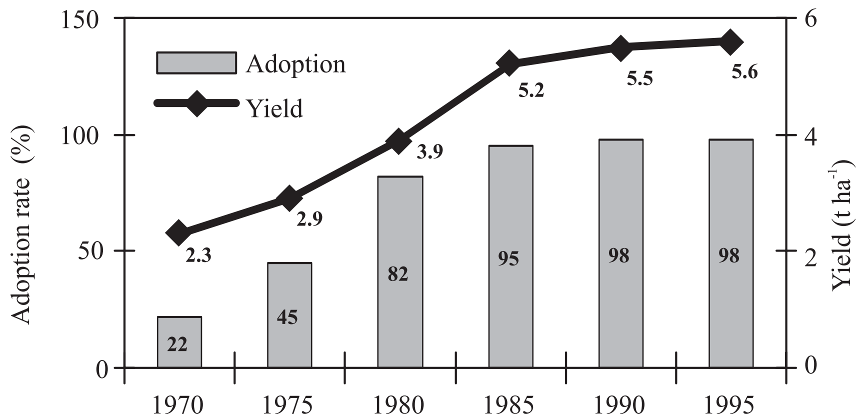
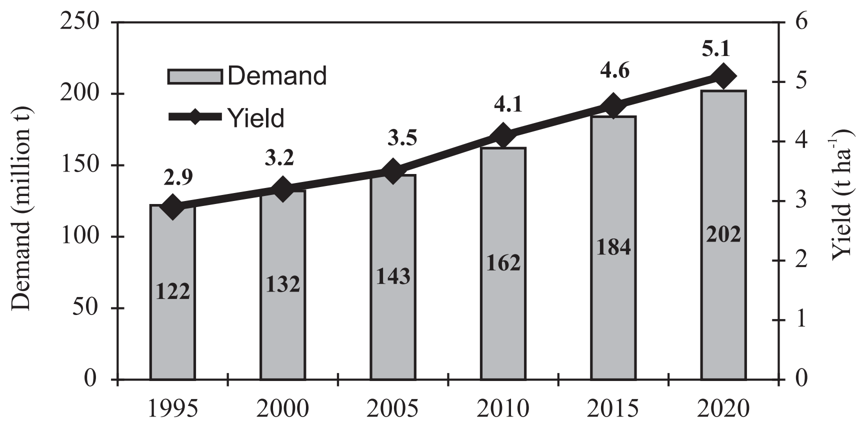


Figure 2. Projected demand and required yield level for rice-paddy in India.



However, with rising population and income levels and growing export opportunities in the post-World Trade Organization (WTO) era, there has been an increase in demand for rice. It is estimated that the demand for rough rice will reach about 162 million tons by 2010 and 202 million tons by the year 2020

(Bhalla 1995). The average yield of rough rice will have to increase by about 75% over the next 20 years in order to meet the demand (Fig. 2).

Hybrid rice, which greatly contributed to increases in rice production in China (Lin 1994; Virmani et al. 1998), was considered by policymakers and research managers as an option to shift the yield frontier upward in the irrigated environments. This paper reviews the current status of hybrid rice research in India, and the targets and expectations in India's economy. It also discusses farmers' experiences with hybrid rice adoption and draws implications for research priorities and policy options to further develop the hybrid rice program.

Hybrid Rice Research: A Historical Perspective

Rice is a self-pollinated crop with tiny florets. Each plant pollinates and fertilizes, producing itself in the same form of seeds of the same variety. The hybridization technique involves two separate parental lines. When the resulting offspring has one or more traits superior to that of the parents, it is termed heterosis or hybrid vigor.

It used to be thought impossible to produce rice hybrids using a procedure similar to the one used in cross-pollinated crops like corn, pearl millet, and cotton. However, long before any other country, Indian rice scientists, Sampath and Mohanty of the Central Rice Research Institute, Cuttack, reported the existence of cytoplasmic male sterility, indicating the possibility of developing hybrids in rice (Sampath and Mohanty 1954). A similar view was expressed during the early 1970s at IRRI (Athwal and Virmani 1972) and in the USA (Carnahan et al. 1972). Yet except for China, no other rice-growing country made serious efforts to explore the possibility of developing rice hybrids till the late 1980s.

Though research on rice hybridization was carried out at IRRI during 1970-72, it was discontinued since doubts were expressed about its commercial feasibility. Almost at the same time, research in the USA and Japan resulted in the development of rice hybrids with 10-15% yield advantage. However, these did not yield additional profits because the market price of existing high quality inbreds was higher than the yield advantage from hybrids, which were more susceptible to pests and required additional labor. As a result, the use of these hybrids was discontinued in these countries (Virmani 1993).

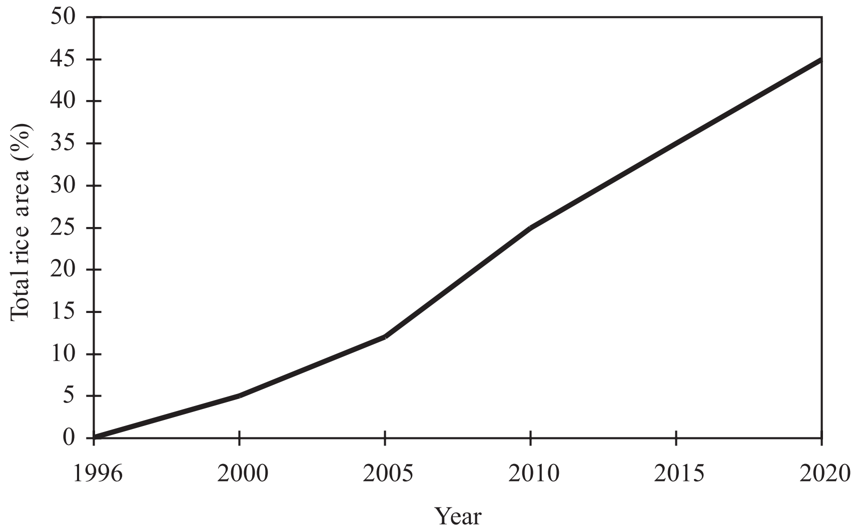
The Chinese hybrid rice program was initiated in Human Province in 1964. The first rice hybrid with marked yield potential was developed in 1974 and released for cultivation in 1976 after on-farm testing across the region (Lin 1991). By 1990, hybrid rice cultivation had expanded rapidly and covered 40% of the total rice area (Lin 1994). It was reported that hybrid rice in China had 15% yield gain over the inbreds but yielded a lower price in the market as compared to conventional HYVs (He et al. 1987). It was further reported that political pressure (government intervention) contributed substantially to the rapid adoption of hybrid rice in China, especially during the initial stage of the pre-reform period, when it was not unusual to promote technologies without considering their relative profitability and other economic rationale (Barker and Herdt 1985; Lin 1991; Lin 1992). Indications are that the area under hybrid rice cultivation has been declining in China since early 1990s (Virmani et al. 1998), with economic liberalization and farmers and consumers expressing their preferences.

The success of hybrid rice in China triggered off an interest at IRRI in the late 1970s and also in Asian countries. India was the first to initiate hybrid research in the early 1950s. However, systematic research efforts began only in the early 1980s in collaboration with IRRI. A goal-oriented program promoting research and development efforts in hybrid rice was initiated by ICAR in 1989. These efforts were strengthened in 1991 with support from the United Nations Development Program (UNDP), the Food and Agriculture Organization (FAO) of the United Nations, and IRRI with the initiation of a nationwide research network on 'Development and use of hybrid rice technology'. Under the network, 12 research centers all over the country under the coordination of the Directorate of Rice Research were involved in developing rice hybrids for irrigated systems and to improve seed production technologies. Ten years of rigorous research under this project has led to the release of 12 rice hybrids by the public sector. Another 7-8 hybrids were marketed by the private sector in India (DRR 1996-99; Rao et al. 1998).

Targets and Expectations

Research on hybrid rice was initially aimed at increasing yields in the intensive rice-rice systems of south India and the rice-wheat systems of north India. However, when it was realized in 1994-95 that the current hybrids were not suitable for the systems in these areas, the focus shifted to the favorable

Figure 3. Targeted adoption rate of hybrid rice in India.



environments of eastern India, especially the *Boro* ricelands (DRR 1997; Rao et al. 1998). Expectations rose and ambitious targets were set at the macro level to expand hybrid rice cultivation, as the late Prof. Dantwala predicted that hybrid rice would bring about another rice revolution in India (Barwale 1993).

It was projected that hybrid rice would cover nearly 12% of the area by 2005, 25% by 2010, 35% by 2015, and 45% by 2020 (Fig. 3) (Barwale 1993). Based on these projections, it was estimated that hybrid rice would meet nearly 35-40% of the additional rice demand by the year 2020 (Janaiah and Ahmed 1996). It was also expected that the technology would generate huge employment opportunities for female workers through hybrid seed production.

Early Experiences with Hybrid Rice Adoption

An ex-ante assessment of the potential of hybrid rice in India based on data from on-farm trials (1992-93 and 1993-94) revealed 12% yield gains over the prevalent inbred varieties. However, rice hybrids tested in the on-farm trials were not readily acceptable to farmers due to their poor grain quality, as indicated by their lower output price in the market, additional cost, and insufficient resistance to major pests and diseases (Janaiah 1995). Farmers' perceptions during on-farm testing also indicated that poor grain quality would constrain large-scale adoption of this technology in India. Many of the currently-released rice hybrids are those which were tested in on-farm trials at that time. Five years after the release of the first rice hybrid in Andhra Pradesh (1993-94 dry season), apprehensions were raised about their impact on India's rice economy in view of their declining adoption after 1996.

The major issues being raised in the context of the diffusion of hybrid rice technology are: (i) Is there a yield gain by cultivating hybrids over the best popular inbred rice varieties under farmers' fields?; (ii) Is hybrid rice seed production profitable?; (iii) Is hybrid rice production profitable?; (iv) Do consumers perceive hybrids as inferior to inbreds with regard to quality?; and (v) Is hybrid rice grain acceptable to traders and millers? These issues have been examined using farm household data from five major rice-growing states in India — Andhra Pradesh, Karnataka, Orissa, Tamil Nadu, and West Bengal. The data were collected from the sample of farmers (67 in Andhra Pradesh, 37 in Karnataka, and 50 each in Tamil Nadu, Orissa, and West Bengal) who grew rice hybrids during 1997-98. Purposive sampling was followed to select the respondents in view of the limited and scattered adoption of hybrid rice. Primary data were collected from a sample of 35 seed growers, 29 traders, and 27 millers from these states to study seed production and marketing issues.

Yield Gains

On an average, the yield gain from hybrids over that from the existing popular inbred varieties was about 16%. Hybrid rice outyielded inbred varieties under normal conditions in Andhra Pradesh, Karnataka, and West Bengal (Table 1). However in Orissa and Tamil Nadu, hybrids yielded less than the inbred varieties. Farm-level experience in China too had revealed that hybrids outyielded conventional varieties by 15% (He et al. 1987; Lin 1991; 1994). The yield advantage reported from on-farm trials in India was 12% during 1992-94. This was primarily due to a parallel shift in the production function of hybrid rice (Lin 1994; Janaiah 1995). Two major factors contributed to low yields of hybrid rice in Orissa. Firstly, concerns were expressed about the suitability/adaptability of hybrid rice introduced by the private sector and cultivated by almost all the sample farmers in Orissa. The hybrids were not systematically evaluated in on-farm trials before marketing. Secondly, according to the farmers, the hybrid seed was of poor quality, resulting in poor germination and low crop yields. In

Table 1. Average yield of hybrid and popular inbred rice varieties in select states of India, 1997-98.

State	Yield of hybrid ($t\ ha^{-1}$)	Yield of inbred variety ($t\ ha^{-1}$)	Yield gain ($t\ ha^{-1}$)	Yield gain (%)
Andhra Pradesh	8.8	7.2	1.6 ** (2.23[1])	22.2
Karnataka	8.3	7.0	1.3 ** (1.83)	18.6
Tamil Nadu	4.8	5.9	-1.1 * (1.41)	-18.6
Orissa	5.5	5.7	0.2 (1.46)	-3.5
West Bengal	7.8	5.1	2.7 *** (2.66)	52.9
India	6.9	5.9	0.9 ** (1.93)	16.1

[1] Numbers in parentheses are t-values.

* = Significant at 10% probability level.

** = Significant at 5% probability level.

*** = Significant at 1% probability level.

Tamil Nadu, the high incidence of pests and diseases was a major reason for low yields of hybrid rice.

The findings revealed that higher yield potential of hybrid rice was clearly demonstrated under farmers' fields, although with wider variability. The technology has the potential to increase rice yields further by about 16% under normal farm conditions in irrigated systems if seed quality is ensured and the hybrids are grown where biotic stresses are minimal.

Profitability of Hybrid Rice Seed Production

Reasonably priced and easily available quality seed is crucial for the success of hybrid technology. The success of hybrid crops like corn, pearl millet, sorghum, sunflower, etc., clearly demonstrates that hybrid seed production and distribution need to be economical and efficient to ensure large-scale adoption of the technology in any country.

Hybrid rice seed production is a highly knowledge-intensive process fraught with great risk from poor synchronization of parental lines, vagaries of weather, etc. Therefore, farmers won't warm up to it unless it is more profitable than cultivating inbred varieties, and the additional profit compensates for the risks and skills involved. The cost-return profile for hybrid rice seed production is summarized in Table 2. Among all the cost components, labor alone accounted for about 48% of total input cost because of the additional labor required in seed production. The cost of female parental line seed (A-seed) and gibberelic acid (GA3, additional inputs) accounted for an additional 9% of the total cost. Put together, additional inputs alone accounted for 48% of the total cost. The average cost of hybrid seed production was Rs 20.65 kg^{-1}. The private sector procured hybrid seed from seed growers at Rs 35 kg^{-1} while public sector agencies like the National Seeds Corporation (NSC) and Andhra Pradesh State Seeds Development Corporation (APSSDC) procured it at Rs 40-45 kg^{-1}. At the average procurement price of Rs 40 kg^{-1}, hybrid rice seed production is 65% more profitable than inbred rice cultivation. Therefore, production of hybrid seed would not be a limiting factor in either the public or private sectors in the future, once demand for it is created among commercial farmers.

Table 2. Cost return profile of hybrid rice seed production, 1997-98.

Items	Rs ha^{-1}
A-line seed	2,800
Fertilizers and manure	4,950
Gibberelic acid (GA3)	2,000
Labor (for 380 mandays)	12,600
Plant protection	600
Miscellaneous cost	2,850
Total input cost	25,800
Hybrid seed yield (kg ha^{-1})	1,250
Seed price (Rs kg^{-1}) paid to rice	40
Return to hybrid seed	50,000
Return to byproduct (male seed and straw)	8,500
Gross return	58,500
Net return	32,700
Unit cost of production (Rs kg^{-1})	20.65

The private sector sells the seed to farmers at Rs 80-100 kg^{-1}, suggesting a huge marketing margin in the distribution business. This margin may be justified at the initial stage in view of the thin and dispersed market for hybrid rice seed. Also, it may be difficult for the private sector to operate at a profit compared to alternative lines of business. However, the exorbitant price of hybrid seed (compared to less than Rs 10 kg^{-1} for inbred seed) would be a constraint to the expansion of hybrid rice cultivation by small and marginal farmers.

Consumers' Perception

A frequently raised concern about the prospects of large-scale adoption of hybrid rice in a country such as India is consumer acceptability of quality. Consumer acceptance determines price, which in turn determines revenue earned per unit of land at a given level of yield. Consumer acceptance plays a greater role in irrigated rice systems where farming is highly commercialized and a market-oriented farm enterprise. In agriculturally progressive regions, a major part of the rice produced goes to the market. Thus, a farmer's basic criterion for selecting a variety is consumer demand in the market and the consumer's willingness to pay a premium for the product. The present hybrid rice technology is basically targeted at highly progressive irrigated environments in order that there is an upward shift in the technology yield frontiers.

About 80-85% of the sample farmers who produced and consumed hybrid rice reported inferior grain quality compared to the popular inbred rice in terms of cooking, storage quality, and greater stickiness of cooked rice (Table 3). Nearly 66% of the sample farmers felt that hybrid rice has an unpleasant odor after cooking; hence its lower market price. The survey found that the price of hybrid rice was 11% lower than the price of inbred varieties.

Table 3. Farmer-consumer perception of hybrid rice grain used for domestic consumption.

Perceptions	Farmers (n=254)	
	Number	%
Poor grain quality	218	85.8
No taste	215	84.6
Poor cooking and keeping quality	230	90.6
Unpleasant post-cooking odor	168	66.1
Stickiness of cooked rice	206	81.1

Relative Profitability of Hybrid Rice Production

Adopting a new variety or hybrid in a market economy is basically an economic decision by a farmer as empirically proved by the pioneering work of Griliches (1957) on the adoption of hybrid corn in the USA. Product value and farm operating surplus are the major factors determining the reallocation of rice land from prevalent varieties to new ones. Three basic factors — yield gain, additional input cost (if any), and higher/lower market price — determine the relative profitability of a new variety/hybrid over an existing one. Average yield gain, input costs, and market price of grain were taken into account while computing economic returns from hybrid and inbred rice cultivation (Table 4). The market price for hybrid rice grain was 11% lower than that for inbred rice grain while the input cost was 19% higher mainly on account of the higher cost of hybrid seed and plant protection. The 16% yield gain was insufficient to compensate for the additional costs and lower output price of hybrid rice production. As a result, the operating farm surplus was about 5% lower, although statistically not significant, as compared to that in inbred rice production. If the market price of hybrid rice grain had been the same as in case of inbred rice grain, then the net return to hybrid rice production would have gone up by 12.3%, despite additional seed cost.

Table 4. Economic returns from hybrid and inbred rice cultivation, 1997-98.

Items	Hybrid	Inbred variety	Difference	Difference (%)
Grain yield (t ha^{-1})	6.90	5.95	0.96 (1.93[1])	16.1
Market price (Rs t^{-1})	4,189	4,692	-503 ** (1.88)	-10.7
Straw value (Rs ha^{-1})	1,375	1,645	-270 ** (2.01)	-16.4
Gross return (Rs ha^{-1})	30,320	29,562	758 (0.86)	2.6
Total input cost (Rs ha^{-1})	11,331	9,563	1768 (2.24)	18.5
Net return (Rs ha^{-1})	18,989	19,999	-1010 (1.08)	-5.1
Cost of production (Rs t^{-1})	1,640	1,607	33 (0.94)	2.1

[1] Figures in parentheses are t-values.
** = Significant at 5% probability level.

Another factor, largely related to technological traits, is the amount of heterosis. A sensitivity analysis was done to assess the minimum yield gain required under different scenarios (Table 5). Assuming that at least a 10% higher net return is needed to induce farmers to shift from the cultivation of inbreds to hybrids given current seed cost and output price, the minimum yield gain required of a hybrid would be 2.0 t ha^{-1} or nearly 34% higher than the present yield level (5.96 t ha^{-1}) (scenario 1). The farmer realizable yield potential of hybrid rice ought to be about 8 t ha^{-1}. Similarly, 2.5 t ha^{-1} of additional yield is required to ensure 20% higher profits from hybrid rice cultivation (scenario 2).

Scenarios 3 and 4 assume that the market prices (grain quality) of hybrid and inbred rice grain are equal. Under scenario 3, about 1.2 t ha^{-1} (20.2%) yield gain would be sufficient to generate 10% higher profitability, while under scenario 4, 1.6 t ha^{-1} (26.9%) yield advantage is required to ensure 20% higher profitability. Two implications arise out of this analysis: that there is a need to explore higher heterosis in hybrid rice technology, and that competitiveness or grain quality of hybrid rice ought to be improved.

Table 5. A sensitivity analysis of the minimum yield gain required for the cultivation of hybrid rice.

	Minimum yield gain required	
Perceptions	**t ha^{-1}**	**%**
Scenario 1: To obtain 10% higher net return with existing difference in market prices of hybrid and inbred variety	2.0	33.0
Scenario 2: To obtain 20% higher net return with existing difference in market prices of hybrid and inbred variety	2.5	42.2
Scenario 3: To obtain 10% higher net return with the same market price for hybrid and inbred variety grain	1.2	20.2
Scenario 4: To obtain 20% higher net return with the same market price for hybrid and inbred variety grain	1.6	26.9

Farmers' Perception

Farmers' own perceptions or their experiences with hybrid rice cultivation were elicited. Nearly 84% of the sample farmers said that they would not continue cultivation of hybrid rice. About 10% of the sample farmers who were willing to continue cultivation said that they would do so with the expectation of getting new hybrids with better quality in the near future (Table 6). Another 14% of the sample farmers felt that higher yield was the reason for continuing hybrid rice production. However, none of the farmers felt that hybrid rice grain was highly priced. Of the total sample, 11% (most of them in West Bengal) were in favor of continuing cultivating hybrid rice whose grain they felt was suitable for parboiling.

Table 6. Factors influencing farmers to continue cultivation of hybrid rice.

Factors	Farmers (n=254)	
	Number	%
Hope of better hybrids	25	9.8
Higher yield	36	14.2
Higher price	0	0
Better adaptability	16	6.3
Suitable for parboiling	28	11.0
Better resistance to pests/diseases	9	3.5

Low output price and low consumer demand, nonsuitability for domestic use, higher risks, nonavailability of pure hybrid seed, and unstable yield were the major reasons for discontinuing cultivation of hybrid rice, according to about 80% of the total sample (Table 7). In addition, formation of chaffy or sterile grains in the productive tillers (sometimes up to 40-50%) was also a major technology constraint. Although higher seed cost was also a constraint, it was the least important one. Poor grain quality was the major impediment to adoption.

Perception of Traders and Millers

The perception of traders and millers with at least 10 years of experience further confirmed hybrid rice's inadequate demand in the grain market (Table 8). About 90% of the respondents revealed that its grain quality was poor. Interestingly, about 93% of the traders and millers reported that head rice recovery (milling percentage) of hybrid rice was lower by 8-10% than that of popular inbred varieties. Traders were therefore reluctant to accept hybrid rice grain due to lack of demand from millers and consumers on account of poor grain quality. Thus it is very clear that most of the marketing constraints are related to quality-induced problems.

Table 7. Farmers' reasons for discontinuing cultivation of hybrid rice.

	Farmers (n=254)	
Reasons	**Number**	**%**
Low yield	46	18.1
Low price	212	83.5
Low market demand	208	82.0
Unfit for domestic use	204	80.3
High seed cost	164	64.6
High risks from pests and diseases	203	80.0
More chaffy or sterile grains	126	49.0
Lack of quality seed	207	81.5
High unstability	186	73.2

Table 8. Traders' and millers' perception of hybrid rice grain, 1997-98.

	Traders (n=29)		Millers (n=27)	
Perceptions	**Number**	**%**	**Number**	**%**
Lower head recovery	27	93.1	27	100.0
No demand from millers	26	89.7	-	-
No consumer demand	29	100.0	27	100.0
Poor grain quality	26	89.7	27	100.0
Low storability	21	72.5	27	81.5

Policy Implications

Researchable Issues

Value Addition Breeding. Higher yield potential alone does not induce commercial farmers to adopt a variety or hybrid. On the contrary, profitability gains do. Hybrid rice cannot make the desired impact on India's rice economy unless consumer demand for its grain is created through grain quality improvement. Therefore, future research should focus on breeding for quality besides yield improvement.

Enhancing Heterosis. Higher yield potential of new varieties or hybrids is equally important in view of the country's food security and growing resource constraints. The yield potential of hybrid rice (and other new varieties) ought to be targeted at least 35-40% higher under farm conditions. Efforts should be initiated to explore higher heterosis to develop new parental lines with higher yield potential.

Resistance Breeding. Lack of resistance to pests and diseases contributes to low yield, especially in the pest-endemic areas of Tamil Nadu. Hybrid rice is more sensitive to the timing of crop management practices (Janaiah 1999). Therefore, resistance breeding should be further strengthened.

Crop Management. Improved complimentary crop management methods are needed to exploit the full potential of hybrid rice. Rice hybrids suitable for direct seeding should be developed in view of the growing labor shortage in irrigated rice systems.

Policy Framework

It was recently debated whether the lack of policy support is contributing to the slow adoption of hybrid rice in India. A few policy implications are drawn here.

Is the Subsidy on Hybrid Seed Enough? One of the easily available policy options to promote a new variety or technology is to subsidize seed supply at the initial stage. Such an option was contemplated for hybrid rice promotion in states like Orissa and West Bengal. However, farmers in Orissa were unwilling to continue hybrid rice cultivation despite the nearly 50% subsidy on hybrid seed. Subsidy on hybrid seed alone does not add much value to rice production (Table 9). Since seed accounts for a small fraction of the cost of production, the possible impact of seed subsidy on hybrid rice promotion is rather meager.

Support Output Price: Is a Special Incentive Price Feasible? Another very important and powerful policy instrument to boost technology adoption is giving an output price incentive as experienced during the Green Revolution era. Usually, market forces determine the output price based on grain quality and consumer demand, especially in the case of foodgrains. An option being considered is whether government can take the initiative in providing equal pricing for hybrid and inbred rice grain. However, under the present policy environment, it is very difficult to do so. However, assuming that output price is the same for hybrid and inbred varieties, the farmer would find hybrid rice production more profitable, by about 12% with current level of yield gains (Table 10). A possible option, though limited in scope, is for the government to procure hybrid rice grain in certain notified areas at the support price fixed for fine varieties, and use the same for public distribution after parboiling, a process which to an extent minimizes quality-related constraints. This was experienced in Andhra Pradesh and West Bengal (Janaiah 1999). Similarly, procured hybrid rice grain can be put to alternative uses in the rice-based industry. However, such large-scale procurement is not feasible unless consumer demand improves.

Reorient Research Policy. More human resources need to be trained and involved in hybrid rice research in order to address the issues of value-addition breeding, resistance breeding, etc., besides frequent monitoring and evaluation of farmers' feedback. Greater involvement of biotechnologists, molecular geneticists, and plant protection specialists is essential.

Is a Policy on Seed Price Necessary? Some seed growers feel that the procurement price paid by private seed agencies is low. The difference between the price seed companies pay to seed growers (Rs 35 kg^{-1}) and the retail price (Rs 100-120 kg^{-1}) is too high. Therefore, the private seed sector should reduce the selling price of the seed and also pay a higher procurement price to seed growers. Protecting seed growers' interests through policy intervention may be neither desirable nor feasible in the long run. If the market for hybrid seed grows through wider adoption, the marketing margin will come down as traders reap economies of scale as a result of competition.

Training Seed Growers. Lack of experience in hybrid seed production is also responsible for low seed yields. Intensive training should be imparted to seed

Table 9. A sensitivity analysis of the subsidy required on hybrid seed for commercial cultivators.

(Rs/ha)

Components	Alternative scenarios		
	25% subsidy	50% subsidy	75% subsidy
Subsidy on hybrid seed	379	758	1, 136
Net seed cost	1, 136	757	379
Total input cost	10, 652	10, 573	10 ,195
Net return to hybrid rice	19, 368	19 ,747	20, 125
Net return to inbred rice	19 ,999	19, 999	19 ,999
Relative profitability of hybrid rice over inbred rice	-631	-252	126
Relative profitability of hybrid over inbred rice (%)	-3.2	-1.3	0.6

Table 10. A sensitivity analysis of the market price required for hybrid rice.

(Rs/ha)

Components		Existing output price	If the market price is the same for both hybrid and inbred grain		
			Without subsidy	25% subsidy	50% subsidy
Total input cost	Hybrid	11,331	11,331	10,952	10,573
	Inbred	9 563	9,563	9,563	9,563
Gross return	Hybrid	30,320	33,797	33,797	33,797
	Inbred	29,562	29,562	29,562	29,562
Net return	Hybrid	18,989	22,466	22,845	23,224
	Inbred	19,999	19,999	19,999	19,999
Relative profitability of hybrid over inbred		-1,010	2,467	2,846	3,225
Relative profitability of hybrid over inbred (%)		-5.1	12.3	14.2	16.1

growers, using currently available institutional strength. At present, there are about 270 Farm Science Centers (FSCs) and Farmer Training Centers (FTCs) located in almost every district in the country. Hybrid rice seed growers (public or private sector) should be trained. The private sector should volunteer to finance FSCs and FTCs so that they train their respective contract seed growers. At present, there is no such link between the private sector and FTCs or FSCs.

References

Athwal, D.S. and **Virmani, S.S.**1972. Cytoplasmic male sterlity and hybrid breeding in rice. Pages 615-620 *in Rice breeding* (Athwal, D.S. and Virmani, S.S., eds). Los Baños, Manila, Philippines: International Rice Research Institute.

Barker, R. and **Herdt, R.W.**1985. *The rice economy of Asia: Resources for the future*. Washington D.C. USA: Resources for the Future.

Barwale, B.R. (ed.) 1993. *Hybrid rice food security in India*, Madras, India: Macmillan India Limited.

Bhalla, G.S. 1995. Globalization and agricultural policy in India. *Indian Journal of Agricultural Economics* 50(1):7-26.

Carnahan, H.L., **Erickson, J.R., Tseng, S.T.** and **Rutger, J.N.** 1972. Outlook for hybrid rice in USA. Pages 603-607 *in Rice breeding: Outlook for hybrid rice in USA*. Los Baños, Manila, Philippines: International Rice Research Institute.

David, C.C. and **Otsuka, K.**1994. *Modern rice technology and income distribution in Asia*. (Boulder and London, eds.). Lynne Rienner Publishers, International Rice Research Institute, Los Baños, Manila, Philippines.

DRR (Directorate of Rice Research). 1996-99. *Progress reports of hybrid rice projects and AICRIP* (various issues). Hyderabad, Andhra Pradesh: Directorate of Rice Research.

DRR (Directorate of Rice Research). 1997. *Development and use of hybrid rice technology in India.* Project Report. Hyderabad, Andhra Pradesh: Directorate of Rice Research.

Evenson, R.E. 1993. Technological distance and rice productivity in India. Paper presented at the National Workshop on *Agricultural Research Evaluation: Methods and Applications*, 5-8 Mar 1993, National Academy of Agricultural Management, Hyderabad.

Evenson, R.E. and **Mckinsey, J.W.** 1991. Research, extension infrastructure and productivity change in Indian agriculture. *In Research and productivity in Asian Agriculture* (Evenson, R.E. and Pray, C.E., eds.). Ithaca, USA: Cornell University Press.

Griliches, Zvi. 1957. Hybrid corn: an exploration in the economics of technological change. *Econometrica* 25:501-522.

He Guiting, Zhu, X. and **Flinn, J.C.** 1987. A comparative study of economic efficiency of hybrid and conventional rice production in Jiangsu Province. *Oryza* 24:285-296.

Hossain, M.1996. Rice economy in India: Achievements, challenges and implications for technology development research. Paper presented at the *IRRI-Indian dialogue*, 28-29 Sep, New Delhi, India.

Janaiah, A. 1995. Economic assessment of hybrid rice potential in India: ex ante study. *Ph.D. thesis*. Institute of Agricultural Science, Banaras Hindu University, Varanasi, India.

Janaiah, A. 1999. Rice hybrids: can Indian farmers and consumers accept them? *Farmers and Parliament* 36(6):15-17.

Janaiah, A. and **Ahmed, M.I.** 1996. Impact of hybrid rice on India's food economy: some possible implications and policy issues. Paper presented at the *3rd International symposium on hybrid rice*, organized by ICAR-IRR, 14-16 Nov 1996, Hyderabad, India.

Kumar, P. and **Rosegrant, M.W.** 1994. Productivity and sources of growth for rice in India. *Economic and Political Weekly* 29 (53):183-188.

Lin, J.Y. 1991. The household responsibility system reform and adoption of hybrid rice in China. *Journal of Development Economics* 36:353-372.

Lin, J.Y. 1992. Hybrid rice innovation in China: A study on market demand induced technological innovation. *Review of Economics and Statistics* 24(1):14-20.

Lin, J.Y. 1994. Impact of hybrid rice on input demand and productivity. *Agricultural Economics* 10:153-164.

Pal, S. and **Jha, D.** 1996. *Funding agricultural research*. Policy Brief 3. New Delhi, India: National Centre for Agricultural Economics and Policy Research.

Pingali, P.L., Hossain, M. and **Gerpecio, R.** 1997. *Asian rice bowls: The returning crisis.* Oxon: CAB International, Wallingford and Los Baños, Philippines: International Rice Research Institute.

Pingali, P.L. and **Hossain, M.** (eds.) 1999. *Impact of rice research*. Thailand Development Research Institute, Bangkok and IRRI, Los Baños, Philippines.

Rao, N.G.P., Singh, Ambika, **Sivasubramanian, V., Murthy, K.S., Mukhopadhyay, A.N.** and **Abraham, C.C.** 1998. Rice research and production in India: Present status and a future perspective. *Quinquennial Review Report*. Hyderabad, Andhra Pradesh: Directorate of Rice Research.

Sampath, S. and **Mohanty, H.K.**. 1954. Cytology of semi-sterile rice hybrid. *Current Science* 23:182-183.

Virmani, S.S.1993. Global status of hybrid rice research and development. Pages 3-21 *in Hybrid rice food security in India* (Barwale, ed.). Madras, India: Macmillan India Limited.

Virmani, S.S., Siddiq, E.A. and **Muralidaran, K.** 1998. *Advances in hybrid rice technology*. Los Baños, Manila, Philippines: International Rice Research Institute.

6

Total Factor Productivity and Sources of Growth of Wheat in India

S Mittal and P Kumar[1]

Introduction

The introduction and rapid spread of high-yielding varieties (HYVs) in the late sixties and early seventies resulted in a phenomenal growth in output. More than 90% of wheat acreage in India is already under HYVs. During the past three decades, the country's wheat production has gone up sixfold, with an annual growth rate of 4.6%. It stood at 69 million tons in 1996-97 with 86% of the wheat area under irrigation. Wheat yield increased from 1242 kg ha^{-1} in 1967-71 to 2486 kg ha^{-1} in 1992-96 with an annual growth rate of 3.1%. Bihar, Haryana, Madhya Pradesh, Punjab, Rajasthan, and Uttar Pradesh are the major wheat-producing states, sharing 94% of the wheat produced. Uttar Pradesh accounts for one-third of the country's area. Nearly 98% of the area is under HYVs and 92% of it is under irrigation. Punjab and Haryana, the other major wheat-growing states, have 42% and 34% of the gross cropped area respectively.

Wheat production in the country registered an impressive 20% increase from 1990-91 to 1997-98, most of it coming from Uttar Pradesh, Madhya Pradesh, and Rajasthan. This paper estimates TFP for wheat in different time periods across different states. This perspective is valuable because states are the units for development and policy implementation in India. Implications of technology change on the real cost of production are examined and the sources

---

Mittal, S. and **Kumar, P.** 2005**.** Total factor productivity and sources of growth of wheat in India. Pages 57-68 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi 110 012, India.

of productivity growth are identified. Marginal rates of return to public investments in wheat research are also computed.

Methodology and Data

Increased use of inputs to a certain extent allows the agricultural sector to move along the production surface. The use of modern inputs may induce an upward shift in production function to the extent that a technological change is embodied in them. However, it has long been recognized that partial productivity measures such as output per unit of individual inputs are of limited use as indicators of real productivity change as defined by a shift in production function. The TFP concept, which implies an index of output per unit of total inputs, measures these shifts in output holding all inputs constant. Thus, TFP measures the increase in total output not accounted for by increases in total inputs. Various methods have been used to compute the TFP index (Christensen 1975).

Measuring TFP

This study uses the Divisia-Tornqvist index to compute total output, total input, TFP and input price indices for crops. Grain and straw from crops are included in the output index. Farm harvest prices are used to aggregate the outputs. Land, seed, fertilizer, manure, pesticide/herbicides, human labor, animal labor, machine labor, irrigation, land rental, and interest are included in the input index. Inputs are aggregated using farm rental prices. Total output, total input, TFP and input price indices, calculated for wheat, are as follows:

Total output index (TOI)

$TOI_t/TOI_{t-1} = \Pi_j(Q_{jt}/Q_{jt-1})^{(R_{jt}+R_{jt-1})^{1/2}}$

Total input index (TII)

$TII_t/TII_{t-1} = \Pi_i(x_{it}/x_{it-1})^{(S_{it}+S_{it-1})^{1/2}}$

Total factor productivity index (TFP)

$TFP_t = (TOI_t / TII_t) * 100$

Input price index (IPI)

$IPI_t/IPI_{t-1} = \Pi_i(p_{it}/p_{it-1})^{(S_{it}+S_{it-1})^{1/2}}$

where, R_{jt} is the share of output j in total revenue

Q_{jt} is the value of output j

S_{it} is the share of input i in total input cost
x_{it} is input i and
p_{it} is the price of input i, all in period t.

By specifying TOI_{t-1}, TII_{t-1} and IPI_{t-1} equal to 100 in the initial year, the above equations provide the total output, total input, total factor productivity and input price indices for the specified period 't'. The real cost of crop production is computed by deflating the cost of production by input price index. The statewise indices are computed for each crop. They are normalized corresponding to the state dominating in crop production. The TFP measures technology change or a shift in the production function due to technical progress under the assumptions of competitive behavior, constant returns to scale, Hicks-neutral technological change and input-output separability.

The past two decades have seen several studies on agricultural productivity in India (Evenson and Jha 1973; Rosegrant and Evenson 1992; Desai and Namboodiri 1998). These studies estimate the effect of technological change for agriculture as a whole or total crop production. Owing to the nonavailability of input allocation data on individual crops, the TFP for the crop sector may be underestimated or overestimated to the extent that rates of technical change differ across crops. Recent studies (Sidhu and Byerlee 1992; Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; Kumar et al. 1998) sought to measure the TFP for individual crops, mainly rice and wheat. These studies showed that growth in crop production had been driven by yield growth. TFP growth has been declining and future production growth is input based in many regions of the country. There has been a reduction in unit cost of production and real prices. Agricultural research has contributed significantly and substantially to these trends, and returns to agricultural research have been both stable and high since the 1970s (Kumar and Rosegrant 1994; Jha and Kumar 1988; Lau and Yotopoulos 1972). However, marked diversities in agroclimatic conditions, resource endowment and population density are expected to lead to uneven agricultural development across regions. This coupled with differences in technological change across regions, could result in significant inter-regional variations in TFP growth.

Marginal Returns to Research Investment

Using the elasticity of TFP with respect to research stock (R), one can easily estimate the value of marginal product (EVMP) of research stock as:

$EVMP (R) = b_r * (V/R)$

where, R is the research stock, V is the value of production associated with TFPI and b is the TFP elasticity of research stock estimated in the equation on TFP determinants .

The benefit stream is generated under the assumption that the benefit of investment made in research in period t-i will start generating benefit after a lag of five years, at an increasing rate the next nine years, remain constant in the next nine years and, thereafter start declining. Using timing weights estimated by Evenson and Pray (1991), an investment of one rupee in year t-i will generate a benefit equal to 0.1 *EVMP in year t-i+6, 0.2*EVMP in year t-i+7.... and so on, and it will be 0.9* EVMP in year t-i+14. After this, the benefit will be equal to EVMP up to t-i+23. Then the benefit for year t-i+24 onwards will be equal to 0.9*EVMP in t-i+25. This benefit stream can then be discounted at the rate of say ‘r’, at which the present value of the benefit is equal to one. Thus ‘r’ is considered as the marginal internal rate of return to public research investment.

Data

Farm-level data on yield, use of inputs and their prices collected under the “Comprehensive scheme for the study of cost of cultivation of principal crops”, of the Directorate of Economics and Statistics (DES), Government of India (GOI), were used in the analysis. The period for which data were available varied across crops and states. The maximum period for which data were available was from 1970-71 to 1995-96. Missing input and price data for a particular year were interpolated based on trends in the available data. State-level time series data on area, yield, production, irrigation and HYV area for the crops under study were taken from various published DES reports. Data on research and extension stock investment by crops for various states compiled earlier by Mckinley et al. (1991) and updated by Kumar (1999) were used.

Results and Discussion

The indices for wheat are normalized by Uttar Pradesh indices for the triennium average of 1971-73. Normalization is done to provide a comparative picture across states. The input index during 1972-95 increased by 2.6% in (Table 1) Punjab, 3.4% in Haryana, 3.1% in Madhya Pradesh, 2.4% in Uttar

Table 1. Trends in indices of input, output and total factor productivity of wheat in India.

	Index (%)[1]					Annual growth rates	
State	**1975**	**1980**	**1985**	**1990**	**1995**	**%**	**Period**
Haryana							1972-95
Input index	95.4	141.0	156.1	178.6	201.3	3.43**	
Output index	82.7	128.8	163.7	214.1	253.4	5.17**	
TFP	86.0	91.5	104.6	119.8	125.5	1.74**	(33.7[4])
Himachal Pradesh							1983-87
Input index	na[2]	na	130.5	na	na	-1.35*	
Output index	na	na	137.7	na	na	-1.96ns[3]	
TFP	na	na	105.3	na	na	-0.62ns	(negative)
Madhya Pradesh							1972-95
Input index	123.7	126.8	152.1	189.6	237.2	3.14**	
Output index	123.8	148.7	160.7	182.4	258.0	3.06**	
TFP	99.5	117.0	105.3	95.6	108.6	-0.08ns	(negative)
Punjab							1972-95
Input index	103.8	131.1	154.0	162.8	172.5	2.61**	
Output index	92.1	118.8	161.0	186.1	199.5	3.94**	
TFP	89.1	90.3	104.1	114.1	115.3	1.33**	(33.8)
Rajasthan							1976-94
Input index	125.0	133.1	130.6	141.5	198.1	1.69**	
Output index	112.2	137.3	137.0	156.5	269.9	3.48**	
TFP	89.1	102.8	105.5	110.1	135.8	1.79**	(51.4)
Uttar Pradesh							1973-90
Input index	112.9	122.8	138.5	158.2	na	2.38**	
Output index	105.3	138.0	173.0	197.6	na	4.02**	
TFP	92.6	111.9	124.8	124.6	na	1.64**	(40.8)

Contd.

Table 1 — Contd.

India							1972-95
Input index	113.1	127.6	144.4	165.5	205.3	2.86**	
Output index	105.5	136.2	163.8	190.9	241.1	3.78**	
TFP	92.5	106.7	113.6	115.6	117.6	0.92**	(24.3)

[1] Index numbers are the averages for the triennium ending 1975, 1980, 1985, 1990 and 1995. The indices are normalized by Uttar Pradesh indices for the triennium average of 1971-73.

[2] na = Data not available.

[3] ns = Statistically not significant.

[4] Figures in parentheses are the shares of TFP in total output.

**= Significant at 1% probability level; *= Significant at 5% probability level.

Pradesh, and 1.7% in Rajasthan. With greater use of inputs and technological change, output increased by 3-5% per year. On the whole, the TFP index for wheat has risen by about 1.3% in Punjab, 1.7% in Haryana, 1.8% in Rajasthan and 1.6% in Uttar Pradesh, while the increase has been negligible in Madhya Pradesh. In Madhya Pradesh, an increase in TFP was observed after the adoption of HYVs; with a decline in the latter period. These fluctuations resulted in negative and insignificant growth in TFP for wheat. A steady rise in TFP indices was observed in the major wheat-growing states of Haryana, Punjab and Uttar Pradesh with the introduction of modern wheat varieties in the late 1960s and early 1970s. Fluctuations in TFP indices were due to weather fluctuations in Rajasthan, Madhya Pradesh and Himachal Pradesh. TFP growth rates in Punjab, Haryana, Uttar Pradesh and Rajasthan are much higher than those in India, Pakistan (around 1%) and post-war US agriculture (around 1.5%) (Rosegrant and Evenson 1992). Productivity growth or technical change is responsible for 34-51% of the total output growth in the frontline states. The average TFP growth for India is estimated to be 0.92% per year. TFP accounts for nearly 1-4.3% of the total wheat output growth in India.

Real Cost of Production

The nominal cost per unit of crop output has been showing an upward trend in spite of rapid growth in yield due to technical change. However, it must be assessed whether this increase came mostly from an increase in prices of farm inputs at a rate higher than the rise in productivity or was it due to higher use of inputs in real terms for obtaining the same yield. This question was examined by assessing cost of production at constant prices. The unit cost of production was deflated by an input price index to obtain the cost of production at constant prices. The annual growth rates in real cost of production (RCP) computed for wheat are presented in Table 2. The real cost of production has shown a decline in nearly all the states. While new technologies have increased the use of modern inputs, increase in crop yields have been much higher than increase in real input costs. Hence, the cost per unit of output has declined steadily at an annual rate of 2.2%. As expected, with rapid technological change, total cost of production per quintal of wheat per year decreased dramatically (2-3%) in Haryana, Punjab, Uttar Pradesh and Rajasthan.

The decline in unit cost of production due to technological change and input subsidies resulted in substantial increases in the marketed surplus of wheat. It contributed to food security mainly by inducing a sharp decline in real prices (2.2% annually). Many of the benefits of higher efficiency in the use of inputs and lower unit costs of production that technological change has generated were shared by both farmers and consumers. The farmers gained because of lower per unit cost of production, while the consumer benefited from the lower prices.

Table 2. Trends in the real cost of production of wheat in India.

	Index (%)[1]					Annual growth rates	
State	**1975**	**1980**	**1985**	**1990**	**1995**	**%**	**Period**
Haryana	96.1	96.8	75.5	56.9	51.1	-3.25**	1972-95
Himachal Pradesh	na[2]	na	95.2	na	na	0.76ns[3]	1983-87
Madhya Pradesh	110.9	86.1	82.1	84.4	74.8	-1.29**	1972-95
Punjab	96.2	90.8	70.2	59.3	57.7	-2.81**	1972-95
Rajasthan	97.0	81.7	67.5	65.3	50.3	-3.20**	1976-94
Uttar Pradesh	101.8	93.2	77.4	72.4	na	-2.17**	1973-90
India	102.4	90.6	76.4	70.3	61.8	-2.20**	1972-95

[1] Index numbers are averages for the triennium ending 1975, 1980, 1985, 1990 and 1995. The indices are normalized by Uttar Pradesh indices for the triennium average of 1971-73.

[2] na =Data not available.

[3] ns = Statistically not significant.

** = Significant at 1% probability level.

TFP Decomposition

TFP index varies not only across states but also over time. The factors that account for changes in TFP include changes in technology, institutional reform, infrastructural development, human resource development, etc. Crop-related technological changes which are often embodied in the seed adopted by farmers, can be divided into two components, the "quality" and the "quantity" of technologies adopted. The former represents either the cost of production or the yield-improving technologies or both, while the latter is the area over which the technology adopted is used. The "quality" reflects the research output that is determined by investment in research. It is an exogenous variable. The "quantity" of technology is linked to adoption and is affected by extension, literacy, infrastructural development and on-farm and off-farm characteristics. The adoption of modern technologies is a choice-variable for farmers; therefore it must be considered an endogenous variable in the TFP model. The simultaneous model is specified as:

TFP = f (RES, HYV, RAIN, STW, DUMMY)

HYV = g (EXT, LIT, PVELECT, NSIRR, DUMMY)

where,

RES	=	Research stock of the crop (Rupees per ha).
EXT	=	Extension stock (Rupees per hectare of net crop area).
RAIN	=	Jul-Sep rain (mm).
STW	=	Share of groundwater in total irrigation.
HYV	=	% of the crop area under HYVs.
LIT	=	% of total rural population that is literate.
PVELECT	=	% of villages electrified.
NSIRR	=	% of net sown area under irrigation (net irrigated area/net cultivated area).
DUMMY	=	Dummy for region.
DW	=	Dummy for western states (Madhya Pradesh, Rajasthan) of India.
DN	=	Dummy for northern states (Himachal Pradesh, Punjab, Haryana, Uttar Pradesh) of India.

The estimated model is specified in double log linear form. The three-stage least square (3SLS) method was used to estimate the model using state-level cross-section-cum-time series data. The econometric estimates of the model are presented in Table 3. The R-square of the TFP structural equation was low (0.22) and the R-square of the adoption of HYVs structural equation was quite high (0.77). The estimated R^2 for the system was 0.81.

Table 3. A simultaneous model of total factor productivity decomposition for wheat in India, 1971-95 (3SLS).

Dependent variables[1]	Variable[2]	Coefficient	't' value
TFP	CONST	4.1960	14.3
	RES	0.0423	3.7
	HYV	0.0258	0.8
	STW	0.0858	1.3
	DUMMY		
	DN	-0.0504	1.6
R-Square		0.20	
HYV	CONST	2.6117	3.9
	RES	0.0638	1.6
	EXT	0.0292	1.0
	LIT	-0.3904	1.6
	ELECT	0.4242	5.3
	NSIRR	0.3221	5.4
	DUMMY		
	DN	0.1031	1.3
R-square		0.77	
System R-square		0.81	

[1] The dependent variable is the log of the total factor productivity index. All variables are specified in logarithms, except those defined in percentage term, which enter linearly (HYV, LIT, STW).

[2] CONST = Intercept term; RES = Research stock of wheat (Rs ha^{-1}); HYV = % of the crop area under HYVs; STW = Share of groundwater in total irrigation; DN = Dummy for northern states of India; EXT = Extension stock (Rs per hectare of net crop area); LIT = % of total rural population that is literate; ELECT= % of villages electrified; and NSIRR = % of net sown area under irrigation (net irrigated area/net cultivated area).

The estimated equations of the model enable us to measure the indirect impact of rural infrastructure (electrification and rural education) on crop productivity. Research, extension, literacy, rural electrification and irrigation are significant determinants influencing the adoption of HYVs. Literacy showed a negative impact on the adoption of HYV in wheat. This finding was supported by earlier studies (Kumar and Mruthyunjaya 1992). It is possible that the terms of trade may have moved in favor of the nonagricultural sector, resulting in the migration of rural educated youth to the nonagricultural sector. Future growth in TFP requires that price parity be maintained in favor of agriculture. This will help educated rural youth remain in agriculture and contribute their knowledge for the efficient use of inputs. This will result in higher TFP growth.

The level of adoption of HYVs for wheat has already reached the ceiling level, particularly in the frontline states. However, research investment has a direct and positive bearing on TFP. It is needed to evolve new varieties which can break the current yield ceiling in irrigated regions. Thus research investment leads to increase in TFP through its impact on variety turnover and efficient use of inputs. The results emphasize the necessity of maintaining the growth in public investment in crop research and development. Research has a direct and indirect effect on TFP, while extension, literacy, electrification, and irrigation have an indirect effect on it.

Using the elasticities of TFP with respect to the positive and significant variables and their growth rates, each variable's contribution to TFP growth was computed (Table 4). It was observed that in the case of wheat, public research accounted for more than half the TFP growth followed by tubewell irrigation (36%) and rural electrification (6.8%).

Table 4. Sources of total factor productivity growth of wheat, India.

Sources	Annual growth rate (%)	Elasticity of TFP	Percent share of TFP
Public research	11.00	0.0439	54.5
Extension	11.62	0.0008	1.0
Literacy	3.06	-0.0101	-
Rural electrification	5.55	0.0109	6.8
Tubewell irrigation	3.68	0.0859	35.7
Irrigation	2.04	0.0083	1.9

Research investment is a significant determinant in the growth of TFP for wheat. The marginal rates of return to public investment in wheat research are given in Table 5. During 1972-95, a Rupee's investment in research stock generated on average an additional income of Rs 35.4, indicating high rates of returns to public investments. The marginal internal rates of return to agricultural research are estimated to be 67% in wheat. Returns to research for wheat have increased over time and peaked during 1981-85. Thereafter, declining returns were observed.

Table 5. Estimated value of the marginal product of research stock and marginal internal rate of return to investment in wheat research in India.

Period	Estimated value of marginal product (Rs)	Marginal internal rate of return (%)
1972-75	32.57	65.6
1976-80	32.53	65.5
1981-85	44.61	71.5
1986-90	36.48	67.8
1991-95	25.48	61.1
1972-95	35.35	67.2

Conclusions

The study revealed significant inter-regional variations in the TFP growth of wheat in India. Research, extension, literacy, rural electrification and irrigation were the most important instruments of growth in TFP. The results of the study have important policy implications for the allocation of scarce public resources to research, extension, education and rural electrification. This will help achieve low-cost production growth, food security and poverty alleviation.

References

Christensen, L.R. 1975. Concepts and measurement of agricultural productivity. *American Journal of Agricultural Economics* 57:910-915.

Desai, B.M. and **Namboodiri, N.V.** 1998. Determinants of total factor productivity in Indian agriculture. *Economic and Political Weekly* 32 (52).

Evenson, R.E. and **Jha, D.** 1973. The contribution of agricultural research system to agricultural production in India. *Indian Journal of Agricultural Economics* 28(4):212-230.

Evenson, R.E. and **Pray, C.E.** 1991. *Research and productivity in Asian agriculture*. Cornell, USA: Cornell University Press.

Jha, D. and **Kumar, Praduman.** 1988. Rice production and impact of rice research in India. Pages 279-291 *in Impact of rice research* (Prabhu L, Pingali and Mahabub Hossain, eds.). TDRI and International Rice Research Institute.

Kumar, Praduman. 1999. Country study on total factor productivity in the green revolution India: State-wise analysis. USA:Yale University.

Kumar, Praduman, and **Mruthyunjaya.** 1992. Measurement and analysis of total factor productivity growth in wheat. *Indian Journal of Agricultural Economics* 47(3):651-658.

Kumar, Praduman and **Rosegrant, M.W.** 1994. Productivity and sources of growth for rice in India. *Economic and Political Weekly* A183-188.

Kumar, Praduman, Joshi, P.K., Johansen, C. and **Asokan, M.** 1998. Sustainability of rice-wheat based cropping system in India. *Economic and Polilical Weekly* 33 (September 26):A-152-158.

Lau, L.J. and **Yotopoulos, P.A.** 1972. Profit, supply and factor demand functions. *American Journal of Agricultural Economics* 54(1):11-18.

McKinley, James, Evenson, Robert E. and **Judd, M. Ann.** 1991. *Data Appendix*. mimeo, Economic Growth Centre, USA:Yale University.

Rosegrant, M.W. and **Evenson, R.E.** 1992. Agricultural productivity and sources of growth in Asia. *American Journal of Agricultural Economics* 74:757-761.

Sidhu, D.S. and **Byerlee, D.** 1992. Technical change and wheat productivity in the Indian Punjab in the post-green revolution period. Economics Working Paper 92-02, Mexico, D.F.: International Wheat and Maize Improvement Centre.

7

Impacts of Improved Sorghum Cultivars in India

U K Deb,[1] M C S Bantilan[2] and B V S Reddy[2]

Introduction

Sorghum (*Sorghum bicolor*) is the third most important cereal crop in India after rice and wheat. During 1995-98, it was grown over 11.2 million hectares with a total production of 9.4 million tons (CMIE 2000). Though the area under sorghum in India has declined over time, production has remained more or less constant due to increase in yield. During 1995-98, Maharashtra ranked first in terms of area under sorghum and its production (Table 1), followed by Karnataka, Madhya Pradesh and Andhra Pradesh.

Indian farmers have plenty of experience in growing improved sorghum cultivars. In fact, the first sorghum hybrid, CSH 1, was released in India in 1964. By 1998-99, 71% of the total sorghum area was under improved cultivars. More than 180 improved sorghum cultivars are now available for cultivation. Often, public and private research institutes in India have developed these cultivars in partnership with ICRISAT. Improved cultivars, particularly rainy-season hybrids, have many desirable traits such as higher productivity, wider adaptability, short duration, and stature (Rao and Rana 1982).

Deb, U.K., Bantilan, M.C.S. and **Reddy, B.V.S.** 2005**.** Impacts of improved sorghum cultivars in India. Pages 69-84 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Formerly of the International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

[2] International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

Table 1. Trends in sorghum area, production, and yield in India, 1970-98.

State	1970-75	1980-85	1990-95	1995-98
Area ('000 ha)				
Andhra Pradesh	2646	2045	1066	833
Gujarat	1088	930	506	319
Haryana	188	135	111	129
Karnataka	2225	2122	2160	1959
Madhya Pradesh	2102	2135	1368	940
Maharashtra	5821	6553	5851	5583
Rajasthan	1003	949	751	592
Tamil Nadu	692	658	511	436
Uttar Pradesh	701	646	476	419
India	16514	16231	12796	11247
Production ('000 t)				
Andhra Pradesh	1240	1256	776	609
Gujarat	389	543	275	258
Haryana	50	34	39	30
Karnataka	1724	1639	1701	1747
Madhya Pradesh	1475	1715	1214	796
Maharashtra	2251	4690	5317	4987
Rajasthan	368	422	304	233
Tamil Nadu	515	493	543	360
Uttar Pradesh	425	481	427	373
India	8461	11313	10593	9414
Yield (kg ha^{-1})				
Andhra Pradesh	469	614	728	731
Gujarat	357	584	543	807
Haryana	266	255	353	233
Karnataka	775	772	787	892
Madhya Pradesh	702	803	887	847
Maharashtra	387	716	909	893
Rajasthan	366	444	405	392
Tamil Nadu	743	750	1063	825
Uttar Pradesh	606	744	897	889
India	512	697	828	837

Source: CMIE (2000).

This study quantifies the impacts of improved sorghum cultivars in India, measured in terms of yield gain, reduction in cost of production and yield stability.

Data and Research Methodology

Data

The study used data collected from three sources: district-level secondary data published in the State Season and Crop Reports and Statistical Abstracts, rapid appraisal techniques, and cost of cultivation data published by the Ministry of Agriculture (1996). District-level yield data for 1966-94 covering 146 sorghum-growing districts in seven states — Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu — were used to estimate yield and stability gains. Together, these districts accounted for about 96% of the total sorghum area and 95% of sorghum production in India (1991-94 average). Data on area under specific varieties of sorghum were collected and validated using rapid appraisal and Delphi techniques. Data on improved cultivars gathered from crop statistics published for different states were complemented by elicitation/validation from experts. The experts comprised specialists in research institutions, private seed companies, state seed certification agencies, the National Seeds Development Corporation, state seed development corporations, directorates of agriculture, Training and Visit (T&V) Offices, and seed dealers. Reduction in cost of production was estimated using cost of cultivation data published by the Government of India.

Analytical Procedure

The adoption of improved sorghum cultivars was measured as a percentage of improved to total sorghum area. Yield gain was measured by calculating the increase in average yield levels in 1992-94 over those in 1966-68 for rainy- and postrainy-season sorghum separately. An analysis of yield and instability in sorghum yield was undertaken for two periods — 1966-67 to 1980-81 and 1981-82 to 1993-94. Yield instability was measured using the Cuddy-Della Valle index. The simple coefficient of variation (CV) overestimates the level of instability in time-series data characterized by long-term trends while the Cuddy-Della Valle index corrects the coefficient of variation by:

$$CV = (CV^*)\ (1 - R^2)^{0.5} \qquad \ldots(1)$$

where,
CV is the Cuddy-Della Valle index, i.e., corrected coefficient of variation referred to either as CV or instability index, CV* is the simple estimate of CV (in %), and R^2 is the coefficient of determination from time-trend regression adjusted by the number of degrees of freedom.

To test the differences in CV between the two time periods, Z* statistics was computed[3] .

$$Z^* = (CV_2 - CV_1)\ \{[(1 + 2c^2)/2](1/n_1 - 1/n_2)\}^{0.5}/c \qquad \ldots(2)$$

where, CV_2 and CV_1 are the CV of periods 2 and 1, respectively
n_1 and n_2 are the number of years during periods 1 and 2, and c is the CV in period 1.

The change in CV for each district was tested using the Central Limit Theorem to compute $Z^* = SZ_i/m^{0.5}$, where Z_i are the standard normal test statistics for each observation of Equation (2) and m is the number of observations in the sample.

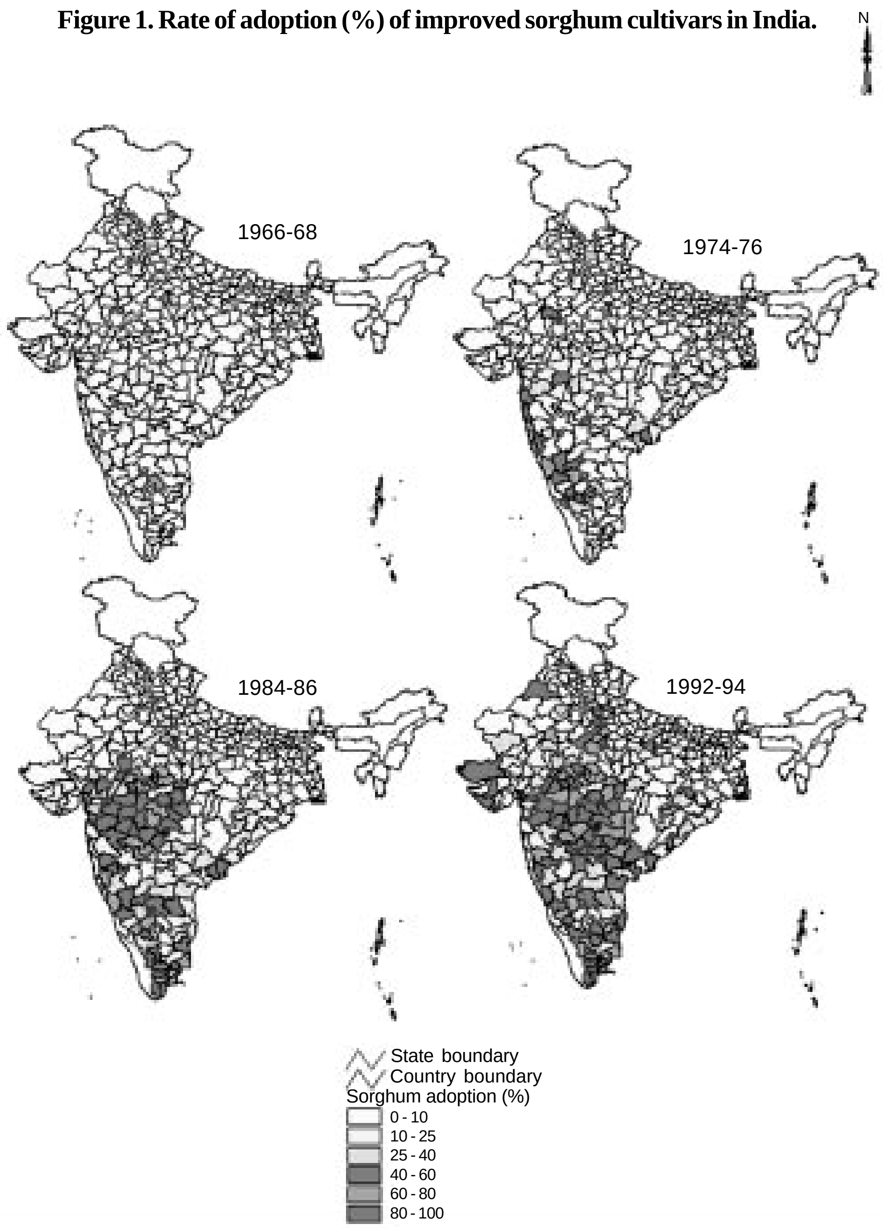
Results and Discussion

Adoption of Improved Sorghum Cultivars

The level of adoption of improved sorghum cultivars in different districts of India for four periods (1966-68, 1974-76, 1984-86, and 1992-94) is shown in Figure 1. A rapid rate of adoption was observed in Tamil Nadu and Maharashtra states while it was very slow in Rajasthan and Gujarat. The rate of adoption was higher (more than 80%) in most districts of Maharashtra and in some districts of Andhra Pradesh. In 1992-94, farmers in 28 districts — Nanded, Jalgaon, Nagpur, Yeotmal, Akola, Amravati, Wardha, Kolhapur, Buldhana, Sangli, Nasik, Osmanabad, and Dhulia (Maharashtra); Indore, Dhar, Betul, and Morena (Madhya Pradesh); Aligarh, Allahabad, and Buduan (Uttar Pradesh); East Godavari, Khammam, and Karimnagar (Andhra Pradesh); Shimoga and Hassan (Karnataka); Ganganagar (Rajasthan); Tirunelveli Kattabomman (Tamil Nadu); and Rajkot (Gujarat) — adopted improved cultivars in more than 80% of the

[3] For details see Kendall and Stewart (1969); Anderson and Hazell (1989).

Figure 1. Rate of adoption (%) of improved sorghum cultivars in India.



sorghum area. Sixteen other districts — Beed, Chandrapur, and Parbhani (Maharashtra); Shivpuri, Khargone, Sehore, Raisen, Chindwara, Khandwa, Shajapur, and Narsimhapur (Madhya Pradesh); Cuddapah (Andhra Pradesh); Chikmagalur and Bellary (Karnataka); North Arcot (Tamil Nadu); and Bulandshar (Uttar Pradesh) — showed adoption levels ranging between 70 and 80%. Trends in the adoption of different improved sorghum cultivars in India are shown in Table 2. The initial rapid adoption of CSH 1 is evident, as is the subsequent adoption of CSH 5, CSH 6, and CSH 9. MSH 51, a cultivar from the private sector and popularly known as Mahyco 51, was widely adopted by farmers. JKSH 22, another cultivar from the private sector, is also gaining ground. Improved varieties were always less popular than hybrids (Rana et al. 1997). Since hybrids provide higher yield and are readily available from a large number of private and public seed companies, their adoption took off easily. Three phases were observed in the spread of improved sorghum cultivars in India. The first phase continued up to 1975 when only CSH 1 was the improved cultivar. During this period, CSH 1 mainly replaced traditional local cultivars. The second phase was between 1976 and 1986 when the major improved cultivars were CSH 5 and CSH 6. This phase was characterized by the replacement of traditional and

Table 2. Trends in adoption of improved sorghum cultivars in India, 1966-98.

	Adoption (% of total sorghum area)							
Cultivar	**1966**	**1971**	**1976**	**1981**	**1986**	**1991**	**1996**	**1998**
CSH 1	1.06	4.14	6.14	0.00	0.00	0.00	0.00	0.00
CSH 5	0.00	0.00	9.21	11.69	13.79	0.00	0.00	0.00
CSH 6	0.00	0.00	0.00	11.69	13.79	0.00	0.00	0.00
CSH 9	0.00	0.00	0.00	0.00	6.90	43.86	20.00	12.00
CSH 13	0.00	0.00	0.00	0.00	0.00	0.00	12.00	15.00
CSH 14	0.00	0.00	0.00	0.00	0.00	0.00	13.00	16.00
MSH 51	0.00	0.00	0.00	0.00	0.00	8.22	14.00	15.00
JKSH 22	0.00	0.00	0.00	0.00	0.00	0.00	6.00	8.00
Other improved cultivars	0.00	0.00	0.00	0.00	0.00	2.74	5.00	5.00
All improved cultivars	1.06	4.14	15.35	23.38	34.48	54.82	70.00	71.00

Source: Estimates are based on rapid appraisal.

initial improved cultivars (CSH 1, CSH 2 and CSH 4) with new ones (CSH 5 and CSH 6). The third phase began after 1986 when the initial cultivars were replaced by new ones (CSH 9, MSH 51, JKSH 22, CSH 13, and CSH 14) at a faster rate. During this period, Indian farmers began to get acquainted with a large number of private sector hybrids in the market.

Average Yield and Yield Gain

Figure 2 shows average rainy-season sorghum yield and yield gains in 1992-94 compared to 1966-68, in different districts of India. Grain yield gains in Maharashtra and Andhra Pradesh were high where adoption rates too were high. The increase in yield was at least 750 kg ha^{-1} in these districts and more than one ton in many others. The yield increase per hectare was more than one metric ton in the districts of Dhulia, Parbhani, Jalgaon, Kolhapur, Nasik, Akola, and Buldhana (Maharashtra); Anantapur (Andhra Pradesh); Shimoga (Karnataka), and Bharuch (Gujarat). Almost all these districts reported more than 80% adoption levels. Yield increased by more than 750 kg ha^{-1} in Ahmednagar, Satara, Pune, Amravati, Osmanabad, Aurangabad, and Nanded districts. Yield doubled in these districts. Yield either doubled or increased by more than 80% in other high-adoption (>80%) districts such as Nagpur and Yeotmal (Maharashtra); Khammam, East Godavari, and Karimnagar (Andhra Pradesh); Allahabad and Buduan (Uttar Pradesh); and Rajkot (Gujarat). A majority of the districts in Andhra Pradesh experienced more than 80% yield gain.

Figure 3 depicts average postrainy-season sorghum yield and yield gains. Increase in grain yield was less during the postrainy season than during the rainy season. Increase in yield was greater than 500 kg ha^{-1} in only four districts (Kolhapur and Jalgaon in Maharashtra, Kurnool in Andhra Pradesh, and Chikmagalur in Karnataka). Postrainy-season sorghum yield in these districts in 1992-94 was more than double that of 1966-68. Yield increased by more than 100% in Anantapur, Mahabubnagar, and East Godavari districts of Andhra Pradesh. In some districts of Maharashtra (Nagpur, Wardha, Osmanabad, Satara, and Ahmednagar), and Karnataka (Chitradurga and Bidar), there was a slight decrease in yield, whose cause needs to be researched. Yields increased in the other districts of Maharashtra, Karnataka, and Andhra Pradesh where private and public seed companies were active and some postrainy-season sorghum hybrids were cultivated.

Figure 2. Average rainy-season sorghum yield and yield gain in India.

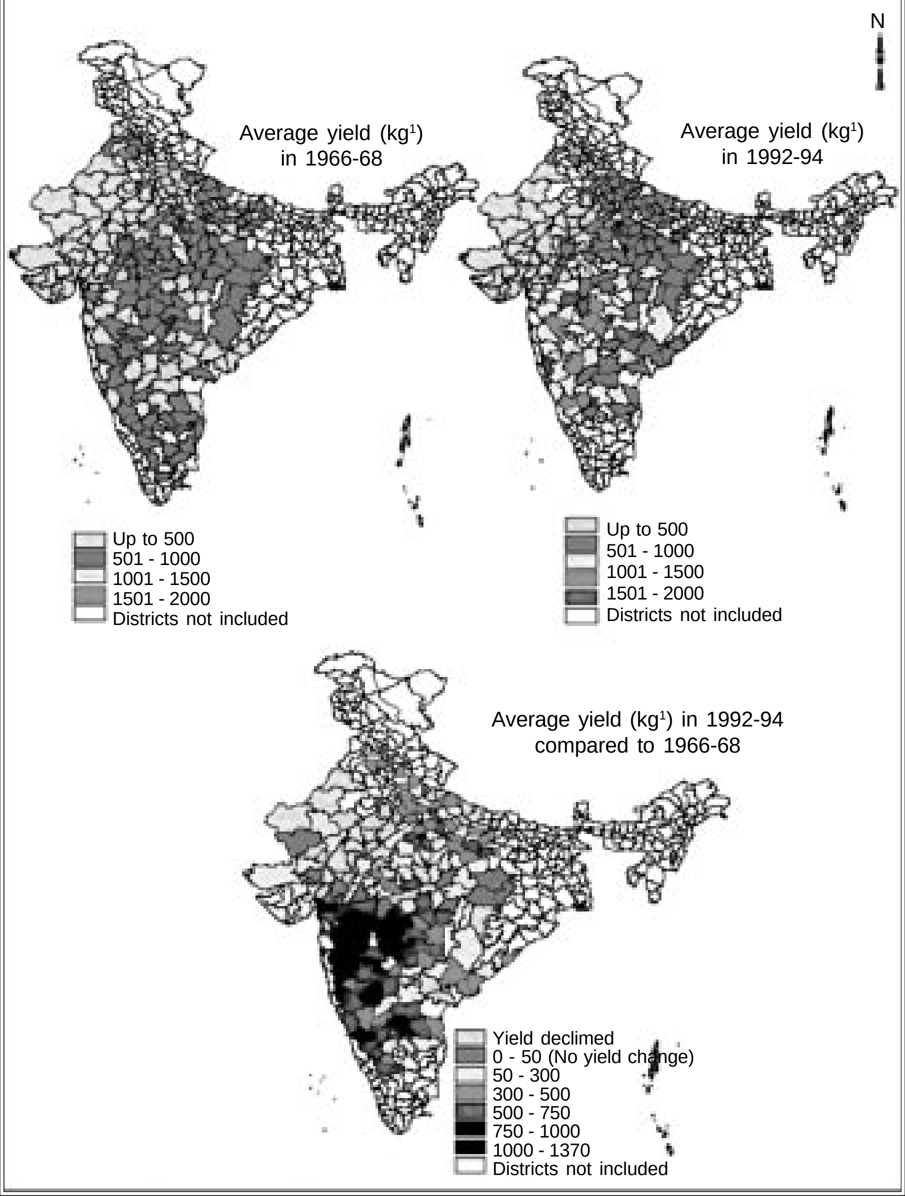


Figure 3. Average postrainy-season sorghum yield and yield gain in India.

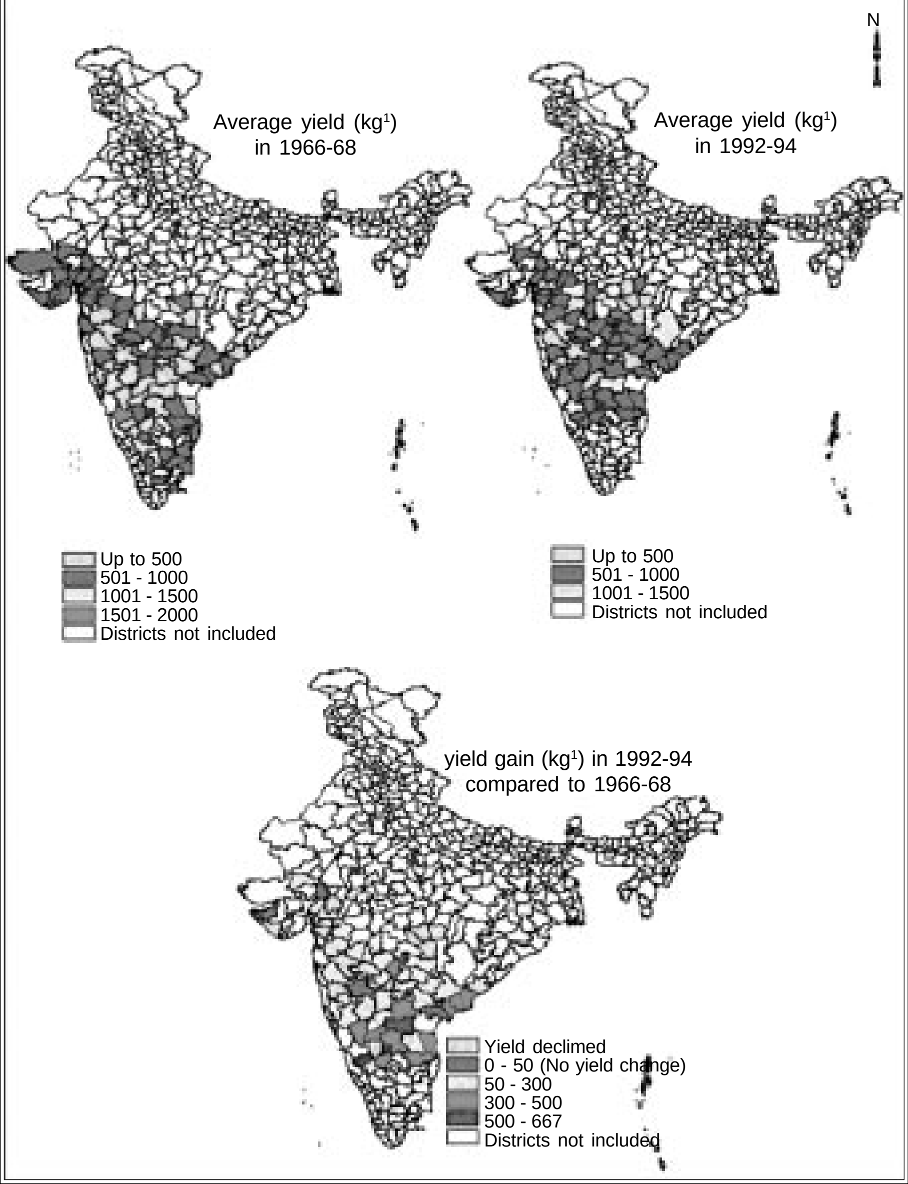
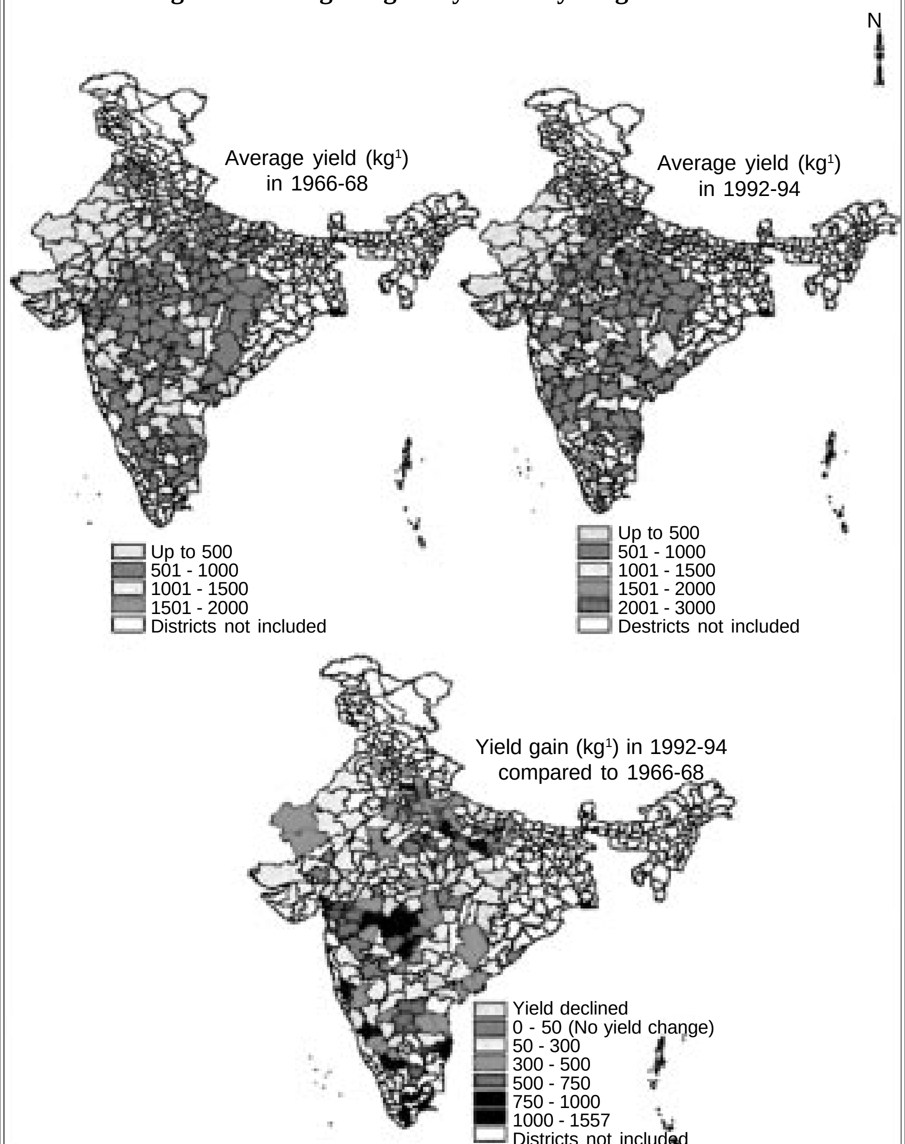


Figure 4. Average sorghum yield and yield gain in India.



An overall increase in sorghum grain yield was observed in a majority of districts (Figure 4). Increase in yield was less in the postrainy season compared to the rainy season. It may be noted that there was an emphasis on research for rainy-season sorghum. There was lesser research and fewer improved cultivars were developed in the case of postrainy-season sorghum. Therefore, it may be concluded that rainy-season research provided improved cultivars suitable for the rainy season, which were then adopted in farmers' fields resulting in greater yield increases. Thus, an increase in rainy-season sorghum's average yield resulted in an overall increase in sorghum yield. Increases in postrainy-season sorghum yield will require improved cultivars which may be developed by greater investment in research.

Reduced Cost of Production

An analysis of the cost of cultivation data in India shows that real cost of production per ton of sorghum declined in the 1980s and 1990s compared to the early 1970s. In Maharashtra, it fell by 40% in the 1990s compared to the 1970s, while it came down by 37% in Rajasthan (Table 3).

Table 3. Impact of improved sorghum cultivars on cost of production[1] per ton in India, 1971-95.

	Average cost (Rs ton^{-1})			Cost reduction (%) compared to the early 70s	
States	Early 1970s[2]	Early 1980s[3]	Early 1990s[4]	Early 1980s	Early 1990s
Karnataka	224	192	231	14	- 4
Madhya Pradesh	223	169	208	24	7
Maharashtra	253	188	153	25	40
Rajasthan	309	264	195	14	37

1 All costs are real cost of production. Real cost in the case of Rajasthan was computed on the basis of 1992 prices, whereas for the other states, it was based on 1989 prices.

2 Early 1970s: For Karnataka (average of 1972-1974), Madhya Pradesh (1976), Maharashtra (average of 1972-74), and Rajasthan (average of 1972-74).

3 Early 1980s: For Karnataka (average of 1981-83), Madhya Pradesh (average of 1981-83), Maharashtra (average of 1982-83), and Rajasthan (average of 1981-1983).

4 Early 1990s: For Karnataka (1991), Madhya Pradesh (average of 1994-95), Maharashtra (1995), and Rajasthan (1992).

Source: Estimated from cost of cultivation reports.

Changes in Average Yield and Yield Instability

Table 4 presents the level and changes in average grain yield and its relative variability from 1966-67 to 1980-81 (period 1) and 1981-82 to 1993-94 (period 2). During period 1, the proportion of area under improved sorghum cultivars was less (< 20% before 1980-81) but it was relatively high during period 2 and gradually increased over time to reach 55% during 1991-92. During period 1, the highest yield per hectare was achieved in Karnataka (985 kg), followed by Tamil Nadu (943 kg), and Madhya Pradesh (729 kg). The lowest yields were observed in Rajasthan (300 kg) and Gujarat (499 kg). During period 2, the highest yield per hectare was observed in Tamil Nadu (1113 kg), followed by Karnataka (957 kg), and Maharashtra (902 kg). The lowest yield was recorded in Rajasthan (412 kg), followed by Gujarat (551 kg) and Andhra Pradesh (661 kg). A comparative analysis of these yield levels shows a general increase, except in Karnataka where it fell by 28 kg. The average yield in India was 582 kg during period 1 and 748 kg during period 2. Coming to yield instability index, it was found that the coefficient of variation (CV) in yield declined in all the states except Gujarat. Given the fact that Gujarat usually contributes less than 3% of total sorghum production and 5% of total sorghum area in India, this implies that the relative variability in sorghum yield has generally declined. At the aggregate level, the CV in sorghum yield in India was 11% during period 1 and 13% during period 2.

Table 4. Average grain yield and relative variability of sorghum in different states of India.

	Period 1 (1966-67 to 1980-81)		Period 2 (1981-82 to 1993-94)		Change (%)	
States	Yield (kg ha^{-1})	CV (%)	Yield (kg ha^{-1})	CV (%)	Yield (kg ha^{-1})	CV (%)
Andhra Pradesh	521	23.02	661	21.66	26.84	-5.91
Gujarat	499	31.55	551	42.51	10.38	34.76
Karnataka	985	26.65	957	23.08	-2.91	-13.40
Madhya Pradesh	729	24.08	896	19.52	22.76	-18.96
Maharashtra	609	29.50	902	26.51	17.99	-6.71
Rajasthan	300	58.62	412	50.77	37.47	-13.40
Tamil Nadu	943	28.13	1113	26.24	17.99	-6.71
India	582	10.59	748	13.02	28.47	22.97

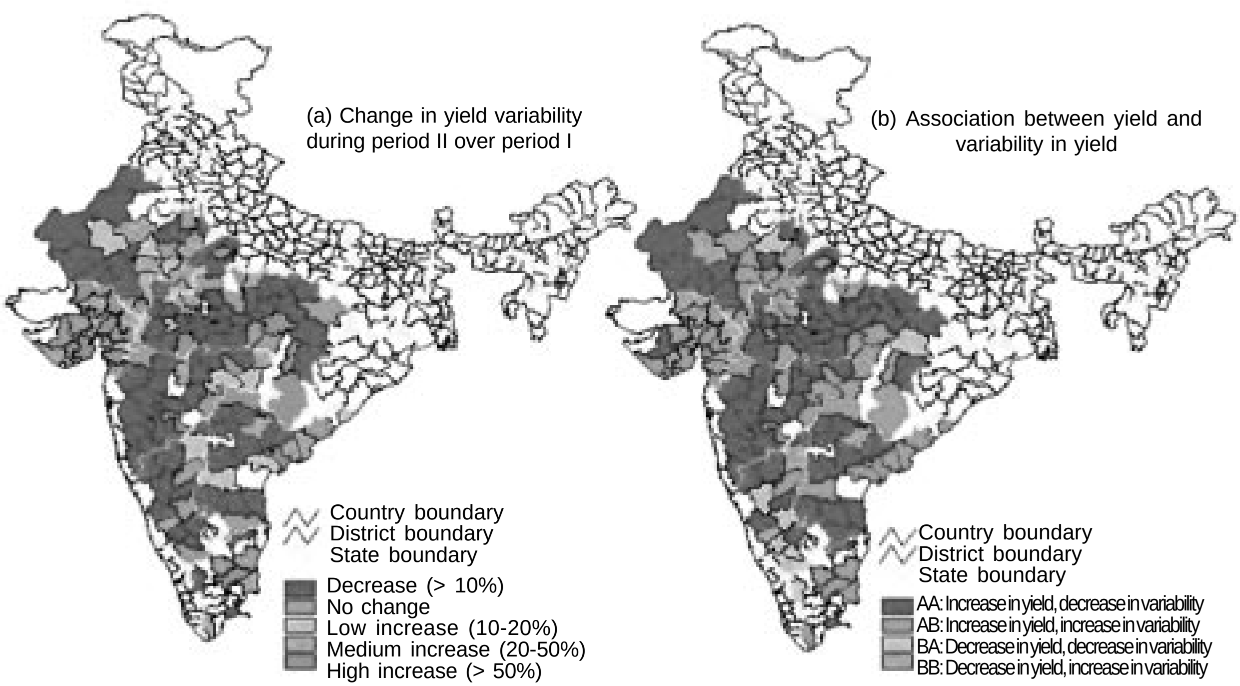
An analysis of the Z* statistics showing the significance in differences in CV between the two periods showed that about 26% of the districts in India comprising only 14% of the total sorghum area, experienced significant increases in CV (Table 5). On the other hand, 39% of the districts comprising 42% of the total sorghum area, experienced a significant decline in CV. This fluctuation over the years is expected to have improved food security in most of the sorghum-producing areas.

Table 5. Districts and sorghum area (%) with statistically significant changes in grain yield variability according to the computed z* statistics.

	Districts (%)		Area (%)	
States	**Increased CV**	**Decreased CV**	**Increased CV**	**Decreased CV**
Andhra Pradesh	25	30	20	43
Gujarat	69	6	76	0
Karnataka	7	36	1	29
Madhya Pradesh	14	50	10	51
Maharashtra	5	45	3	50
Rajasthan	48	43	64	20
Tamil Nadu	33	44	25	52
India	26	39	14	42

The association between sorghum yield and its relative variability is given in Figure 5. Four types of association were found: AA— increase in yield associated with decrease in relative variability, AB — increase in yield associated with increase in relative variability, BA — decrease in yield associated with decrease in relative variability, and BB — decrease in yield associated with increase in relative variability. From the development point of view, AA is the best situation, whereas BB indicates the worst scenario. AB is preferable to BA. The distribution of districts according to the type of association shows that half the districts experienced an increase in yield accompanied by a decrease in variability. More than a third of the districts experienced increase in yield associated with increase in variability, while only 6% showed decrease in yield associated with decrease in variability. Ten districts — Warangal (Andhra Pradesh), Gulbarga and Chikmagalur (Karnataka), Panchmahals, Mehsana, Ahmedabad, Amreli, and Banaskantha

Figure 5. Impact of improved sorghum cultivars on variability in yield in India.



(Gujarat), and Jodhpur and Dungarpur (Rajasthan) — showed a decline in yield associated with increase in variability. The analysis shows that more of the less desirable and most of the undesirable outcomes were experienced by the districts of Gujarat.

Adoption of Improved Cultivars and Yield Instability

An analysis of the relationship between the adoption of improved cultivars and grain yield instability (Table 6) revealed that the rate of adoption of improved sorghum cultivars increased over time in all the states except Rajasthan, where improved cultivars were not adopted on a large scale. An increase in adoption of improved cultivars in Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu was accompanied by a decrease in yield instability.

Table 6. Relationship between adoption of improved cultivars and instability in sorghum yield in different states of India.

	Adoption level (%)			Index of yield instability		Change in instability index
States	**1968**	**1981**	**1993**	**Period 1**	**Period 2**	**(%)**
Andhra Pradesh	0.56	20.28	46.76	23.02	21.66	-5.91
Gujarat	0.15	7.78	53.16	31.55	42.51	34.76
Karnataka	3.03	22.76	22.97	26.65	23.08	-13.40
Madhya Pradesh	0.92	29.17	49.48	24.08	19.52	-18.96
Maharashtra	8.47	30.02	68.09	29.50	26.51	-6.71
Rajasthan	0.42	4.64	1.52	58.62	50.77	-13.40
Tamil Nadu	1.35	27.65	99.31	28.13	26.24	-6.71
India	3.68	23.39	52.42	10.59	13.02	22.97

Conclusion

This study had three important outcomes. First, an analysis of the three phases of adoption featured the replacement of traditional varieties with new generations of improved sorghum cultivars. Secondly, there was a significant yield gain and reduction in cost of production per ton with the adoption of improved cultivars. Thirdly, a significant improvement in yield stability was observed and correlated with the uptake of improved sorghum cultivars.

References

Anderson, J.R. and **Hazell, P.B.R.** 1989. Changing variability in cereal production in Australia. *In Variability in grain yields: Implications for agricultural research and policy in developing countries* (Hazell, P.B.R. and Anderson, J.R., eds.). Baltimore, USA: John Hopkins University Press.

CMIE (Center for Monitoring Indian Economy). 2000. *India's agricultural sector: A compendium of statistics*. Bombay, India: Center for Monitoring Indian Economy Pvt. Ltd.

Kendall, M. and **Stewart, A.** 1969. *The advanced theory of statistics*. Vol. 1. *Distribution theory*. New York, USA: Macmillan.

MOA (Ministry of Agriculture). 1996. *Cost of cultivation of principal crops in India 1996*. Government of India, New Delhi: Directorate of Economics and Statistics.

Rana, B.S., Swarnalata, Kaul and **Rao, M.H.** 1997. Impact of genetic improvement on sorghum productivity in India. Pages 141-165 *in Proceedings of the International conference on Genetic Improvement of Sorghum and Pearl Millet*, 22-27 Sep 1996, Lubbock, Texas. International Sorghum/ Millet Collaborative Research Support Program and International Crops Research Institute for the Semi-Arid Tropics.

Rao, N.G.P. and **Rana, B.S.** 1982. Selection in temperate-tropical crosses of sorghum. Pages 403-419 *in Sorghum in the eighties: Proceedings of the International symposium on Sorghum*, 2-7 Nov 1981, Patancheru, Andhra Pradesh, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Impacts of Improved Pearl Millet Cultivars in India

U K Deb,[1] M C S Bantilan[2] and K N Rai[2]

Introduction

Pearl millet (*Pennisetum glaucum*) is the fourth most important cereal in India in terms of area cultivated after rice, wheat, and sorghum. It provides grain and fodder to milch animals and is usually grown under harsh environments and on poor soils. India grows about 7 Mt of pearl millet grain from 10 Mha of land. The major pearl millet-growing states in India are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Haryana, Karnataka, Tamil Nadu, Madhya Pradesh and Andhra Pradesh (Table 1). In terms of yield in 1995-98, Uttar Pradesh stood first, followed by Gujarat, Tamil Nadu, Haryana, Madhya Pradesh, Andhra Pradesh, Maharashtra, Karnataka, and Rajasthan. These nine states covered more than 99% of the total pearl millet area and production in 1995-98. While the area under pearl millet has been declining over time in all the states, except Maharashtra, production has gone up in all the states, except Andhra Pradesh and Tamil Nadu (Table 1). Pearl millet yield increased in all the states and more than doubled in a majority of them in the late 1990s compared to the early 1960s. Increase in yield was associated with increase in area under improved pearl millet cultivars.

Deb, U.K., Bantilan, M.C.S. and **Rai, K.N.** 2005. Impacts of improved pearl millet cultivars in India. Pages 85-99 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Formerly of the International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

[2] International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

Table 1. Trends in area, production, and yield of pearl millet in India, 1960-98.

State	1960-65	1970-75	1980-85	1990-95	1995-98
			Area ('000 ha)		
Andhra Pradesh	620	550	490	176	120
Gujarat	1440	1750	1400	1196	1080
Haryana	790	920	820	579	570
Karnataka	500	460	510	361	370
Madhya Pradesh	180	209	176	150	140
Maharashtra	1690	1690	1680	1861	1760
Rajasthan	4470	5080	4810	4754	4550
Tamil Nadu	480	430	340	233	220
Uttar Pradesh	1030	1050	980	806	850
Other states	40	50	45	60	30
India	11240	12189	11251	10176	9690
			Production ('000 t)		
Andhra Pradesh	320	280	320	131	100
Gujarat	640	1220	1400	1106	1280
Haryana	290	560	500	531	580
Karnataka	130	360	200	190	220
Madhya Pradesh	120	137	112	130	130
Maharashtra	480	430	690	1222	1300
Rajasthan	970	1500	1470	2012	1920
Tamil Nadu	300	280	330	275	240
Uttar Pradesh	530	690	790	882	1100
Other states	40	45	48	40	30
India	3820	5502	5860	6519	6900
			Yield (kg ha^{-1})		
Andhra Pradesh	516	509	653	744	833
Gujarat	444	697	1000	925	1185
Haryana	367	609	610	917	1018
Karnataka	260	783	392	526	595
Madhya Pradesh	667	656	636	867	929
Maharashtra	284	254	411	657	739

Contd.

Table 1 — Contd.

Rajasthan	217	295	306	423	422
Tamil Nadu	625	651	971	1180	1091
Uttar Pradesh	515	657	806	1094	1294
Other states	11240	12189	11251	10176	9690
India	340	451	521	641	712

Source: CMIE (2000).

This paper quantifies the extent of adoption and impacts of improved pearl millet cultivars in India.

Data and Research Methodology

Data

This study used data from farm-level surveys, crop statistics, and cost of cultivation reports. A reconnaissance survey was conducted to gain preliminary insights into the adoption of production technologies and constraints farmers faced in pearl millet cultivation. This was followed by the collection of secondary data and discussions with officials of the Directorate of Agriculture, scientists from ICRISAT, ICAR, and other research institutes, and representatives from the private seed sector. This was undertaken to provide the basis for an in-depth, on-farm level adoption study. A sampling scheme was designed to select representative pearl millet growers in the top five pearl millet-producing states of India. A total sample of 1683 farmers from 154 villages in 39 districts from Gujarat, Haryana, Maharashtra, Rajasthan, and Tamil Nadu was selected. It may be noted that the survey in Rajasthan was representative of the situation only in eastern Rajasthan (Table 2).

Analytical Procedure

The study estimated adoption rates of improved pearl millet cultivars and their impact on yield, cost of production, labor employment, and farm income. Information was gathered for each of the cultivars grown by the farmers. Based on their origin, the cultivars were split into six groups — ICRISAT cultivars, NARS public cultivars (IC material), Private (IC material), NARS Public, Private, and Local. ICRISAT cultivars include varieties and hybrids bred by ICRISAT.

Table 2. Distribution of sample farms in India.

State	Survey year	Districts	Blocks	Villages	Sample size
Maharashtra	1994	9	18	36	360
Rajasthan	1996	7	14	28	331
Gujarat	1995	11	21	42	419
Haryana	1996	5	10	20	237
Tamil Nadu	1994	7	14	28	336
Total		39	77	154	1683

NARS public cultivars (IC material) refer to those varieties and hybrids developed by the Indian Agricultural Research System operated in the public sector but contain germplasm and elite materials collected from ICRISAT in the pedigree. The group of private cultivars (IC material) represents private proprietary hybrid developed from ICRISAT germplasm. On the other hand, NARS public and private cultivars are those developed by the Indian public agricultural research institutes and the private sector respectively, and do not contain any ICRISAT germplasm in their pedigree. Locals are landraces grown by farmers. During the survey, there were occasions when some farmers did not know the name of some of the cultivars but were sure that they were improved ones. Such cultivars were categorized as unidentified improved cultivars.

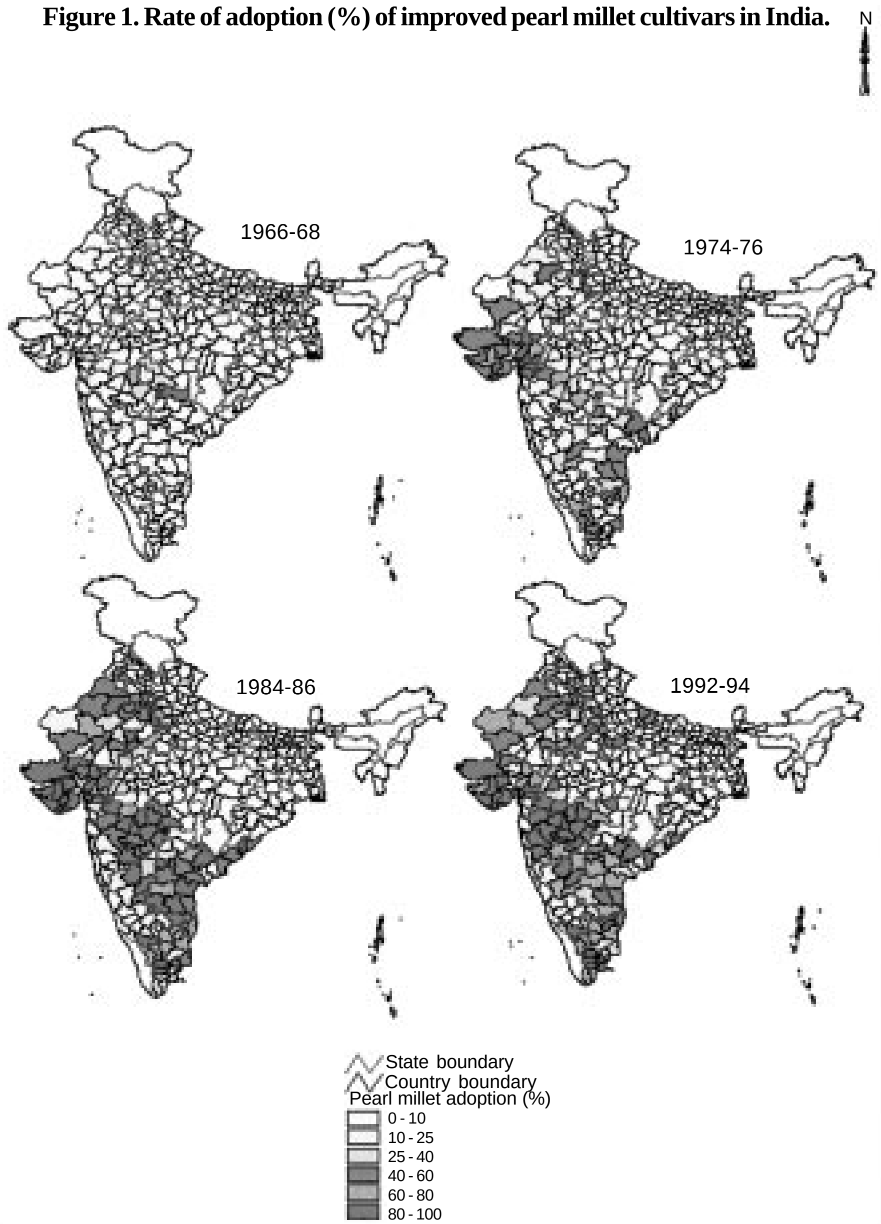
The adoption level of all improved cultivars was defined as the sum of adoption rates of different improved cultivar groups. Adoption level was defined as the percentage of area under improved pearl millet cultivars to the total pearl millet area.

Results and Discussion

Trends in Adoption of Improved Cultivars

Figure 1 shows adoption trends of improved pearl millet cultivars in different districts in India during 1966-94, based on district-level data obtained from published sources. Adoption of improved pearl millet cultivars increased significantly over time, starting from very low adoption levels in the late 1960s. In 1992-94, adoption was over 80% in most districts in Maharashtra, Gujarat,

Figure 1. Rate of adoption (%) of improved pearl millet cultivars in India.



and Tamil Nadu. About 40 districts in India have attained more than 80% adoption. Increase in adoption over time was influenced by the development of downy mildew-resistant varieties at 4-5-year intervals. Widespread adoption led to major yield gains.

On-farm surveys were conducted to determine the extent of adoption of improved cultivars in farmers' fields in Maharashtra, Gujarat, Haryana, eastern Rajasthan and Tamil Nadu. Table 3 shows the adoption level of different types of improved cultivars adopted by farmers in these states. Adoption was found to be high in Maharashtra, Gujarat, Haryana and Tamil Nadu, while local varieties dominated in Rajasthan. Among the improved cultivars, ICRISAT crosses and public and private sector releases with ICRISAT parentage dominated in Maharashtra and Gujarat. In Haryana, releases by the private and public sectors from ICRISAT materials were grown. However in Tamil Nadu, private releases from non-ICRISAT sources dominated. In eastern Rajasthan, farmers grew public and private sector releases from non-ICRISAT sources.

Maharashtra. The area under HYV pearl millet reached 94% in 1994. Adoption of ICRISAT cultivars (ICTP 8203, WC-C75, and MH 179) increased from 35% in 1990 to 47% in 1992, and declined to 36% in 1994. The area under ICTP 8203 increased to 43% in 1992 compared to 29% in 1990 but declined to 30% in 1994. The area under WC-C75 and MH 179 was reported to have declined due to nonavailability of seeds as well as replacement by newer released varieties.

The adoption of NARS-public cultivars (BK 560, BJ 104, MH 169, and RHRBH 8609) declined from 24% in 1990 to 5% in 1994. The area under BK 560 and BJ 104 declined due to their susceptibility to downy mildew. Meanwhile, the area under MH 169 and RHRBH 8609 increased. The average area under NARS-public cultivars during 1990-94 was 19%, of which 4% comprised of hybrids developed using ICRISAT materials.

The adoption of private cultivars (MLBH 104, MLBH 267, etc., from Vijay, Nath, Paras, Mahyco, Pro-agro, Nandi, and Pioneer seed companies) increased from 19% in 1990 to 44% in 1994. The average area under private sector cultivars during 1990-94 was 31%, of which 23% was covered by hybrids developed using ICRISAT materials.

The area under local cultivars declined from 22% in 1990 to 6% in 1994 due to their low yield potential and long duration.

Table 3. Distribution (%) of pearl millet area under different types of cultivars in India, 1990-96.

Year	ICRISAT bred	NARS-public (IC material)	Private-(IC material)	NARS-public	Private	Unidenti-fied	Local
			Maharashtra				
1990	35.00	0.00	9.00	24.00	10.00	0.00	22.00
1991	44.00	0.00	13.00	21.00	8.00	0.00	14.00
1992	47.00	3.00	22.00	14.00	7.00	0.00	7.00
1993	37.00	9.00	32.00	10.00	8.00	0.00	4.00
1994	36.00	9.00	34.00	5.00	10.00	0.00	6.00
			Eastern Rajasthan				
1992	6.75	1.41	1.52	21.40	2.55	10.40	55.97
1993	8.83	1.39	2.50	18.32	3.72	9.82	55.42
1994	11.42	2.53	5.43	19.25	8.93	7.73	44.71
1995	13.09	3.57	5.86	17.56	11.33	4.46	44.13
1996	11.99	2.50	7.14	18.93	12.94	3.52	43.75
			Gujarat				
1990	25.76	3.48	6.18	51.39	6.49	0.00	6.68
1991	26.69	5.22	10.24	43.91	10.54	0.00	3.42
1992	29.75	10.52	13.00	33.86	11.13	0.00	1.73
1993	33.70	16.41	19.70	17.81	11.31	0.00	1.07
1994	31.75	21.21	21.41	11.92	12.68	0.00	1.03
1995	31.32	24.81	21.08	7.40	14.40	0.00	1.00
			Haryana				
1992	0.63	25.43	13.36	0.00	4.83	0.16	55.60
1993	0.60	32.73	16.38	0.00	6.90	0.60	42.79
1994	1.11	39.76	22.16	0.00	10.42	0.32	26.22
1995	1.68	42.53	24.89	0.00	14.23	0.25	16.43
1996	1.94	42.79	22.90	0.00	18.06	0.25	14.06
			Tamil Nadu				
1994	22.6	0	6.6	11.6	36.5	0	22.7

Source: Farm surveys for Maharashtra, Rajasthan, Gujarat, and Haryana, and Ramasamy et al. (1999) for Tamil Nadu.

Rajasthan. The uptake of improved pearl millet cultivars in eastern Rajasthan increased from 44% in 1992 to 56% in 1996. BK 560 ranked first among improved cultivars and occupied 20% of the area in 1992 and 18% in 1996. The adoption of another public sector cultivar, HHB 67, increased from 1% in 1992 to 3% in 1995 and then declined to 2% in 1996. MH 179, an ICRISAT-developed cultivar, showed an increase in adoption from 3% in 1992 to 9% in 1996. The adoption of Eknath, a private-sector hybrid based on ICRISAT germplasm materials, increased from less than 1% in 1992 to 4% in 1996. A major shift in adoption occurred in 1994 when many private seed companies introduced their hybrids in the market. The share of local or d*esi* pearl millet cultivars among those grown in farmers' field was around 48%.

Gujarat. There was a high rate of adoption of improved technologies in Gujarat. Adoption in the rainy season increased from 95% in 1990 to 99% in 1995. During this period, adoption of ICRISAT-developed cultivars (ICTP 8203 and MH 179) increased from 26 to 31% while the adoption of NARS-public cultivars declined from 54 to 32%. In particular, the area under three earlier releases — BK 560, BJ 104, and CJ 104 — declined due to their susceptibility to downy mildew. At the same time, the area under pearl millet cultivars developed by the NARS-public sector based on ICRISAT materials increased from 12% in 1990 to 34% in 1995 and the area under NARS-public cultivars without ICRISAT material fell from 49% in 1990 to 5% in 1995. The uptake of hybrids from the private sector (Nandi 18, Navbharat, Vijay, Prashanth, Deepak, Paras, Mahyco, Pro-agro, and Pioneer) increased from 12 to 35%. It was observed that the area under pearl millet hybrids developed by private seed companies based on ICRISAT germplasm materials increased from 5% in 1990 to 18% in 1995. Notable was the decline in area grown to local cultivars in Gujarat, from 5% in 1990 to less than 1% in1995, mainly due to their low yields and long duration.

Haryana. The adoption of improved pearl millet cultivars increased from 44% in 1992 to 86% in 1996 in Haryana. The percentage of farmers who adopted them increased from 56% in 1992 to 86% in 1996. HHB 67, a public-sector cultivar developed using ICRISAT materials, was widely adopted in the state, covering about 21% of the area in 1992 and increasing to 38% in 1996. It ranked first among the adopted pearl millet hybrids in the state. Nandi 18, an ICRISAT-derived private sector cultivar, ranked second, and its share (cultivated area as a percentage of the total pearl millet area) increased from

9% in 1992 to 17% in 1995 before declining to 16% in 1996. Pro-agro 7701, a private-sector cultivar, stood third in terms of importance in 1996 though it had a much smaller share compared to HHB 67 and Nandi 18 in 1992. Adoption of ICRISAT cultivar MH 179 was about 2% throughout the study period. Cultivars like KH 322, PG 5834, and Nandi 18 showed an increasing trend over the five-year period. Local cultivars declined sharply over the years (from 56% in 1992 to 14% in 1996).

Tamil Nadu. NARS private cultivars dominated in Tamil Nadu. The share of ICRISAT cultivars (ICMS 7703, ICMV 221, and WC-C75) was 23%, and they occupied second place. NARS-public cultivars occupied 12% of the area while local varieties were grown over 23% of the area. The rest of the area was under private cultivars. It may be noted that WC-C75 covers about half of the area under ICRISAT cultivars. Among private hybrids, Pioneer dominated two-thirds of the total area under private-sector cultivars. The leading cultivars among NARS public were CO 7 and KM 2 (Ramasamy et al. 1999).

Traits Preferred and Constraints Faced by Farmers

Farmers were asked to rank the traits they preferred in the improved cultivars they were growing. High grain yield ranked first across the states (Table 4). High fodder yield ranked second in Maharashtra, Haryana, and Gujarat. The other traits farmers liked were short duration, disease resistance, drought resistance, better taste, and bold grain size.

Table 4. Traits of improved pearl millet cultivars preferred by farmers in select states of India.

	Ranks provided by farmers of				
Traits	**Maharashtra**	**Rajasthan**	**Gujarat**	**Haryana**	**Tamil Nadu**
High grain yield	1	1	1	1	1
High fodder yield	2	4	2	2	
Short duration		2	6	3	
Disease resistance	3	5	3	4	3
Drought resistance	2	3	5	5	2
Better taste	4	7	4		
Bold grain size	5	6			4

Farmers were also asked to cite and rank the constraints they faced in growing improved pearl millet cultivars. According to them, nonavailability of seed, low fodder yield of existing cultivars, lack of awareness, greater water need, poor extension service, and poor grain and fodder quality were the major constraints (Table 5).

Table 5. Constraints Indian farmers faced in growing pearl millet cultivars.

	Ranks provided by farmers of			
Traits	**Maharashtra**	**Rajasthan**	**Gujarat**	**Haryana**
Nonavailability of seed	1	2		
Low fodder yield		1		
Lack of awareness	2	3		
More water required	4	4		2
Poor extension	3		2	
Poor grain quality		5	1	3
Poor fodder quality	5	1	3	1

Impacts of Improved Cultivars

The farm surveys (Table 6) revealed that improved cultivars gave higher grain and fodder yields than local varieties in all the states. The percentage increase was higher for grain yield than for fodder yield. Figure 2 shows the average yield and yield gain in pearl millet in India. District-level yield data for 1992-94 and 1966-68 from 238 districts in India were compared in order to estimate the impact on yield. Yield was found to have increased in almost all the districts. For example, in the late 1960s, most districts of Maharashtra and Gujarat recorded yields of less than 500 kg ha^{-1} and slightly higher than 500 kg ha^{-1} in Tamil Nadu and Haryana. However, in the 1990s, this increased by 500-1000 kg ha^{-1} in Gujarat, Maharashtra, and Haryana. Yield increases were particularly substantial in Cuddapah (Andhra Pradesh), and Chengaianna and Salem (Tamil Nadu) where adoption levels were high. Results from cost of cultivation data showed similar yield gains. Compared to 1972-74, yield gain in 1992-94 was 139% in Gujarat, 126% in Haryana, and 110% in Rajasthan (Table 7).

Figure 2. Average yield and yield gain of pearl millet in India.

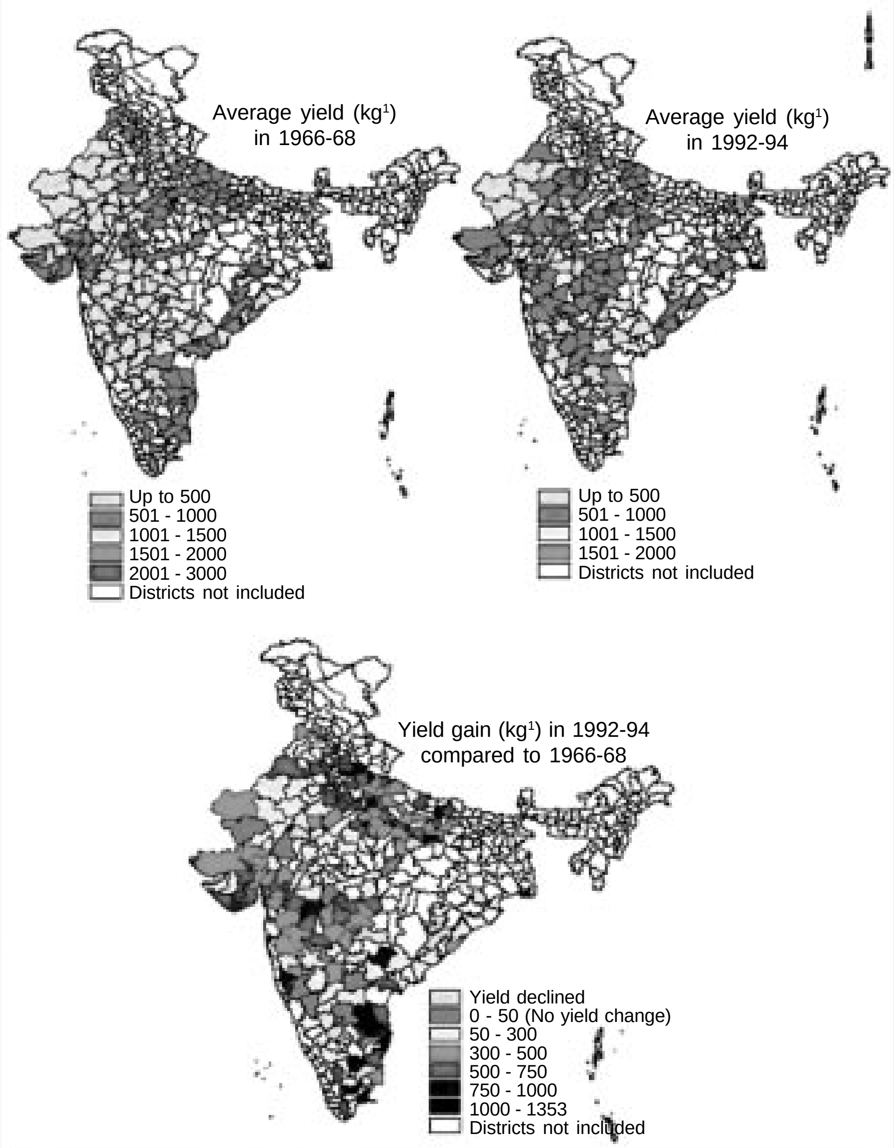


Table 6. Impact of improved pearl millet cultivars on grain and fodder yields in farm surveys in India.

	Yield ha^{-1}	
Description/state	**Grain (kg ha^{-1})**	**Fodder (kg ha^{-1})**
Local variety		
Haryana	587	1600
Rajasthan	355	1800
Maharashtra	929	1800
Improved cultivars		
Haryana	1665	2700
Rajasthan	1170	2000
Gujarat	1955	2500
Maharashtra	1807	1900
Increase in yield (%)		
Haryana	183	7500
Rajasthan	230	1000
Maharashtra	95	600

Table 7. Impact of improved pearl millet cultivars on pearl millet yield in India, 1972-94.

	Average yield (kg ha^{-1})			Yield gain (%) compared to 1972-74	
State	**1972-74**	**1981-83**	**1992-94**	**1981-83**	**1992-94**
Gujarat	641	1380	1534	115	139
Haryana	578	725	1309	25	126
Rajasthan	265	373	557	41	110

Source: MOA (1996).

Farm survey results showed that improved cultivars had more than 40% lower cost of production estimated on a full cost basis (Table 8). Results from cost of cultivation data revealed that the average cost of pearl millet production per ton in 1992-94 compared to 1972-74 had declined by 35% in Gujarat, 42% in Haryana, and 59% in Rajasthan (Table 9).

Table 8. Impact of improved pearl millet cultivars on per unit cost of production in India.

Description/state	Cost of production (Rs t^{-1}) on the basis of		
	Variable cost	Fixed cost	Total cost
Local variety			
Haryana	5308	3022	8329
Rajasthan	5122	4997	10120
Maharashtra	4153	3769	7921
Improved cultivars			
Haryana	3283	1110	4394
Rajasthan	3452	1912	5364
Gujarat	2942	1002	3944
Maharashtra	2429	2047	4476
Reduction in unit cost (%)			
Haryana	38	63	47
Rajasthan	33	62	47
Maharashtra	42	46	43

Table 9. Impact of improved pearl millet cultivars on unit cost of production[1], 1971-95.

State	Average cost (Rs t^{-1})			Cost reduction (%) compared to 1972-74	
	1972-74	1981-83	1992-94	1981-83	1992-94
Gujarat	3814	2665	2464	30	35
Haryana	4277	2881	2488	33	42
Rajasthan	3898	1676	1593	57	59

[1]All costs are real costs of production. Real cost is computed on the basis of 1992 prices.

Source: Estimated from cost of cultivation reports.

In a labor surplus economy like India's, creation of employment opportunities is treated as a benefit of new technology. Table 10 shows that improved cultivars required more labor than local cultivars, thus creating scope for employment. Since employment opportunities were created for both male and female labor, the improved cultivars had a positive gender effect.

Table 10. Impact of improved pearl millet cultivars on labor employment in India.

	Labor use (ha^{-1})		
Description/states	**Male**	**Female**	**Total**
Local variety			
Haryana	20	16	36
Rajasthan	16	5	22
Maharashtra	26	45	71
Improved cultivars			
Haryana	29	23	52
Rajasthan	24	12	36
Gujarat	33	33	66
Maharashtra	32	52	89
Increase in labor use (%)			
Haryana	45	41	43
Rajasthan	50	140	64
Maharashtra	23	16	25

Improved cultivars also increased net farm income (Table 11). Local cultivars provided negative income on a full cost basis while improved cultivars provided significant positive income ranging between Rs 1100 and Rs 9700 ha^{-1} in different states. Net income computed on the basis of variable cost showed that improved cultivars increased farm income by up to five times.

Conclusions

The study found that the adoption level of improved pearl millet cultivars has increased to a large extent over the last two and a half decades. Indian farmers largely adopted improved pearl millet cultivars developed by ICRISAT, and public and private sector research institutes from ICRISAT germplasm materials. Pearl millet hybrids developed by the private sector using ICRISAT materials started to dominate the market due to a more effective delivery system and growing investment in research and development. Development of new downy mildew-resistant cultivars, public and private sector efforts in seed multiplication, and timely distribution facilitated the high adoption of improved cultivars in farmers' fields. Qualitative data gathered during on-farm surveys indicate that future research for the development of new pearl millet cultivars

Table 11. Impact of improved pearl millet cultivars on income of pearl millet growers.

Description/states	Returns to pearl millet (Rs ha^{-1}) Gross returns	Net farm income (variable cost basis)	Net farm income (total cost basis)
Local variety			
Haryana	4050	932	-843
Rajasthan	3236	1417	-358
Maharashtra	5833	1976	-1524
Improved cultivars			
Haryana	9116	3837	2062
Rajasthan	6499	2909	1134
Gujarat	10603	5304	3529
Maharashtra	17379	13181	9681
Increase in income (%)			
Haryana	125	312	
Rajasthan	101	105	
Maharashtra	198	567	

should focus on duality of purpose (grain and fodder cultivars) and traits such as short duration to escape drought, maintenance research for downy mildew resistance, drought resistance, bold grain, and better taste.

References

CMIE (Center for Monitoring Indian Economy). 2000. *India's agricultural sector: A compendium of statistics*. Bombay, India: Center for Monitoring Indian Economy Pvt. Ltd.

MOA (Ministry of Agriculture). 1996. *Cost of cultivation of principal crops in India 1996*. New Delhi, India: Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India.

Ramasamy, C., Bantilan, M.C.S., Elangovan, S. and **Asokan, M.** 1999. Perceptions and adoption decisions of farmers in cultivation of improved pearl millet cultivars — A study in Tamil Nadu. *Indian Journal of Agricultural Economics* 54 (2):139-154.

Adoption and Impact Assessment of Hybrid Maize Seed in India

R P Singh[1] **and M L Morris**[2]

Maize was the first major crop to be affected by hybridization in India. However, its impact on the maize sector was not immediately apparent. Following the release of the first commercial maize hybrid in 1961, adoption of hybrid seed remained modest until the early 1980s. During this period, the production and distribution of seed of most staple food crops was largely in the hands of public organizations. Policy reforms introduced during the late 1980s encouraged greater participation of the private sector in the Indian seed industry. During the early 1990s, the number of private maize seed companies operating in India rose sharply, and private sector investment in maize research increased significantly (Singh et al. 1995). Meanwhile, the increased availability of proprietary hybrids produced by private seed companies accelerated the diffusion of hybrid maize seed in the country.

Although these changes have benefited many Indian farmers, there are concerns that in the quest for profit generation, private seed companies are concentrating on limited, large-scale commercial growers while ignoring small-scale, subsistence-oriented farmers who do not represent an attractive commercial market for hybrid seed. In view of the lack of detailed information

Singh, R.P. and **Morris, M.L.** 2005. Adoption and impact assessment of hybrid maize seed in India. Pages 101-113 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi 110 012, India.

[2] Economics Program, Centro International de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico.

on the circumstances under which maize seed is actually used, it is difficult to know whether or not this concern is justified. This paper attempts to examine the extent of adoption of hybrid maize seed and its impact in a range of production environments, and explores options for future maize research and development policies.

Sources of Data

Data for this study was collected through a six-stage survey of 864 maize-growing households during 1994-95. A five-stage, clustered, purposive sampling procedure was used to select the sample households. The five stages involved the selection of states, districts, blocks, villages, and farm households.

Maize Economy of India

Maize is one of the important cereal crops of India. It was traditionally grown as a staple food meant primarily for domestic consumption, wherein farm household requirements were governed by quality and taste preferences influenced production decisions. However in recent years, significant changes have occurred as a result of the increasing commercial orientation of the agricultural economy and maize's rising demand for diversified end uses such as poultry and cattle feed, high quality industrial starches, and a wide array of pharmaceutical definitives such as dextrose, maltose, ethanol, maize oil, etc. Of late, a variety of maize-based fast foods and snacks have been launched in the domestic as well as international markets (Singh and Babu 1998).

In India, maize is grown in a wide range of production environments, ranging from the temperate hill zones in Himachal Pradesh in the north to the semi-arid desert margins in Rajasthan in the west and the humid tropical zone in Karnataka in the south. Between 1951 and 1970, the total area sown to maize expanded at an annual rate of around 3%, resulting in a near doubling of area from 3 Mha to almost 6 Mha. Production trends reflect the combined effects of area and yield growth patterns. Rising yields coupled with steady expansion in area led to an annual growth of 5.92% in maize production during the 1950s and 5.25% during the 1960s. During the 1970s, production growth slowed down noticeably as maize area stabilized around 6 Mha. However, growth in yield continued to fuel overall annual growth in maize production which ranged between 2.59% during the 1980s to 3.17% in the 1990s (Table 1). This resulted in production surpassing

Table 1. Growth in maize area, production and yield in India, 1950-98.

Year	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})
1950-52	3360	2 227	0.66
1960-62	4520	4 333	0.99
1970-72	5787	6 327	1.09
1980-82	5890	6 803	1.16
1990-92	5900	9 047	1.53
1997-98	6182	10 384	1.67
Compound growth rate (% per year)			
1950-60	2.85	5.92	2.92
1960-70	3.52	5.25	1.67
1970-80	0.04	1.15	1.36
1980-90	0.07	2.59	2.53
1990-98	1.07	3.17	2.08

Source: GOI (various years).

10 Mt in 1997-98. Much of this growth was attributed to the adoption of new, seed-fertilizer-based technology in maize production.

Maize Utilization on Farms

Since the adoption of improved maize production technology may be influenced by household utilization patterns for the crop, it is relevant to examine this aspect as well. Utilization patterns for maize reported by the sample households revealed marked differences in its economic role between states (Table 2). For instance in Andhra Pradesh and Karnataka, maize is undisputedly a commercial crop; most households sell almost their entire produce and retain only negligible amounts for domestic consumption or for use as in-kind wages to pay farm labor. In Madhya Pradesh, Rajasthan, and Uttar Pradesh, maize serves partly as a commercial crop and partly as a subsistence crop; most households sell less than half of their produce, preferring instead to retain important quantities for domestic consumption or for use as in-kind wages. Bihar represents an intermediate case; over half of the maize produced here is sold, but a relatively

Table 2. Utilization of maize (% of total production) by sample households.

State	On-farm feed use	On-farm food use	On-farm seed use	Used to pay laborers	Sold
Andhra Pradesh	2	5	<1	2	91
Bihar	10	6	2	28	54
Karnataka	5	6	<1	3	86
Madhya Pradesh	30	3	2	22	44
Rajasthan	32	2	2	22	42
Uttar Pradesh	27	6	2	20	44
Total	18	5	1	16	60

large percentage of the total produce is retained for domestic consumption, especially for use as in-kind wages.

Adoption of Improved Germplasm

In India as elsewhere, an accurate measurement of farm-level adoption patterns of maize varieties is difficult for three reasons. First, many farmers have difficulty in precisely identifying the improved materials. Improved open-pollinated varieties (OPVs) and hybrids are frequently known by the name of the government organization or private company from which seed was originally purchased, i.e., “SSC” (for State Seed Corporation) or “Pro-agro” (for Pro-agro Seed Company). Moreover, since some farmers don’t understand the difference between OPVs and hybrids, information they provide on the type of materials used may be inaccurate. Secondly, where farmers are able to correctly identify the variety or hybrid, plants actually growing in the field may not bear a close resemblance to the variety or hybrid whose seed was originally purchased. Since maize plants readily mate with other maize plants nearby, when both flower at the same time, the common practice of recycling seed (i.e., saving harvested seed to replant in the following season) leads to a loss in genetic purity through natural outcrossing. Consequently, where seed has been recycled for a number of years, it is difficult to classify the variety or hybrid. Thirdly, many of the hybrids grown by Indian farmers are proprietary hybrids whose pedigrees are closed, making it difficult to identify the germplasm. Since several seed companies under different names sometimes market the same varieties and hybrids, variety- and hybrid-specific adoption data may be inaccurate.

The use of improved OPVs and hybrids varied considerably between states. Improved materials were used the most in states where maize was an important commercial crop (Karnataka and Andhra Pradesh) and the least where it was mainly grown for domestic consumption (Madhya Pradesh, Rajasthan, and Uttar Pradesh). Bihar represented an interesting intermediate case, where use of improved materials was high during the postrainy season (when the main commercial maize crop is grown) and low during the rainy season (when many small farmers sow maize as a supplementary food crop).

These findings are generally consistent with official statistics published by the Ministry of Agriculture on the adoption of maize HYVs. Only in two of the six states surveyed — Bihar and Rajasthan — did the results differ significantly. The survey results indicated that in 1995, 81% of the maize area in Bihar was sown to improved OPVs or hybrids, significantly more than the 57% reported by the Ministry of Agriculture. This discrepancy arose because official statistics refer to only the rainy-season maize crop, not the postrainy-season crop. Since the use of improved maize seed in Bihar is greater during the postrainy season, it is not surprising that our estimate was higher. The case of Rajasthan is more perplexing. Here, the survey indicated that during 1995, approximately 36% of the maize was sown to improved OPVs and hybrids, significantly higher than the 3% reported by the Ministry of Agriculture. Since there is no reason to assume that the survey results of Rajasthan are less accurate than those for other states, it must be concluded that the adoption of improved maize seed in Rajasthan has accelerated rapidly in recent years and that official statistics have yet to reflect this fact.

The survey results showing marked differences between states in the level of adoption of improved maize germplasm are consistent with what is known about the activities of the national maize seed industry. Previous studies have shown that private seed companies tend to concentrate on areas with high production potential (Singh et al. 1995). Many seed companies have established breeding stations and seed production facilities in Karnataka, Andhra Pradesh, and to some extent in Bihar, where they have concentrated on developing hybrids adapted to the needs of local commercial maize growers who represent an attractive market. As a result, relatively unfavorable production environments, such as those found in Uttar Pradesh, Rajasthan, and Madhya Pradesh, have been neglected.

Seed Replacement Patterns

How often do maize farmers replace their seed? In Andhra Pradesh, Karnataka, and Bihar, where maize is an important commercial crop and adoption of hybrids is extensive, the vast majority of maize-growing households replace their seed annually (Table 3). However in Madhya Pradesh, Rajasthan, and Uttar Pradesh, where maize is grown mainly for domestic consumption and the adoption of hybrids is low, a vast majority of maize-growing households rarely or never replace their seed, preferring instead to replant seed saved from their own harvest. Households reporting rare or no replacement of seed gave several reasons to explain their behavior. The high cost of seed was often cited as a major constraint, particularly in Andhra Pradesh, Karnataka, and Bihar. In Madhya Pradesh, Rajasthan, and Uttar Pradesh, many households indicated that they do not replace seed more frequently because of its nonavailability. A significant number of households in these three states indicated that frequent seed replacement is unnecessary.

Despite efforts by government extension agents and seed company representatives to discourage the planting of F_2 hybrid seed, there is much anecdotal evidence suggesting that this practice is widespread. In an attempt to shed light on this issue, sample households were asked whether or not they replant F_2 hybrid seed. Slightly more than one-fifth of all households reported that they sometimes did. Among the many reasons given to explain this practice,

Table 3. Frequency of maize seed replacement (% of sample households).

	Frequency of seed replacement			
State	Replaced annually	Replaced every 2-3 years	Replaced every 4 years or more	Never replaced
Andhra Pradesh	79	10	3	8
Bihar	74	13	3	10
Karnataka	85	7	3	6
Madhya Pradesh	4	14	14	68
Rajasthan	4	13	13	71
Uttar Pradesh	6	17	17	60
Total	42	12	8	38

two dominated. Firstly, many households indicated that they plant F_2 hybrid seed because they are reluctant to invest scarce resources in a crop as risky as maize. This attitude was very evident in states where two cycles of maize are grown, particularly Bihar. Many households in Bihar reported that they purchased F_1 hybrid seed to plant during the postrainy season, when the crop is grown under irrigation, but that they preferred to replant F_2 seed during the rainy season when the maize crop is dependent on highly uncertain rainfall. Secondly, many of the households that reported planting of F_2 hybrid seed indicated that the yield difference between F_1 and F_2 generations is relatively small. Considering that many of the commercial hybrids currently being sold in India are double cross hybrids, this is undoubtedly correct; the expected yield decline in the F_2 generation of many double cross hybrids is as low as 10-15%. Depending on the circumstances, and taking into account the possibility of weather-induced crop failure, farmers may be acting entirely rationally in planting F_2 hybrids.

Where do Indian farmers procure maize seed from? Table 4 shows where the sample households got their seed from and the marked differences between states. In Andhra Pradesh, Karnataka, and Bihar, more than three-quarters of the maize-growing households purchased their seed from external sources, usually private traders, or far less frequently from one of the government seed agencies. However, in Madhya Pradesh, Rajasthan, and Uttar Pradesh, two-thirds of the households got their seed by saving a part of their own produce for replanting.

This extensive reliance on purchased seed provides compelling household-level evidence of the gains achieved in recent years by the formal maize seed industry. Judging from the data (Table 4), it can be concluded that the private sector has been particularly effective in convincing farmers of the value of hybrid seed and inducing them to make regular purchases. This finding is supported by data reported previously on recent growth in hybrid seed sales (Singh et al. 1995).

Input-use Pattern

Although improved seed can contribute to productivity independent of other inputs, it has the ability to increase the productivity of other inputs. For instance, if farmers can obtain hybrid seed that performs well under local conditions, the efficiency with which other inputs are converted into economically valuable outputs increases, thereby increasing the incentives to invest in the other inputs. Therefore, it is not surprising that technical change in agriculture is frequently

Table 4. Sources of maize seed (% of seed used by sample households).

	Maize seed procured from				
State	Own harvest	Other farmers	Private traders	Government agency	Others
Andhra Pradesh	8	1	84	7	< 1
Bihar	15	2	77	6	< 1
Karnataka	5	1	73	20	< 1
Madhya Pradesh	64	3	14	19	< 1
Rajasthan	69	6	13	12	< 1
Uttar Pradesh	67	10	9	14	< 1
Total	38	4	45	13	< 1

driven by changes in crop varieties, which in turn depend on farmers having reliable access to improved seed.

Fertilizer

Table 5 presents information on nitrogen (N), phosphorus (P), and potassium (K) fertilizer applied to maize by sample households. It may be noted that in states where two maize crops were grown annually, considerably more fertilizer was applied during the postrainy season. This presumably happened because postrainy-season maize is generally irrigated; therefore farmers face little risk of losing their investment in fertilizer as a result of drought-induced crop failure.

Table 5. Seasonwise use of fertilizers (N, P and K, kg ha^{-1}) on maize OPVs and hybrids by sample households.

	Rainy season			Postrainy season		
State	OPVs	Hybrids	Difference	OPVs	Hybrids	Difference
Andhra Pradesh	43	80	+86%	52	89	+71%
Bihar	45	67	+49%	72	118	+64%
Karnataka	43	77	+79%	62	100	+61%
Madhya Pradesh	54	61	+14%	na	na	na
Rajasthan	51	58	+14%	na	na	na
Uttar Pradesh	52	79	+52%	na	na	na

na = Not available.

Secondly, hybrids receive considerably more fertilizer than OPVs. No doubt this is attributable to the greater ability of hybrids to respond to improved fertility, which makes investment in fertilizers more attractive. Thirdly, relatively more fertilizer is applied to OPVs grown during the rainy season in Madhya Pradesh, Rajasthan, and Uttar Pradesh than elsewhere. Although fertilizer use is expected to be lower in these states where maize is often produced under highly uncertain rainfed conditions, at least two factors could be contributing to the relatively high rate of fertilizer application: (1) there are relatively few hybrids available with good adaptation to local conditions; therefore farmers prefer OPVs; and (2) only one maize crop per year is grown in these three states; so farmers apply more fertilizer because there is no carryover effect from fertilizer applied during the postrainy season.

Irrigation

Table 6 presents information on the average number of irrigations applied to maize. Two features of this data are noteworthy. First, the postrainy-season crop received more irrigations than the rainy-season crop, which is hardly surprising considering that the latter was sown to coincide with the onset of the monsoon. Secondly, regardless of the season, there was little difference in the number of irrigations applied to OPVs and hybrids. This suggests that adoption of hybrid maize seed does not seem to be associated with greater use of irrigation.

Table 6. Average number of irrigations applied to different types of maize germplasm by sample respondents.

	Rainy season			Postrainy season		
State	**OPVs**	**Hybrids**	**Difference**	**OPVs**	**Hybrids**	**Difference**
Andhra Pradesh	1.50	1.70	+13%	6.07	6.28	+3%
Bihar	1.47	2.80	+42%	5.45	5.54	+<1%
Karnataka	1.85	2.19	+18%	5.55	5.86	+6%
Madhya Pradesh	0.60	0.86	+43%	na	na	na
Rajasthan	0.78	0.84	+8%	na	na	na
Uttar Pradesh	0.86	0.93	+8%	na	na	na

na = Not available.

Impact of Improved Maize Technology

The survey results support the view that adoption of improved maize seed and complementary crop management practices have accelerated sharply in recent years. Uptake of improved technologies was particularly pronounced in states in which maize is an important commercial crop, most notably Karnataka and Andhra Pradesh (during both rainy and postrainy seasons), as well as in Bihar (during the postrainy season). In these states, use of improved germplasm was extensive; in some cases 100% of the area sown to maize is now being sown to hybrid seed. Adoption of improved germplasm has been accompanied by an increase in the use of complementary inputs, most notably fertilizer and irrigation. Maize growers do not appear to be using purchased inputs indiscriminately; however they appear to be increasing application rates whenever it is profitable to do so.

What impact did the adoption of improved maize technologies have? Since detailed plot-level input-output data were not collected as part of the survey, production functions could not be estimated to isolate the yield increase attributable to each input (improved seed, fertilizer, herbicide, pesticide, etc.) However, by comparing the average yields reported for OPVs and hybrids, it was possible to determine the combined effect of adopting hybrid seed, applying greater quantities of purchased inputs, and/or introducing improved crop management practices. A number of patterns are evident from the yield data presented in Table 7.

Table 7. Average maize yields (kg ha^{-1}) on sample farms, 1994-95.

	Rainy season			Postrainy season		
State	**OPVs**	**Hybrids**	**Difference**	**OPVs**	**Hybrids**	**Difference**
Andhra Pradesh	2358	3451	+46%	3151	4097	+30%
Bihar	1723	2769	+61%	3257	4351	+34%
Karnataka	2267	3368	+49%	3298	4341	+32%
Madhya Pradesh	1897	2419	+28%	na	na	na
Rajasthan	1945	2427	+25%	na	na	na
Uttar Pradesh	1956	2881	+47%	na	na	na

na = Not available.

Firstly, average yields of maize during the postrainy season were significantly higher than those in the rainy season, reflecting the more favorable growing conditions (e.g., more reliable water supply, higher level of solar radiation, and lower insect and disease pressure) under which most of the postrainy-season crop was produced. Secondly, average yields were significantly higher in states where maize was grown as a commercial crop (Andhra Pradesh, Karnataka, and Bihar) than in states where it was grown as a subsistence crop (Madhya Pradesh, Rajasthan, and Uttar Pradesh). Thirdly, in all the six states, average hybrid yields were significantly higher than those for OPVs; the yield difference ranged from 25% in Rajasthan to 61% in Bihar.

Given the increasing use of purchased inputs associated with adoption of hybrid seed, the yield difference cannot be entirely attributed to the adoption of hybrids. However, it would be fair to say that adoption of hybrid seed serves as a catalyst for changes in crop management practices, and that the combined effect on yield is substantial.

Based on the differences observed between average yields of OPVs and those of hybrids, and taking into account the area sown to OPVs and hybrids in each state, it is possible to estimate the gross annual increase in maize production attributable to the adoption of hybrids and associated crop management practices (Table 8). In the absence of hybrids, maize production in these states would have been more than one million tons lower during 1994-95 than it actually was.

Table 8. Increase in maize production attributed to the adoption of hybrids, 1994-95.

	Rainy season			Postrainy season		
State	**Yield difference ('000 t)**	**Hybrid area[1] ('000 ha)**	**Increase in produ-ction ('000 t)**	**Yield difference (kg ha^{-1})**	**Hybrid area ('000 ha)**	**Increase in produ-ction ('000 t)**
Andhra Pradesh	1093	200	219	946	45	43
Bihar	1046	162	170	1094	196	215
Karnataka	1101	243	268	1043	50	52
Madhya Pradesh	522	68	36	na	na	na
Rajasthan	482	74	36	na	na	na
Uttar Pradesh	925	84	78	na	na	na
Total			807			310

[1] Based on the total maize area in each state and the level of adoption of hybrid maize.
na = Not applicable.

Conclusions and Policy Implications

The adoption data presented in this study indicate that India's maize research has been quite successful in developing improved OPVs and hybrids. Both public and private breeding programs can take the credit because their activities are in many ways complementary. With the emergence of a flourishing private maize seed industry, many public breeding programs have begun to shift the focus of their activities, moving "upstream" in the research pipeline in a conscious effort to strengthen their involvement in activities such as prebreeding, basic population improvement, development of special trait germplasm, and inbreeding, that are unlikely to be taken up by the private sector. Meanwhile, private seed companies have become adept at identifying specific markets and developing commercial hybrids adapted to them. The growing collaboration between the public and private research systems has been reflected in recent years in the increasing exchange of germplasm, information, and personnel.

Although the emergence of a flourishing private maize seed industry has relieved some of the pressure on public breeding programs, government research administrators must ensure that the allocation of research resources remains consistent with national policy objectives. In the past, efforts in maize breeding in the public and private sectors focused disproportionately on favorable production environments, resulting in high expected payoffs. The strategy has paid-off till now. However, at some point of time, a shift in focus will certainly become necessary. With hybrid adoption levels in some states already exceeding 90%, returns from further research investment targeted at these states are undoubtedly declining, and eventually it may become appropriate to shift attention elsewhere.

Addressing the special needs of maize growers located in marginal production environments will not be easy. Experience suggests that it is usually very difficult to breed for the traits required by these environments, especially early maturity, drought tolerance, and waterlogging tolerance. Even if this is possible, effective demand for commercial seed will often be weak. For these reasons, private companies are unlikely to show much interest in marginal environments, which means that the responsibility for these environments is likely to fall squarely on the shoulders of the public sector.

References

GOI (Government of India). Various years. *Estimates of area, production and yields of principal crops in India*. New Delhi, India: Directorate of Economics and Statistics, Ministry of Agriculture.

Singh, R.P., Pal, S. and **Morris, M.L.** 1995. *Maize research, development and seed production in India: contribution of public and private sectors*. CIMMYT Economics Programme Working Paper 95-03. Mexico, D.F.: Centro Internacional de Mejoramiento de Maiz y Trigo.

Singh, R.P. and **Sathees Babu, K.** 1998. Maize economy in India — poised for a breakthrough. *Indian Farming* 48 (1):76-83.

10

Chickpea in Nontraditional Areas: Evidence from Andhra Pradesh

P K Joshi,[1] M Asokan[1] and M C S Bantilan[2]

Introduction

Although chickpea is not traditionally a prominent pulse crop in areas with a hot and dry climate, this region contributes more than 70% of the total chickpea production in India, and has enormous potential for further expansion. The hot and dry climate poses major production-limiting biotic constraints like wilt, root rots among major diseases; and pod borer and leaf miner among insects (Ali et al. 1997). Although the biotic and abiotic constraints have remained unchanged over the years, chickpea area in the nontraditional region has increased substantially since 1990. This raises questions on its sources of area expansion, and reasons thereof. The objectives of this study were to:

- assess the growth in chickpea area, production, and yield in hot and dry climate regions
- determine the sources of area expansion in chickpea, and
- examine the role of policy and technology (improved varieties) in area shift in favor of chickpea.

Joshi, P.K., Asokan, M. and **Bantilan, M.C.S.** 2005**.** Chickpea in nontraditional area: evidence from Andhra Pradesh. Pages 115-129 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Formerly of the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 502 324, Andhra Pradesh, India.

[2] International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 502 324, Andhra Pradesh, India.

The study postulated two hypotheses: (i) postrainy fallow and marginal lands released substantial areas for chickpea cultivation, and (ii) the availability of improved technology (e.g., new varieties) facilitated area expansion.

Methodology

Study Area

The study confirmed the set hypotheses in Andhra Pradesh, where chickpea area has increased substantially since 1990 — from around 50,000 ha during the 1980s to a record 1,68,000 ha in 1994-95 (GOI 1995). Chickpea production has grown by more than 16% annually during the past five years.

Andhra Pradesh is located in the southern part of India which experiences severe hot and dry conditions not generally conducive for chickpea production. Chickpea is largely grown under rainfed conditions. Annual rainfall in the state is less than 1000 mm (925 mm), with about 70% of it occurring during the southwest monsoon (Jul to Sep) and 23% of it during the northeast monsoon (Oct to Dec) and winter period (Jan and Feb). Chickpea is sown from late September to late November in the state. While the September and October rains influence the acreage sown to the crop, the northwest monsoon and winter rains have a bearing on yields.

The state is divided into the Coastal, Rayalaseema, and Telangana regions. This study focuses on the Rayalaseema and Telangana regions in view of their large share under chickpea area (about 90% of the chickpea is sown here).

Data

The study used both primary and secondary data to test the hypotheses. Districtwise secondary data were collected and used to analyze trends in area, production, and yield of chickpea from 1970-71 to 1995-96.

Primary data was also collected (1995-96) to assess the adoption of improved chickpea varieties in the selected districts as information on this important aspect is seldom documented. This was done using a questionnaire enquiring about farmers' recollection of adoption patterns related to different chickpea varieties from 1991-92 to 1994-95. The same was confirmed with officials of the extension department of the Andhra Pradesh government.

A systematic sampling scheme was designed to choose the districts which sow over 10,000 ha of chickpea. The districts were Anantapur and Kurnool in Rayalaseema region and Medak in Telangana region, which cover almost 80% of the total chickpea area of about 1,35,000 ha in the two regions, and about 65% in Andhra Pradesh.

A three-stage stratified sampling method was employed to select chickpea growers from these districts. In the first stage, mandals were chosen and divided into three strata according to the intensity of chickpea cultivation: the top 33% of the chickpea-growing mandals were designated as high-intensity areas; the next 33% as medium-intensity areas; and the remaining as low-intensity areas. One mandal was randomly picked from each stratum from each district. Only one mandal was selected from Anantapur district from the high-intensity stratum as the area under chickpea was too low in the other two strata. In all, seven mandals were selected from three districts.

In the second stage, three villages were randomly selected from each mandal. Finally, in the third stage, 10 chickpea-growing farmers from each mandal were randomly chosen, making a total of 210 chickpea farmers which comprised the study sample.

Analytical Approach

To evaluate chickpea performance in area, production, and yield, their compound growth rates were estimated between 1970-71 and 1995-96. To study decadewise performance, a span of 25 years was divided into three periods: (i) 1970-71 to 1979-80, (ii) 1980-81 to 1989-90; and (iii) 1990-91 to 1995-96.

Sources of Chickpea Area Expansion. To examine the sources of area expansion of chickpea, temporal changes in cropping patterns during the postrainy season between 1989-90 and 1995-96 were studied. Similarly, information was estimated on the extent of postrainy fallow which is neither compiled nor reported. To estimate the area under postrainy fallow, the following procedure was used: The crops were split into two groups: rainy season and postrainy season. When a crop was in the field during both the seasons (e.g., sugarcane, cotton, pigeonpea), it was included in both the seasons. The total area under these crops during the two seasons was calculated by adding individual crop areas.

The total area under all the crops (both seasons) was subtracted from the gross cropped area, giving the area of all other crops (e.g., vegetables, spices, other grains) which were not included in the first step.

Since there was no information on the seasonality of these crops, it was arbitrarily assumed that half of the area was sown during the rainy season and the other half during the postrainy season. These other crops usually cover less than 5% of the gross cropped area in a district.

The postrainy season area under the main crops was added to half the area of all the other crops to estimate the total area under postrainy season crops.

The area calculated in the previous step was subtracted from the net cropped area to estimate the postrainy fallow.

Extent of Improved Chickpea Varieties. To understand how improved chickpea varieties were spreading in the selected districts, their adoption patterns between 1991-92 and 1994-95 were estimated on the basis of an on-farm survey.

Chickpea Area Response Model. An area response model was estimated to identify factors which determine allocation of chickpea area. The model used was as follows:

$$AREA_{cp} = f\,(AREA^{-1}_{cp},\ Y^{-1}_{cp},\ Y^{-1}_{cc},\ P^{-1}_{cp},\ P^{-1}_{cc}, CV_{cp},\ CV_{cc},\ HYV_{cp},\ IR,\ RF_{s},\ t), pP, CC, P, Icp$$

where,

$AREA_{cp}$ = chickpea area in period t

$AREA^{-1}_{cp}$ = chickpea area in t-1 period

Y^{-1}_{cp} = yield of chickpea in t-1 period

Y^{-1}_{cc} = yield of the competing crop in t-1 period

P^{-1}_{cp} = farm harvest prices of chickpea in t-1 period

P^{-I}_{cp} = farm harvest prices of the competing crop in t-1 period

CV_{cp} = coefficient of variation in chickpea yield (based on moving 3 years)

CV_{cc} = coefficient of variation of competing crop yield (based on moving 3 years)

HYV_{cp} = dummy used for the availability of improved varieties from 1991 onward

IR = irrigated area in period t

RF_s = rainfall in September-October
t = time trend.

Technology-related information in this model is represented by chickpea yield, CV in chickpea yield, and area under improved chickpea varieties. Similarly, the prices of chickpea and competing crops are proxy for price policy.

Results and Discussion

The area under chickpea was about 70,000 ha in the early 1970s but substantially declined to 51,000 ha in the early 1980s, and crossed 1,00,000 ha in the early 1990s (Table 1). However, in an unprecedented trend, chickpea area fell until 1980-81 and stabilized around 50,000 ha during the early 1980s. Chickpea area almost doubled in 1995-96 compared to that in 1980-81. Chickpea production too followed a similar pattern.

Annual compound growth rates in area, production, and yield of chickpea were computed for different periods (Table 2). The compound growth rate of chickpea production declined at an annual rate of 2.31% during 1970-80 due to a drop in its area and yield. Chickpea production increased at an annual rate of 5.75% in 1980-90; most of it came from yield increments (about 60%) and area expansion (about 40%). During 1981-90, chickpea regained the area that was lost during the 1970s. Chickpea production increased sharply during 1991-96 (an unprecedented annual compound growth rate of 16.05%). Interestingly, the entire growth in production was contributed by area expansion. The area under chickpea during 1991-96 increased at an annual rate of about 20%. Ironically, yield levels during this period showed a decline; the annual compound growth rate was -3.20%.

The analyses of growth rates in area and yield during 1991-96 indicated that chickpea cultivation was spreading in marginal environments. Growth in

Table 1. Chickpea area and production in Andhra Pradesh.

Year[1]	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})
1970	78.87	22.86	290
1980	55.81	16.35	293
1990	60.14	37.50	624
1995	105.68	36.37	723

[1] Triennium average ending 1970, 1980, 1990, and 1995.

Table 2. Annual compound growth rates (%) of production, area, and yield of chickpea, Andhra Pradesh.

Period	Production	Area	Yield
1970-80	-2.31	-1.12	-1.12
1981-90	5.75	2.28	3.39
1991-96	16.05	19.88	-3.20

yield was declining despite substantial increases in area. This happens when gain in chickpea area comes from marginal land where yield is much lower than that from normal land. Obviously, the lower yield levels from marginal land bring down average yields.

Spatial Variation in Chickpea Growth

Districtwise annual compound growth rates in area, production and yield of chickpea were computed (Table 3). So were districtwise temporal changes in chickpea area (Table 4). About 40% of the districts in Andhra Pradesh showed a decline in chickpea area during 1971-80. These districts covered about 36.3 thousand hectares during 1971-75, accounting for about half the total chickpea area and production in the state. With a few exceptions, the decline in chickpea area continued during 1981-90 with more districts joining the group. During 1981-90, about 70% of all the districts showed negative growth rates in chickpea area, accounting for about 80% of the chickpea area and nearly 75% of the total chickpea production in the state. Interestingly, there was a reversal in trend during 1991-96 when all the districts, except Krishna and Srikakulam, showed positive growth rates in chickpea area. Krishna and Srikakulam districts covered a negligible area (less than 100 ha) under chickpea.

During 1981-90, chickpea production declined because of a fall in area and yield. This indicates that chickpea area was released from better-endowed regions for other competing crops, and that it was largely confined to the more marginal lands. Such a phenomenon was evident from declining yields. Chickpea production increased in all the districts between 1990-91 and 1995-96, area expansion being the source of this growth. Area expansion surpassed negative yield effect in six districts — Adilabad, Anantapur, Cuddapah, Khammam, Kurnool, and Visakhapatnam — for a positive and high growth in chickpea production. Together, these districts covered about 66% of the total chickpea area in the state. Area

Table 3. Districtwise annual compound growth rates (%) of chickpea production, area, and yield, Andhra Pradesh.

District	1970-79			1980-89			1990-95		
	Pro-duction	Area	Yield	Pro-duction	Area	Yield	Pro-duction	Area	Yield
Adilabad	-0.17	-3.65	3.61	-14.53	-6.08	-9.00	32.98	11.53	19.21
Anantapur	6.87	0.13	6.73	17.35	21.17	-3.15	24.55	36.88	-9.00
Cuddapah	5.66	3.77	1.82	21.59	27.39	-4.56	15.59	18.88	-2.77
Guntur	2.08	1.53	0.54	-5.49	-4.19	-1.35	44.31	45.09	-0.54
Hyderabad	0.02	-1.93	1.99	-14.36	-3.55	-11.21	25.96	10.46	14.02
Karimnagar	-2.38	-7.52	5.56	-18.71	-12.43	-7.17	31.52	2.88	27.84
Khammam	7.06	1.32	5.67	-19.85	-25.40	7.44	0.00	19.90	-16.59
Krishna	0.93	1.17	-0.24	-14.76	-14.20	-0.65	22.47	-18.35	50.00
Kurnool	5.10	5.12	-0.02	26.54	16.99	8.16	7.21	18.95	-9.87
Mahabub-nagar	0.62	-3.66	4.45	-7.15	-2.29	-4.98	51.77	20.22	26.24
Medak	-7.31	0.45	-7.73	6.23	-0.41	6.67	21.16	11.36	8.80
Nalgonda	3.26	4.47	-1.16	-20.98	-17.97	-3.67	67.30	27.02	31.71
Nellore	0.00	8.16	-7.55	20.43	24.72	-3.44	68.58	62.47	3.76
Nizamabad	-15.70	-4.06	-1.14	13.44	-4.88	19.26	12.82	7.65	4.80
Srikakulam	20.76	24.93	-3.34	3.19	-9.56	14.10	0.00	8.71	9.54
Visakha-patnam	-11.78	-8.73	-3.35	11.05	8.05	2.77	4.88	32.29	-20.72
Warangal	-2.39	-3.39	1.04	-7.21	-4.93	-2.39	11.77	3.15	8.36

expansion along with declining growth rates in yield show that chickpea's importance in marginal lands is growing.

Sources of Area Expansion

About 48,000 hectares of new area were brought under chickpea cultivation between 1990-91 and 1995-96, which may have come from either crop substitution or utilization of fallow and marginal lands or both. Though, it is not possible to obtain such information from district-level data, some indications come from a shift in cropping pattern and the extent of fallow land (Table 5). Utilization of fallow and marginal lands is expected to be the most important source of area expansion in chickpea.

Table 4. Districtwise chickpea area ('000 ha) during different periods, Andhra Pradesh.

District	1971-75	1981-85	1991-95
Adilabad	5.14	3.00	2.24
Anantapur	2.28	2.64	16.07
Cuddapah	0.90	1.10	7.44
Guntur	5.30	4.70	6.56
Hyderabad	7.70	4.80	4.24
Karimnagar	5.30	1.88	0.96
Khammam	0.86	0.56	0.09
Krishna	1.04	0.38	0.03
Kurnool	5.40	6.38	35.21
Mahabubnagar	4.06	2.64	3.10
Medak	15.82	12.98	14.81
Nalgonda	1.56	1.40	0.76
Nellore	0.12	0.36	2.43
Nizamabad	11.90	6.48	3.64
Srikakulam	0.06	0.38	0.03
Visakhapatnam	0.12	0.16	0.06
Warangal	2.08	1.00	0.91

Crop Substitution

An important source of chickpea area expansion is area released from competitive crops. It has been observed that the area under postrainy-season sorghum and tobacco has been declining (Table 5). Area released from these crops will be shared (though not equally) with other competing crops. The area under postrainy-season sorghum declined in three selected districts and that of tobacco in Anantapur and Kurnool. Some area under postrainy-season sorghum may be substituted with chickpea. Crop substitution may be due to crop competition, made possible by the higher profitability of chickpea compared to postrainy-season sorghum.

Fallow Lands. Another significant source of chickpea area expansion is its cultivation in fallow lands. Most of the crop land in rainfed areas is kept fallow during the postrainy season due to the nonavailability of irrigation water and

Table 5. Sources of chickpea expansion in select districts of Andhra Pradesh.

District	Status of crop area		Status of fallow area
	Sorghum	Tobacco	
Anantapur	Declining	Declining	Declining
Kurnool	Declining	Declining	Declining
Medak	Declining	-	Declining
Andhra Pradesh	Declining	Declining	Declining

other resources, and the low production potential of the soil (marginal lands). Over time, a decrease in the area under postrainy fallow in selected districts has been observed (Table 6). In Kurnool, it declined by 74,000 ha between triennium averages ending 1990-91 and 1994-95. The corresponding figures were 50,000 ha for Anantapur and 32,000 ha for Medak districts. On the other hand, chickpea area in these districts increased. It is believed that a large part of the area of postrainy fallow was used for chickpea cultivation. Between triennium averages ending 1990-91 and 1994-95, chickpea area in Kurnool district increased by 16,000 ha, which was about 22% of the postrainy fallow area which declined during the same period. Similarly, chickpea area between triennium averages ending 1990-91 and 1994-95 increased by 13,000 ha in Anantapur district, which was 26% of the fallow area that declined. In Medak district, chickpea area increased by 5,000 ha, 16% of the decreasing postrainy fallow area between triennium averages ending 1990-91 and 1994-95.

Table 6. Trends in postrainy fallow area ('000 ha) in select districts of Andhra Pradesh.

Year	Anantapur	Kurnool	Medak	Andhra Pradesh
1989	862	570	265	6437
1990	822	562	254	6237
1991	797	511	245	6195
1992	814	514	236	6472
1993	784	534	239	5246
1994	727	401	229	4864
1995	819	486	202	5113

Reasons for Area Expansion

There are two important reasons for expanding chickpea area in the hot and dry climates: rapid increase in chickpea prices and the availability of improved chickpea varieties.

Role of Price

The average farm harvest price of chickpea in the select districts increased by 60% between 1989-90 and 1995-96 (Table 7). On the other hand, the farm harvest price of postrainy-season sorghum during the same period increased by only 45%. The temporal changes in absolute prices between chickpea and postrainy-season sorghum were statistically significant at 1% probability level. Higher prices influenced chickpea area in two ways: chickpea became more competitive compared to postrainy-season sorghum, inducing farmers to release postrainy-season sorghum area for chickpea. Secondly, the low yield levels made chickpea profitable at higher prices. It was estimated that the minimum yield of chickpea required to cover total cost (Rs 700 kg ha^{-1} in 1989-90) fell to 400 kg ha^{-1} due to rise in output prices. This made it possible for farmers to cultivate chickpea on marginal soils with low production potential.

Table 7. Changes in farm harvest prices (Rs t^{-1}) of chickpea and postrainy-season sorghum in Andhra Pradesh.

	Average price of chickpea			Average price of postrainy-season sorghum		
District	**1988-90**	**1993-95**	**Change (%)**	**1988-90**	**1993-95**	**Change (%)**
Anantapur	627	1100	75	220	360	63
Kurnool	680	1030	51	225	340	51
Medak	655	1005	53	255	320	25

Role of Improved Chickpea Varieties

Another very important reason for expansion in chickpea area was the availability of new, improved chickpea varieties. Since 1990, three improved chickpea varieties — ICCC 37, ICCV 2, and ICCC 10 — have been released for cultivation in Andhra Pradesh. These were developed by ICRISAT in collaboration with the national program, such as the Andhra Pradesh Agricultural University (APAU). It was observed that ICCC 37 and ICCV 2 were becoming popular in Andhra Pradesh due to desirable traits such as the ability to overcome major constraints like crop mortality due to terminal drought and low crop yields due to wilt disease. ICCC 37 is a high-yielding variety that matures in 90-100 days, and is resistant to wilt and tolerant to dry root rot (Kumar et al. 1985).

Similarly, ICCV 2 is an extra-short duration variety that matures in 85 days. It is a *kabuli* type resistant to fusarium wilt. It is adapted to normal and late sowing, escapes drought, and its green pods are preferred as vegetable. Early-maturing varieties score in the sense that they avoid terminal drought in comparison to local varieties (e.g., Annigeri) which mature in about 140 days. In 1989, the Government of Andhra Pradesh released ICCC 37 and ICCV 2 for general cultivation.

Adoption of Improved Chickpea Varieties

Based on the on-farm survey, the area under improved varieties was estimated in select districts of Andhra Pradesh (Table 8). About 30% of the sample farmers had sown improved chickpea varieties in 1994-95. Among these, the popularity of ICCC 37 grew in Medak and Anantapur districts, while ICCV 2 was more popular in Kurnool district. Interestingly, the local high-yielding variety, Annigeri was still the ruling variety in Anantapur and Kurnool districts, covering about 32% and 68% of the chickpea area, respectively.

In Medak district, ICCC 37 adoption reached more than 50% of total chickpea area in 1993-94 and dropped marginally to 48% in 1994-95. In Anantapur district, the area under ICCC 37 was nearly 20% in 1994-95. ICCV 2 experienced consistent increase in adoption, reaching 22% in 1994-95. These varieties were slowly replacing the traditionally-grown ones. At the aggregate level, their share increased from 8% in 1991-92 to 26% in 1994-95. Annigeri and other local varieties were largely replaced by these two varieties in Kurnool and Medak districts. In Anantapur district, both ICCC 37 and Annigeri predominated.

The varying adoption preferences imply that farmers in these regions attach varying levels of importance to the new varieties. For instance in Kurnool district, ICCV 2 was preferred for its ability to escape drought as chickpea here is largely grown in the uplands where moisture recedes rapidly (Kumar et al. 1985). Terminal drought was not the major problem in Anantapur and Medak districts; therefore farmers preferred the high-yielding and wilt-resistant

ICCC 37. In Anantapur district, chickpea was generally grown under a favorable moisture environment, e.g. tank beds. In Medak district, rainfall distribution is such that the crop gets sufficient moisture for vegetative growth and flowering.

The high-yielding trait of the new chickpea varieties and their early maturity induced farmers to sow them in hitherto postrainy fallow lands, and also in marginal areas. Results reveal that the new varieties are spreading very fast in the hot and dry climate. Such a trend will certainly increase farm income. Also, the utilization of fallow land helps control soil erosion and conserve soil moisture.

Table 8. Adoption of improved chickpea varieties in Andhra Pradesh (percentage of total chickpea area).

District	Cultivar	1991-92	1992-93	1993-94	1994-95
Anantapur	Annigeri	24.20	23.15	19.45	32.35
	ICCC 37	5.70	5.15	12.15	19.40
	Local	70.10	71.70	68.40	48.25
Kurnool	Annigeri	86.20	77.40	81.90	67.50
	ICCC 37	0.22	0.20	0.15	0.90
	ICCV 2	4.90	8.40	8.90	22.25
	Other improved	0.60	6.20	0.95	2.00
	Local	8.08	7.80	8.10	7.35
Medak	Annigeri	15.20	7.80	8.10	7.35
	ICCC 37	38.30	49.00	51.45	48.1
	Local	46.50	39.10	33.75	38.05
Andhra Pradesh	Annigeri	74.50	66.20	70.10	57.60
	ICCC 37	4.25	5.50	6.40	8.60
	ICCV 2	4.05	6.85	7.30	17.35
	Other improved	0.60	5.05	0.75	1.55
	Local	16.60	16.40	15.45	15.20

Factors Influencing Area Expansion

Regression analysis was done to identify factors influencing area expansion in chickpea (Table 9). The linear regression equations were found to be best-fit in comparison to log-log and quadratic equations. The variables included in the model explained 93-99% of the variation in determining chickpea area.

Table 9. Results of the regression analysis on factors influencing area expansion of chickpea in Andhra Pradesh.

Variables	Anantapur	Kurnool	Medak
Intercept	137.5403	122.2052	35.1811
Lagged chickpea area	-	-	-0.4499**
			(0.1285)
Chickpea yield	0.0064***	-0.0038	0.0248**
	(0.003)[1]	(0.0071)	(0.0248)
Sorghum yield	-0.0029*	-0.0045	-0.0194***
	(0.0021)	(0.0074)	(0.0028)
Chickpea price	0.0293***	0.0615***	0.0264***
	(0.0071)	(0.0113)	(0.0036)
Sorghum price	0.0276	-0.0047	-0.0273***
	(0.0236)	(0.226)	-0.0042
Chickpea yield risk	0.0067	-0.0528	0.0562*
	(0.0298)	(0.0990)	(0.0201)
Sorghum yield risk	0.1419***	0.2302**	-0.6012***
	(0.0515)	(0.0945)	(0.0676)
Irrigated area	-0.6309*	-0.6260	0.1498*
	(0.4360)	(1.0691)	(0.0801)
Postrainy fallow	-0.1162**	-0.0942	-0.0329
	(0.0518)	(0.0518)	(0.0805)
Presowing rainfall	-0.0061*	-0.0047	0.0132***
	(0.0044)	(0.0109)	(0.0025)
Chickpea HYVs	-4.4211*	20.0504***	5.2733***
	(3.1130)	(7.2910)	(0.7509)
Time	-2.3556***	-3.8707**	-1.5247*
	(0.7965)	(1.7832)	(0.9031)
R^2	0.9343	0.9345	0.9909
Adjusted R^2	0.8826	0.8830	0.9547

[1] Figures in parentheses are the standard errors of the estimated coefficients.

*** Significant at 1% probability level.

** Significant at 5% probability level.

* Significant at 10% probability level.

In Anantapur district, chickpea yield, its price, and postrainy-season sorghum yield instability (represented by CV in yield) positively and significantly influenced chickpea area allocation. On the other hand, the regression coefficients of postrainy-season sorghum yield, irrigated area, and postrainy-season rainfall were negative and significant, indicating that any increase in these variables would *ceteris paribus* result in a decline in chickpea area.

In Kurnool district, chickpea prices, postrainy-season sorghum yield, and the availability of improved chickpea varieties showed a positive response to chickpea area allocation. In Medak district, chickpea yield, its prices, irrigated area, postrainy- season rainfall, and availability of improved chickpea varieties positively and significantly determined chickpea area. The negative regression coefficients of yield, yield risk, and prices of postrainy-season sorghum suggest that any increase in their magnitude would release chickpea area for other crop(s) in Medak district.

It is interesting to note that there was a negative relationship between allocation of area to chickpea and the extent of postrainy fallow in the select districts. This meant that any decline in postrainy fallow would increase chickpea area, *ceteris paribus*. The regression coefficient was significant at 10% probability level in Anantapur district and nonsignificant in Kurnool and Medak. Time trend also showed a negative sign, which implied that chickpea area would have declined if the variables included in the model had remained constant. This shows that in the absence of relatively favorable prices and yield of chickpea compared to competing crop (postrainy-season sorghum), the decline in fallow area would have resulted in decline in chickpea area.

This analysis clearly implies that a supportive policy (favorable prices) and technological change (improved high-yielding and short-duration varieties) are necessary for expansion in chickpea area in regions experiencing hot and dry climate.

Conclusions

Chickpea area has rapidly increased from 1990-91 onwards in regions experiencing a hot and dry climate, and invariably in nontraditional chickpea-growing regions. A large part of the expansion in chickpea area comes from the area released by either postrainy-season sorghum or postrainy-season fallow or both. This was possible due to higher output prices and the availability of improved chickpea varieties that were high yielding, of short duration and disease resistant in comparison to local varieties.

It was found that the area under improved chickpea varieties increased rapidly in the hot and dry regions. Farmers preferred the early-maturing, short-duration chickpea variety ICCV 2 in areas where soil moisture recedes rapidly, and the high-yielding and wilt-resistant variety ICCC 37 in a more favorable moisture regime. Farmers' preferences for specific varieties and adoption patterns are largely influenced by the targeting of improved varieties to suit agroclimatic conditions.

The analysis confirmed that technological breakthrough (yield enhancement, quality improvement, and risk minimization) and policy support (higher prices) are necessary for expanding the area under chickpea in nontraditional areas. A large area under postrainy-season sorghum and postrainy fallow was released for chickpea due to the availability of improved high-yielding varieties and higher output prices. The new scenario (i.e., favorable prices and availability of improved varieties) has witnessed a silent chickpea revolution in nontraditional regions. This must be sustained by ensuring the availability of appropriate seeds of improved varieties.

References

Ali, Masood, Joshi, P.K., Pande, S., Asokan, M., Virmani, S.M., Kumar, Ravi and **Kandpal, B.K.** 1997. Legumes in Indo-Gangetic Plain of India. Presented at the workshop on *Legumes in rice-wheat cropping system of the Indo-Gangetic Plain: Constraints and Opportunities*, 15-17 Oct 1997, ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Kumar, J., Haware, M.P. and **Smithson, J.B.** 1985. Registration of four short-duration fusarium wilt-resistant kabuli (garbanzo) chickpea germplasms. *Crop Science* 25:576-577.

GOI (Government of India) 1995. *Area and production of principal crops in India 1994-95*. Ministry of Agriculture, New Delhi, India: Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

Assessment of Varietal Preferences of Chickpea in Gujarat

R L Shiyani,[1] P K Joshi,[2] M Asokan[2] and M C S Bantilan[3]

Introduction

Gujarat produces more than 1,22,000 t of chickpea from an area spanning about 1,53,000 ha. Chickpea yield is about 800 kg ha^{-1}, higher than the national average of 700 kg ha^{-1}. The crop accounts for about 13% of the total pulse area and contributes more than 14% to total pulse production in Gujarat. It ranks second after pigeonpea in area and production.

During the past two decades, a limited number of improved chickpea varieties have been released in Gujarat by the State Varietal Release Committee and the National Varietal Release Committee. ICCV 1 was released as ICCC 4 in the early 1980s, and its adoption pattern is yet to be examined. This study attempts to assess the adoption of different chickpea varieties in Gujarat and identify farmers' preferences for different varietal traits.

Background and Data

Chickpea covered an area of about 77,000 ha with a production of 63,000 t in 1970. The area covered improved marginally in the 1980s, yet

Shiyani, R.L., Joshi, P.K., Asokan, C. and **Bantilan, M.C.S.** 2005. Assessment of varietal preferences of chickpea in Gujarat. Pages 131-140 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Gujarat Agricultural University, Junagadh, Gujarat, India.

[2] Formerly of the International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

[3] International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

production declined. However, a consistent increase in area, production, and yield of chickpea took place in 1995, when Gujarat produced 1,22,000 t of chickpea from 1,53,000 ha. A look at the share of each district in the total area and production will reveal that Panchmahals emerges as the predominant district both in area and production (Table 1). Surendranagar district ranked second in 1970, but it was replaced by Jamnagar district in 1995. The other important districts in the state are Ahmedabad and Junagadh. Panchmahals, Ahmedabad, Jamnagar, and Junagadh districts together contributed two-thirds of the total area and production of chickpea. Therefore, they were selected for the present study. Two blocks from each district and three villages from each block were randomly selected. Ten farmers were selected at random from each village.

Table 1. Districtwise area (%) and production (%) of chickpea in Gujarat.

District	1970		1980		1990		1995	
	Area	Production	Area	Production	Area	Production	Area	Production
Panchmahals	39	46	38	57	31	36	29	29
Jamnagar	1	1	3	3	13	12	15	21
Ahmedabad	3	5	1	1	2	0	14	10
Junagadh	7	7	10	8	9	8	7	6
Surendranagar	27	21	6	4	15	14	8	4
Rajkot	3	0	3	0	6	7	5	10
Sabarkantha	3	4	3	5	1	2	4	5
Mehsana	3	3	8	7	9	8	4	3
Baroda	3	3	3	2	2	2	3	2
Amreli	1	0	4	0	1	1	3	3
Kaira	2	2	2	4	3	2	2	2
Surat	4	4	2	3	2	2	2	2
Bhavnagar	1	1	6	0	1	1	1	1
Banaskantha	1	1	5	3	1	1	1	1
Bulsar	1	1	1	1	1	1	1	1
Broach	1	1	2	2	3	3	1	0
Kutch	0	0	3	0	0	0	0	0
Dangs	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100

Table 2. Characteristics of sample farmers.

Characteristics	Ahmedabad	Jamnagar	Junagadh	Panchmahals	All
Irrigated area (%)	10.66	62.87	20.02	63.43	18.06
Chickpea area (%)	29.82	22.28	16.48	44.16	28.25

This gave a sample of 240 farmers. Data was collected through personal interviews of farmers in each village during Feb-Apr 1996.

The farmers of Jamnagar and Panchmahals had better irrigation facilities (63%) compared to those in the other two districts (Table 2). The share of chickpea in the total landholding ranged between 16.48% (Junagadh) and 44.16% (Panchmahals), with an overall average of 28.25%.

The crops grown before chickpea are divided into three main heads: cereal-based, legume-based, and cash crop-based. Table 3 shows that sorghum-chickpea was followed by 52% of the farmers and cotton-chickpea by 48% in Ahmedabad district. Maize-chickpea and paddy-chickpea were adopted by 40% and 60% of the farmers in Panchmahals, respectively. Almost all the sample farmers in Jamnagar adopted groundnut-chickpea. In Junagadh district, groundnut-chickpea (50%), cotton-chickpea (2%), and fallow-chickpea (33%) rotations were practised. Aggregated data showed that cereal-based chickpea was followed by 38%, legume-based chickpea by 37%, cotton-based chickpea by 12%, and fallow-chickpea by 8% of the farmers.

Table 3. Crops grown before chickpea (%).

Cropping system		Ahmeda-bad	Jam-nagar[1]	Juna-gadh[1]	Panch-mahals	All
Cereal-based	Sorghum-chickpea	52				13
	Maize-chickpea				40	10
	Paddy-chickpea				60	15
Legume-based	Groundnut-chickpea		97	50		37
Cash crop-based	Cotton-chickpea	48		2		12
Others	Fallow-chickpea			33		8

[1] Three percent of the farmers in Jamnagar and 15% in Junagadh district did not respond.

Adoption of Improved Varieties

Research on ICCC 4 was initiated in 1973-74. It was first identified in 1982 and released in 1983 for cultivation in Gujarat by the State Varietal Release Committee. On-farm trials were conducted during 1985.

Rating was done to determine the traits most preferred by the farmers. These included grain quality, biotic and abiotic constraints, marketing, seed quality, risk, and agronomic practices. Table 4 reveals the districtwise share of different cultivars in total chickpea acreage from 1992 to 1995. Dahod Yellow was the ruling variety in all the four districts with a share of about 97%. Chaffa was cultivated on a very limited area by the farmers of Ahmedabad district. ICCC 4 is finding its niche in Jamnagar district; its share in total acreage was estimated to be more than 20%. The groundnut-chickpea cropping system and better irrigation facilities might have accelerated the adoption of ICCC 4 in Jamnagar district, where farmers started cultivating it in 1986 (Table 5). The percentage of farmers adopting it increased from 1.67 in 1986 to 5 in 1987 and to more than 8 in 1991.

Information on sources of chickpea seed is very useful for follow-up action and to determine the extent of adoption. The seed sources in this study included own seed, seed shops, other farmers, and research institutes. It is apparent (Table 6) that a majority of the farmers (>79%) were using their own seed. Seed shops ranked second with more than 14% of the farmers, followed by fellow farmers (>3%) as the source of seed. The role of research institutions in seed distribution was limited. In Panchmahals district, all the farmers had sown their own seed. Of course, for the past 3-4 years, KRIBHCO, a voluntary organization, has started seed multiplication and distribution of improved chickpea varieties in the tribal area of Panchmahals. These are expected to be widely preferred and adopted by the tribal farmers.

Varietywise data on the production of foundation and certified chickpea seeds in Gujarat are presented in Table 7. The share of certified seed production of Chaffa drastically declined from 44% in 1993-94 to 14% in 1994-95. However, consistent production of certified seed of Dahod Yellow variety was noticed in both the years. On the other hand, the production of certified seed of ICCC 4 more than doubled in 1994-95 over the previous year. Its share in total certified seed production which was about 23% in 1993-94,

Table 4. Districtwise share (%) of different chickpea cultivars from 1992-1995.

		Extent of adoption			
District	**Variety**	**1992**	**1993**	**1994**	**1995**
Ahmedabad	Chaffa	0.63	0.53	0.85	0.55
	Dahod Yellow[1]	99.37	99.47	99.15	99.45
Jamnagar	ICCC 4[2]	20.63	20.63	24.94	24.61
Junagadh	Dahod Yellow	100.00	100.00	100.00	100.00
Panchmahals	Dahod Yellow	100.00	100.00	100.00	100.00
	Local				
All	Chaffa	0.41	0.38	0.58	0.44
	ICCC 4	1.91	1.71	2.60	1.52
	Dahod Yellow	97.68	97.91	96.82	98.04

[1] Dahod Yellow was the leading variety in the study area.

[2] ICCC 4 is finding its niche in Jamnagar district.

Table 5. Extent of ICCC 4 adoption by sample farmers in Jamnagar district.

Year	Farmers (%)	Area (acres)
1986	1.67	2
1987	5.00	9
1988	3.33	5
1989	3.33	4
1990	5.00	6
1991	8.34	12

increased to more than 49% in 1994-95, implying that this variety is becoming popular among chickpea growers. The area under ICCC 4 ranged between 3225 and 3767 ha in 1994-95. On the basis of seed sales, the area under it is estimated to be 3767 ha, whereas reconnaissance survey estimates reveal that it was adopted on over 3225 ha. With increased seed production, it is expected that the area under ICCC 4 will further expand.

Farmers' preferences for grain quality traits in chickpea (Table 8) indicate that except in Panchmahals district, majority of the farmers in other districts

Table 6. Farmers' sources (%) of chickpea seed in select districts of Gujarat.

Sources	Ahmedabad	Jamnagar	Junagadh	Panchmahals[1]	All
Own seed	66.67	76.67	73.33	100.00	79.17
Seed shops	33.33	13.33	10.00		14.17
Other farmers			13.33		3.33
Research institutes			3.24		0.83
Others		10.00			2.50

[1] During the past 3-4 years, KRIBHCO has started seed multiplication and distribution of improved chickpea varieties in the tribal areas of Panchmahals district.

preferred bold, yellow-colored, round, desi-type grain with a smooth seed coat. On the other hand, medium-sized, brown-colored, wrinkled, desi type with rough seed coat were the traits most preferred by the tribal farmers of Panchmahals. The preference for small-sized chickpea grain by 45% of the farmers in Jamnagar district could be attributed to its better taste, higher yield, and fewer problems associated with the pod borer.

The most preferred quality trait in chickpea grain was rated by the sample farmers (Table 9). Among the six different quality traits, chickpea type was ranked first by almost all the farmers of Ahmedabad district. Color, size, texture, seed coat, and cooking quality of chickpea grain were ranked in descending order by a majority of the farmers. In Jamnagar district, first preference was given to color, followed by size, texture, seed coat, type, and cooking quality. In Junagadh district, it was color, size, texture, seed coat, cooking quality, and type of chickpea. The most preferred quality traits were type, size, color, texture, seed coat, and cooking quality. At the aggregate level, type of chickpea seemed to be the dominantly preferred trait, followed by size, color, texture, seed coat, and cooking quality.

Chickpea growers' rating of biotic and abiotic constraints (Table 10) revealed that except in Panchmahals district, farmers ranked wilt, insect/pests, drought, and frost in that order. This implies that wilt-insect-resistant, and drought-escaping varieties were preferred by a majority of them. In Panchmahals district, the first rank was assigned to insect/pest, followed by frost, wilt, and drought.

Table 7. Varietywise production of foundation and certified chickpea seeds in Gujarat.

	Foundation seed (t)		Certified seed (t)	
Variety	1993-94	1994-95	1993-94	1994-95
Chaffa	43.10	214.85	380.40	807.50
	(12.33[1])	(7.94)	(44.26)	(14.09)
Dahod Yellow	79.70	571.50	281.60	1905.20
	(22.79)	(21.11)	(32.76)	(33.24)
ICCC 4	226.90	940.40	197.50	2825.25
	(64.88)	(34.75)	(22.98)	(49.30)
PG 5		979.80		
		(36.20)		
Others				193.00
				(3.37)
Total	349.70	2706.55	859.50	5730.95
	(100)	(100)	(100)	(100)

[1] Figures in parentheses are percentages of the total.

Table 8. Farmers' preferences (%) for chickpea grain quality.

Characteristics	Ahmedabad	Jamnagar	Junagadh	Panchmahals	All
Size					
Bold	100.00	50.00	86.67		59.17
Medium		5.00	10.00	100.00	28.75
Small		45.00	3.33		12.08
Color					
Yellow	100.00	100.00	100.00	18.33	79.58
Brown				81.67	20.42
Texture					
Round	100.00	100.00	100.00	20.00	80.00
Wrinkled				80.00	20.00
Type					
Desi	100.00	96.67	91.67	88.33	94.17
Kabuli		3.33	8.33	11.67	5.83
Seed coat					
Smooth	100.00	51.67		16.67	42.08
Rough		48.33	100.00	83.33	57.92

Table 9. Sample farmers' (%) ranking of quality traits in chickpea in Gujarat.

	Ranking					
Traits	**1**	**2**	**3**	**4**	**5**	**6**
Ahmedabad						
Size			51.67	31.66	16.67	
Color	3.33	85.00	11.67			
Texture		10.00	36.66	51.67	1.67	
Type	96.67	3.33				
Seed coat		1.67		16.67	81.66	
Cooking quality						100.00
Jamnagar						
Size	21.67	48.33	18.33	11.67		
Color	50.00	40.00	6.67	1.66	1.67	
Texture	5.00	6.67	43.33	45.00		
Type	23.33	3.33	18.34	11.67	28.33	15.00
Seed coat		1.67	13.33	30.00	51.67	3.33
Cooking quality					18.33	81.67
Junagadh[1]						
Size	16.67	63.33	13.33	3.33		
Color	75.00	18.33	3.33			
Texture	3.33	10.00	56.67	25.00	1.66	
Type				1.66	30.33	65.00
Seed coat		5.00	23.33	66.67		1.66*
Cooking quality	1.66				65.00	30.00*
Panchmahals						
Size	46.67	50.00	1.67	1.66		
Color	1.67	1.67	55.00	41.66		
Texture		3.33	3.34	20.00	45.00	28.33
Type	50.00	45.00	1.66	1.67		1.67
Seed coat				3.33	46.67	50.60
Cooking quality	1.66		38.33	31.68	8.33	20.00
Overall[2]						
Size	21.25	40.42	21.25	12.08	4.17	
Color	32.50	36.25	19.17	10.83	0.42	

Contd.

Table 9 — Contd.

Texture	2.08	7.50	35.00	35.42	12.08	7.09
Type	42.50	12.92	5.00	3.75	14.58	20.42
Seed coat		2.08	9.17	29.17	45.00	13.75
Cooking quality	8.34		9.58	7.92	22.92	57.91

[1] In Junagadh district, 3.34% of the farmers did not respond.

[2] Overall, 0.83% of the farmers did not respond.

Table 10. Chickpea growers' (%) rating of biotic and abiotic constraints.

	Ranking			
Constraints	**1**	**2**	**3**	**4**
Ahmedabad				
Frost		1.67		98.33
Drought	5.00	5.00	90.00	
Wilt		86.67	11.67	1.66
Insects/pests	8.33	81.66	8.34	1.67
Jamnagar				
Frost	13.33	15.00	20.00	51.67
Drought		1.67	55.00	43.33
Wilt		78.34	18.33	3.33
Insects/pests	8.33	65.00	21.67	5.00
Junagadh				
Frost	25.00	13.33	11.67	50.00
Drought		5.00	65.00	30.00
Wilt	55.00	33.33	3.33	8.34
Insects/pests	20.00	48.34	20.00	11.66
Panchmahals				
Frost	1.67	63.33	26.57	8.33
Drought		30.00	21.67	48.33
Wilt	33.33	6.67	51.66	8.34
Insects/pests	65.00			35.00
Overall				
Frost	10.00	23.33	14.59	52.08
Drought	1.25	10.42	57.91	30.42
Wilt	63.33	17.50	15.00	4.17
Insects/pests	25.42	48.75	12.50	13.33

Conclusions

A majority of the farmers in Gujarat still grow local chickpea varieties, Dahod Yellow being the most popular one. ICCC 4 is slowly finding its niche in Jamnagar district. However, the area under improved chickpea cultivars in the state is negligible. The study revealed that farmers in Gujarat prefer bold, yellow-colored, round, desi-type grains.Wilt-and insect-resistant, drought-escaping varieties were also preferred by a majority of them. It is suggested that large-scale on-farm demonstrations supported by seed production by public sector companies will accelerate the rate of adoption of improved chickpea varieties in Gujarat.

12

Impacts of Improved Groundnut Varieties in India

U K Deb,[1] M C S Bantilan[2] and S N Nigam[2]

Introduction

India is the largest producer of groundnut in the world. About 88% of the groundnut area and production in India is concentrated in five states: Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu, and Maharashtra. Nearly 83% of the total area is under rainy-season groundnut and the other 17% is cultivated during the postrainy season. During 1995-98, groundnut was grown in India over 7.47 Mha with a total production of 8.02 Mt (CMIE 2000). However, the past three decades have seen a slight increase in the area under the crop. Production too has increased by 50% due to increase in yield (Table 1). During 1995-98, the area under groundnut was the highest in Andhra Pradesh (2.08 Mha), followed by Gujarat (1.89 Mha), Karnataka (1.17 Mha), Tamil Nadu (0.97 Mha), Maharashtra (0.55 Mha), Madhya Pradesh (0.25 Mha), and Orissa (0.09 Mha) (Table 1). In terms of production, Gujarat ranked first (2.03 Mt), followed by Andhra Pradesh (1.95 Mt), Tamil Nadu (1.57 Mt), Maharashtra (0.26 Mt), and Orissa (0.09 Mt). However, Tamil Nadu yielded the highest (1619 kg ha^{-1}) followed by Maharashtra (1190 kg ha^{-1}), Gujarat (1076 kg ha^{-1}), Madhya Pradesh (1013 kg ha^{-1}), Andhra Pradesh (939 kg ha^{-1}), Orissa (923 kg ha^{-1}), and Karnataka (869 kg ha^{-1}).

Deb, U.K., Bantilan, M.C.S. and **Nigam, S.N.** 2005. Impacts of improved groundnut varieties in India. Pages 141-152 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Formerly of the International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

[2] International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India.

Table 1. Trends in area, production, and yield of groundnut in India, 1970-98.

State	1970-75	1980-85	1990-95	1995-98
	Area ('000 ha)			
Andhra Pradesh	1432	1520	2360	2077
Gujarat	1671	2120	1894	1888
Karnataka	872	788	1250	1167
Madhya Pradesh	455	312	280	253
Maharashtra	779	784	707	546
Tamil Nadu	1058	926	1098	972
Orissa	90	243	210	94
India	7183	7230	8303	7467
	Production ('000 t)			
Andhra Pradesh	1199	1281	2105	1951
Gujarat	1087	1708	1376	2031
Karnataka	620	656	1039	1013
Madhya Pradesh	286	196	242	257
Maharashtra	465	679	738	650
Tamil Nadu	1073	828	1618	1573
Orissa	124	348	275	87
India	5485	6206	7813	8023
	Yield (kg ha^{-1})			
Andhra Pradesh	837	843	892	939
Gujarat	650	805	726	1076
Karnataka	710	832	831	869
Madhya Pradesh	628	627	864	1013
Maharashtra	597	866	1044	1190
Tamil Nadu	1014	894	1474	1619
Orissa	1384	1434	1308	923
India	764	858	941	1074

Source: CMIE (2000).

In collaboration with ICRISAT, NARS partners have developed many improved groundnut varieties, important among the releases being ICGSs 11, 21, 44, 49, and 76. These varieties are high-yielding, resistant to diseases and pests, and tolerant to drought. Indian NARS has also developed groundnut varieties such as JL 24, TAG 24, TG 26, Kopargaon, and Khandwa. Farmers have adopted these varieties widely in major groundnut-growing states.

This study tracks the adoption and impacts of improved groundnut varieties in farmers' fields in Andhra Pradesh and Maharashtra. It also quantifies groundnut yield gain at the district level based on secondary data.

Data and Research Methodology

Data

The study is mainly based on farm surveys in Andhra Pradesh and Maharashtra. Three districts each in Andhra Pradesh (Anantapur, Chittoor, and Prakasam) and Maharashtra (Nasik, Dhule, and Kolhapur) were randomly selected based on groundnut area, production, and yield. In addition, two districts in Andhra Pradesh (Guntur and West Godavari) and three in Maharashtra (Nanded, Parbhani, and Satara) were purposively selected to ascertain the impacts of the adoption of ICRISAT groundnut varieties which is very high in these districts. A random sample of 10-12 farmers belonging to small, medium, and large-farm size groups was selected in each village. Thus a total of 485 farmers from 45 villages in 11 districts were interviewed (Table 2).

Table 2. Distribution of sample farms in India.

State	Districts	Villages	Sample size
Andhra Pradesh	5	23	261
Maharashtra	6	22	224
Total	11	45	485

In addition, district-level secondary data published in State Season and Crop Reports and Statistical Abstracts were collected. District-level yield data covering 92 groundnut-growing districts in five states (Table 3) — Andhra Pradesh (20 districts), Gujarat (18), Karnataka (19), Maharashtra (25), and Tamil Nadu (10) for the period 1966-68 and 1992-94 — was used to estimate yield gain. Together,

Table 3. List of districts studied using secondary data.

States	Districts studied
Andhra Pradesh	Adilabad, Anantapur, Chittoor, Cuddapah, East Godavari, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahabubnagar, Medak, Nalgonda, Nellore, Nizamabad, Srikakulam, Visakhapatnam, Warangal, and West Godavari (20)
Gujarat	Ahmedabad, Ahwa, Amreli, Banaskantha, Bharuch, Bhavnagar, Bhuj, Jamnagar, Junagadh, Kheda, Mehsena, Panchmahals, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara, and Valsad (18)
Karnataka	Bangalore Urban, Belgaum, Bellary, Bidar, Bijapur, Chikmagalur, Chitradurga, Dakshin Kannad, Dharwad, Gulbarga, Hassan, Kodagu, Kolar, Mandya, Mysore, Raichur, Shimoga, Tumkur, and Uttar Kannad (19)
Maharashtra	Ahmednagar, Akola, Amravati, Aurangabad, Beed, Buldhana, Bhandara, Chandrapur, Dhule, Jalgaon, Kolhapur, Nagpur, Nanded, Nasik, Osmanabad, Parbhani, Pune, Raigarh, Ratnagiri, Sangli, Solapur, Satara, Thane, Yavatmal, and Wardha (25)
Tamil Nadu	Coimbatore, Kanyakumari, Madurai, North Arcot, Ramanathapuram, South Arcot, Salem, Thanjavur, Tirunelveli Kattabomman, and Tiruchirapalli (10)

the five states accounted for about 89% of the total area under groundnut and 90% of the total production in India (1995-98 average).

Analytical Procedure

Adoption rates of improved varieties and their impacts on groundnut yield, cost of production, and farm income were estimated. Information was collected for each of the varieties grown by the farmers. Adoption level was defined as the percentage of area under improved groundnut varieties to the total groundnut area. The adoption rate for each variety was defined as the percentage of area under the variety to the total groundnut area. District-level yield gain was measured as the percentage of increase in yield during 1992-94 compared to 1966-68. Yield gain from improved varieties was measured as the percentage of increase in yield compared to the best performing local variety. To compute reduction in unit cost, the percentage of reduction in per ton cost of production of the respective improved variety compared to the best performing local variety in the respective season was used. Increase in farm income was measured on a per hectare basis. The percentage increase in per hectare net return (computed on a total cost basis), derived from the improved variety compared to the local variety, was used.

Results and Discussion

Adoption of Improved Groundnut Varieties

Farmers of Andhra Pradesh grew several improved groundnut varieties (JL 24, Kadiri, and ICGS 44) while farmers of Maharashtra adopted JL 24, TAG 24, UF-70-103, TG 26, and Karad 4-11 in the year 1997. ICRISAT varieties were popular in Guntur and West Godavari districts (Andhra Pradesh) and in Nanded, Parbhani, and Satara districts (Maharashtra) (Table 4). ICGS 44 was widely grown by farmers in Guntur and West Godavari; its adoption rate among sample farmers was 98% during the rainy season, 58% during the postrainy season, and 32% during the summer season in 1997. It may be mentioned here that TMV 2 was widely cultivated in Andhra Pradesh and SB 11 in Maharashtra. These two varieties, which were recommended by the Government of India in the early 1940s, were widely cultivated because of seed availability, drought resistance, and yield stability.

ICGS 11, ICGS 44, ICGS 21, and ICGS 49 were observed on farmers' fields in locations where technology was disseminated and seeds were made available. The low adoption of these varieties in Maharashtra was mainly due to the nonavailability of seed and longer duration. The most preferred traits in rainy-season groundnut varieties were medium duration, high pod yield with more oil content, and shelling percentage. On the other hand, farmers in Andhra Pradesh preferred varieties with high pod yield with pest and disease resistance. (Bantilan et al. 1999).

Table 4. Adoption level (%) of improved groundnut varieties in Andhra Pradesh and Maharashtra, 1997.

Districts	Variety	Season	Adoption rate (% groundnut area)
Andhra Pradesh			
Guntur, West Godavari	ICGS 44	Rainy	98.00
Guntur, West Godavari	Local (TMV 2)	Rainy	2.00
Anantapur, Chittoor, Prakasam	JL 24	Rainy	30.00
Anantapur, Chittoor, Prakasam	Kadiri	Rainy	7.00
Anantapur, Chittoor, Prakasam	Local (TMV 2)	Rainy	63.00
Guntur, West Godavari	ICGS 44	Postrainy	58.00
Guntur, West Godavari	ICGS 91117	Postrainy	2.00
Guntur, West Godavari	Local (TMV 2)	Postrainy	40.00
Anantapur, Chittoor, Prakasam	ICGS 44	Postrainy	1.00
Anantapur, Chittoor, Prakasam	JL 24	Postrainy	24.00
Anantapur, Chittoor, Prakasam	Kadiri	Postrainy	15.00
Anantapur, Chittoor, Prakasam	Local (TMV 2)	Postrainy	60.00
Guntur, West Godavari	ICGS 44	Summer	31.74
Guntur, West Godavari	Local (TMV 2)	Summer	68.36
Maharashtra			
Nanded, Parbhani, Satara	JL 24	Rainy	39.05
Nanded, Parbhani, Satara	Karad 4-11	Rainy	5.71
Nanded, Parbhani, Satara	TAG 24	Rainy	49.52
Nanded, Parbhani, Satara	Local (SB 11)	Rainy	5.71
Nasik, Dhule, Kolhapur	JL 24	Rainy	11.24
Nasik, Dhule, Kolhapur	TMV 10	Rainy	9.08
Nasik, Dhule, Kolhapur	Kopargaon	Rainy	0.37
Nasik, Dhule, Kolhapur	Local (SB 11)	Rainy	74.25
Nanded, Parbhani, Satara	ICGS 21	Postrainy	31.71
Nanded, Parbhani, Satara	TAG 24	Postrainy	48.78
Nanded, Parbhani, Satara	Local (SB 11)	Postrainy	19.51

Contd.

Table 4 — Contd

Nanded, Parbhani, Satara	ICGS 11	Summer	3.31
Nanded, Parbhani, Satara	ICGS 49	Summer	14.92
Nanded, Parbhani, Satara	JL 24	Summer	1.10
Nanded, Parbhani, Satara	TAG 24	Summer	56.35
Nanded, Parbhani, Satara	UF-70-103	Summer	9.94
Nanded, Parbhani, Satara	Local (SB 11)	Summer	9.94
Nasik, Dhule, Kolhapur	JL 24	Summer	4.49
Nasik, Dhule, Kolhapur	Local (SB 11)	Summer	95.51

Impacts of Improved Varieties

To estimate the contribution of improved varieties as well as other yield-contributing factors such as fertilizer, labor, irrigation, and location, a multiple regression analysis was conducted. Following are its results.

$$\underset{(0.3625)}{\text{Yield} = 3.307} - \underset{(0.0514)}{0.0307\ \text{FERT}} + \underset{(0.0823)}{0.85334\ \text{LAB}^{**}} + \underset{(0.06827)}{0.0979\ \text{IRRG}} + \underset{(0.05564)}{0.132\ \text{IMPV}^{*}} + \underset{(0.05387)}{0.2155\ \text{APDUM}^{**}}$$

Adjusted $R^2 = 0.7256$

The results show that the location where groundnut is grown has a significant positive effect on yield. Groundnut yield in Andhra Pradesh was higher than that in Maharashtra. The dummy for Andhra Pradesh had a significant positive effect at 1% level of significance. Human labor too had a significant positive effect on yield at 1% level of significance. Improved groundnut varieties had a significant positive effect at 5% level of significance.

Table 5 details the impacts of improved groundnut varieties on yield in Andhra Pradesh and Maharashtra. Yield gain from improved varieties, compared to the best performing local varieties, ranged between 13 and 108% in Maharashtra and 27 and 107% in Andhra Pradesh in 1997. In Andhra Pradesh, the highest yield gain (107%) was observed in the case of Kadiri during the summer season. However, the highest yield during the postrainy season was obtained by JL 24 (3118 kg ha^{-1}). In Maharashtra, the highest yield gain was observed during the summer season (108%) with TAG 24 yielding the highest (3152 kg ha^{-1}) during the summer season in Nanded, Parbhani, and Satara districts.

Table 5. Impacts of improved varieties on groundnut yield in Andhra Pradesh and Maharashtra, 1997.

Districts	Variety	Season	Yield ($kg ha^{-1}$)	Yield gain (%)
Andhra Pradesh				
Guntur, West Godavari	ICGS 44	Rainy	2518	50
Anantapur, Chittoor, Prakasam	JL 24	Rainy	2635	57
Anantapur, Chittoor, Prakasam	Kadiri	Rainy	2347	40
Anantapur, Chittoor, Prakasam	Local (TMV 2)	Rainy	1680	-
Guntur, West Godavari	ICGS 44	Postrainy	2591	27
Anantapur, Chittoor, Prakasam	JL 24	Postrainy	3118	52
Guntur, West Godavari, Anantapur, Chittoor, Prakasam	Local (TMV 2)	Postrainy	2058	-
Guntur, West Godavari	ICGS 44	Summer	2649	91
Guntur, West Godavari	Kadiri	Summer	2865	107
Guntur, West Godavari	Local (TMV 2)	Summer	1383	-
Maharashtra				
Nanded, Parbhani, Satara	JL 24	Rainy	1248	20
Nanded, Parbhani, Satara	Karad 4-1	Rainy	1383	33
Nasik, Dhule, Kolhapur	JL 24	Rainy	1362	31
Nasik, Dhule, Kolhapur	TMV 10	Rainy	1179	13
Nasik, Dhule, Kolhapur	K2	Rainy	1729	66
Nasik, Dhule, Kolhapur	Local (SB 11)	Rainy	1039	-
Nanded, Parbhani, Satara	ICGS 21	Postrainy	1328	37
Nanded, Parbhani, Satara	TAG 24	Postrainy	1811	86
Nanded, Parbhani, Satara	Local (SB 11)	Postrainy	972	-
Nanded, Parbhani, Satara	ICGS 11	Summer	1803	19
Nanded, Parbhani, Satara	ICGS 49	Summer	2822	86
Nanded, Parbhani, Satara	TAG 24	Summer	3152	108
Nanded, Parbhani, Satara	UF-70-103	Summer	2190	44
Nasik, Dhule, Kolhapur	JL 24	Summer	2964	95
Nasik, Dhule, Kolhapur	Khandwa	Summer	2865	85
Nanded, Parbhani, Satara, Nasik, Dhule, Kolhapur	Local (SB 11)	Summer	1517	-

The impact of improved groundnut varieties on per unit cost of production is reported in Table 6. Per ton cost of production was 15-37% lower in Maharashtra except for TMV 10, which had higher per ton production cost compared to the best performing local variety (SB 11). In Andhra Pradesh, the per ton production costs of improved varieties were 11-37% lower, except for ICGS 44, which had a slightly higher per ton cost of production.

Table 6. Impacts of improved groundnut varieties on per unit cost of production in Andhra Pradesh and Maharashtra, 1997.

Districts	Variety	Season	Per ton total cost of production (Rs)	Reduction per ton of cost of production (%)
Andhra Pradesh				
Anantapur, Chittoor, Prakasam	JL 24	Rainy	7956	14
Anantapur, Chittoor, Prakasam	Kadiri	Rainy	5807	37
Anantapur, Chittoor, Prakasam	Local	Rainy (TMV 2)	9239	-
Guntur, West Godavari	ICGS 44	Postrainy	7159	-4
Anantapur, Chittoor, Prakasam	JL 24	Postrainy	6919	0
Guntur, West Godavari, Anantapur, Chittoor, Prakasam	Local (TMV 2)	Postrainy	6915	-
Guntur, West Godavari	ICGS 44	Summer	6212	11
Anantapur, Chittoor, Prakasam	Local (TMV 2)	Summer	6952	-
Maharashtra				
Nanded, Parbhani, Satara	JL 24	Rainy	8764	24
Nanded, Parbhani, Satara	Karad 4-11	Rainy	6498	44
Nanded, Parbhani, Satara	Local (SB 11)	Rainy	-	
Nasik, Dhule, Kolhapur	JL 24	Rainy	9801	15
Nasik, Dhule, Kolhapur	TMV 10	Rainy	10826	-27

Contd.

Table 6 — Contd.

Nasik, Dhule, Kolhapur	Kopargaon	Rainy	9702	31
Nasik, Dhule, Kolhapur	Local (SB 11)	Rainy	11503	-
Nanded, Parbhani, Satara	TAG 24	Postrainy	6597	23
Nanded, Parbhani, Satara	Local (SB 11)	Postrainy	8513	-
Nanded, Parbhani, Satara	ICGS 11	Summer	6800	25
Nanded, Parbhani, Satara	ICGS 49	Summer	6897	24
Nanded, Parbhani, Satara	TAG 24	Summer	5736	37
Nanded, Parbhani, Satara	UF- 70-103	Summer	5696	37
Nasik, Dhule, Kolhapur	JL 24	Summer	6596	27
Nanded, Parbhani, Satara, Nasik, Dhule, Kolhapur	Local (SB 11)	Summer	9044	-

Table 7 provides information about impacts of improved groundnut varieties on farm income. All improved varieties provided higher net returns on a per hectare basis. Compared to the best performing local variety, per hectare net return was 50-594% higher in Maharashtra and 36-191% higher in Andhra Pradesh. ICGS 49 gave the highest net return (Rs 47217 ha^{-1}) followed by TAG 24 (Rs 37124 ha^{-1}) during the summer season in Nanded, Parbhani and Satara districts.

Table 7. Impacts of improved groundnut varieties on farm income in Andhra Pradesh and Maharashtra, 1997.

			Returns ha^{-1} (Rs)			
District	**Variety**	**Season**	**Gross return**	**Net return (variable cost basis)**	**Net return (total cost basis)**	**Increase in net return ha^{-1} (%)**
Andhra Pradesh						
Anantapur, Chittoor, Prakasam	JL 24	Rainy	28027	10566	7066	36
Anantapur, Chittoor, Prakasam	Kadiri	Rainy	28776	18650	15150	191

Contd.

Table 7 — Contd.

Anantapur, Chittoor, Prakasam	Local (TMV 2)	Rainy	20723	8705	5205	-
Guntur, West Godavari	ICGS 44	Postrainy	31308	16255	12755	71
Anantapur, Chittoor, Prakasam	JL 24	Postrainy	33673	15596	12096	62
Guntur, West Godavari, Anantapur, Chittoor, Prakasam	Local (TMV 2)	Postrainy	23829	10952	7452	-
Guntur, West Godavari	ICGS 44	Summer	27238	13969	10647	45
Anantapur, Chittoor, Prakasam	Local (TMV 2)	Summer	16954	10839	7339	-
Maharashtra						
Nanded, Parbhani, Satara	JL 24	Rainy	17500	9743	6243	100
Nanded, Parbhani, Satara	Karad 4-11	Rainy	20023	14534	11034	254
Nasik, Dhule, Kolhapur	JL 24	Rainy	19712	9862	6362	104
Nasik, Dhule, Kolhapur	TMV 10	Rainy	17456	8187	4687	50
Nasik, Dhule, Kolhapur	K2	Rainy	22069	11859	8359	168
Nasik, Dhule, Kolhapur	Local (SB 11)	Rainy	15071	6617	3117	-
Nanded, Parbhani, Satara	TAG 24	Postrainy	27211	18762	15262	109
Nanded, Parbhani, Satara	Local (SB 11)	Postrainy	15582	10811	7311	-
Nanded, Parbhani, Satara	ICGS 11	Summer	27167	18407	14906	119
Nanded, Parbhani, Satara	ICGS 49	Summer	66681	50717	47217	594
Nanded, Parbhani, Satara	TAG 24	Summer	55202	40624	37124	445
Nanded, Parbhani, Satara	UF-70-103	Summer	28364	19389	15889	133
Nasik, Dhule, Kolhapur	JL 24	Summer	43472	27422	23922	251
Nasik, Dhule, Kolhapur, Nanded, Parbhani, Satara	Local (SB 11)	Summer	20560	10307	6807	-

In another farm survey conducted in Maharashtra in 1994-95 covering 355 farm households (Joshi and Bantilan 1998), data on adoption of improved groundnut varieties was gathered for the period between 1989 and 1994, while information on yield and cost of production was gathered for the period 1994-95. The rate of adoption of improved varieties among the sample farms in 1989 was 6%, which increased to 84% in 1994. Yield of improved groundnut varieties using traditional management practices was 2.6 t ha^{-1} whereas yield of local varieties was 1.7 t ha^{-1}, indicating a yield gain of 53%. The per ton cost of production for improved varieties was Rs 2566 while it was Rs 3201 for local varieties, meaning a 20% decrease in unit cost of production.

Conclusions

It was found that the adoption level of improved groundnut varieties was high among sample farmers. Varieties jointly developed by the NARS and ICRISAT were adopted in specific locations where technology was disseminated and seeds were made available. Promotion and extension through NARES, and ensuring timely supply of seed will definitely enhance the adoption of ICRISAT varieties in the future. Improved varieties provided higher yield, reduced per unit cost of production, and increased farm income.

Acknowledgements

The authors wish to thank V K Chopde, Y Mohan Rao, G D Nageswara Rao, G V Anupama, and Md Moinuddin for their assistance in completing this study.

References

Bantilan, M.C.S., Nigam, S.N., Rao, Y.M., Chopde, V.K., Rao, G.D.N. and **Deb, U.K.** 1999. *Adoption of improved groundnut varieties in India*. SEPP Annual Report. Vol. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. Mimeo.

CMIE (Center for Monitoring Indian Economy). 2000. *India's agricultural sector: A compendium of statistics*. Bombay, India: Center for Monitoring Indian Economy Pvt. Ltd.

Joshi, P.K. and **Bantilan, M.C.S.** 1998. *Impact assessment of crop and resource management technology: A case of groundnut production technology.* Impact Series no. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 60 pp.

13

Impact of Improved Varieties on Sugarcane Production in India: Relevant Issues and Constraints

Jagdish Lal,[1] L S Gangwar[2] and A K Srivastava[2]

Introduction

Sugarcane occupies an important place in Indian agriculture. It is grown on nearly 4.0 million hectares with an average productivity of about 70 t ha^{-1}. The country's rising population calls for an increase in sugar production per unit of area, time and energy use. Projections for sweeteners indicate a rise in demand to 27.27 Mt for sugar and 21 Mt for g*ur (*jaggery*)* and *khandsari* (powdered jaggery) by 2020. In order to fulfill this domestic demand for sweeteners, India will have to produce 415 Mt of sugarcane with an average sugar recovery rate of 11% (IISR 1997). Sugarcane production will have to increase at an annual rate of 8.27% during the X Five-Year Plan (Ram 1998). Future sugar recovery will have to increase from its present level to meet production targets. Improved sugarcane varieties and management practices have the potential to enhance sugar recovery over time.

Since its inception, the Sugarcane Breeding Institute (SBI), Coimbatore, has evolved a large number of improved cane varieties for commercial cultivation in different agroclimatic zones. A quantum jump in sugarcane productivity through improved "Co" varieties was achieved in the country during the earlier

Lal, Jagdish, Gangwar, L.S. and **Srivastava, A.K.** 2005. Impact of improved varieties on sugarcane production in India: relevant issues and constraints. Pages 153-164 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Project Directorate for Cropping System Research, Modipuram, Meerut, India.

[2] Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh, India.

years of breeding. Though replacing low-yielding, indigenous cane varieties was the prime objective of the breeding program, the focus was subsequently shifted to increasing sugarcane area in suboptimal environments; for such environments, the breeding objectives became multiplicand, diversified and complex. Given the fact that land and water are the most limiting factors in the expansion of sugarcane area, the horizontal expansion of sugarcane cannot be achieved beyond a limit. Therefore, alternative strategies to increase productivity and recovery become important national priorities.

At present, there are more than 60 improved "Co" varieties under cultivation in different states. Keeping in view future targets of self-sufficiency in sweeteners, this paper attempts to assess the impact of improved cane varieties on sugarcane and sugar productivity.

History of Technology Development

The first mention of cane varieties in Indian literature occurs in the *Charaka Samhita* and later in the *Susruta Samhita*. A sugarcane breeding program was initiated in Java in 1888. Sugarcane breeders initiated hybridization programs involving cultivated varieties and wild species, which resulted in the development of sugarcane varieties with higher yields and sugar content, and wider adaptability and tolerance to insect pests and diseases. The first successful hybrid involving *S. officinarum* x *Kassoor* was developed in 1893 by a Dutch breeder. Later, *Kassoor* was identified as a natural hybrid of *S. officinarum* x *S. spontaneum*. A large number of PoJ varieties (Java cane) were evolved through nobilization. PoJ 2878, the most outstanding variety developed in 1921, was cultivated over 90% of Javanese sugarcane area by 1929. In India, crop improvement on sugarcane was initiated at SBI in 1912 to develop suitable high-yielding varieties for north Indian climatic conditions. The interspecific crosses (*S. officinarum var. Vellai* x *S. spontaneum* clone) were made at Coimbatore. The first batch of seedlings (Co 201 - Co 206) was sent to north Indian farms in 1914. These seedlings were selected from *S. officinarum var. Vellai* and the wild form of *Saccharum spontaneum*. The aim was fulfilled when the seedlings of Co 205 (first Indian sugarcane hybrid variety), was accepted for commercial cultivation in Punjab. It replaced the then widely grown variety Kaitha because of its resistance to waterlogging. In subsequent years, many popular "Co" varieties like Co 213, Co 281, Co 290, Co 312 and Co 313 in the subtropics and Co 413, Co 419 and Co 475 in the tropics were developed and released for commercial cultivation before independence. These varieties contributed to tillering, better ratoonability, disease tolerance, insect pest and adverse biotic environment. The selection of a sugarcane variety has evolved as a result of a clear understanding of the diverse requirements of cane production and in order to meet the challenges of production constraints limiting crop productivity in different regions.

Keeping in view the importance of sugar industries in the state economy, the Government of Uttar Pradesh sanctioned a scheme for conducting research on sugarcane. Variety selection was initiated at Shahjahanpur in 1918 with the introduction of clones from SBI, Coimbatore. The need for decentralized selection and location-specific varieties to maximize sugarcane productivity was understood in the mid-1930s. The seedling raising and selection program was expanded in the mid-1970s by incorporating the expertise available with the State Agricultural Universities (SAUs). The All India Co-ordinated Research Project on Sugarcane was launched in 1976 to create a network of seedling evaluation and selection centers. A national hybridization garden was established to facilitate national breeding programs in collaboration with state departments and SAUs. The research programs yielded popular varieties such as CoC 671, CoJ 64, CoS 687, CoM 7125, CoS 767, CoS 737, CoS 95255, Co Lk 8102, Co Pant 84211 and Co Pant 90223, which were commercially grown in different agroclimatic environments. These varieties further facilitated the expansion in sugarcane cultivation in nontraditional areas. These efforts have resulted in the identification and release of many new varieties with different maturity levels to provide raw material to meet the rising demand from agro-based industries.

Recently, the crop improvement strategy was critically reviewed to meet future challenges. The emphasis has now been shifted to developing sugarcane varieties tolerant to drought, waterlogging, soil salinity, diseases and insects. The priority is to develop high sugar and red rot-resistant varieties. The emphasis is on strengthening the Zonal Variety Trial to facilitate identification of promising clones and release of varieties for commercial cultivation.

Methodology

Efforts were made to collect information on expenditure incurred on developing improved varieties in different states and compare the same with their performance. Since information on expenditure incurred on technology development was not maintained at different research stations, this was compiled from the institutions concerned where sugarcane research was undertaken. The impact of agricultural research on sugarcane and development of Indian sugar industries was studied by examining the performance of improved varieties developed over time. Increase in sugarcane productivity, sucrose content, recovery and improvement in crushing capacity were taken as indicators. It was assumed that varieties developed through conventional methods or hybridization and improved cultural practices were scale neutral. These do not cause economic disparities across cane growers in the region. The relevant information regarding improved varieties, sugarcane area, productivity, development of sugar industries and other parameters were collected from various publications of the Indian Sugar Mill Association (ISMA).

Results and Discussion

Research Investment and Economic Returns

Sugarcane production has increased from 74 Mt to 256 Mt during the past five decades (Table 1). This increase is attributed to area expansion and yield enhancement. The possibility of a further expansion in area is remote unless irrigation and other infrastructural facilities are developed. Average cane productivity increased from 35.4 t ha^{-1} in the 1930s to 66.8 t ha^{-1} in the 1990s. Cane productivity showed a marked increase during the 1980s; average crushing capacity too increased significantly.

Table 1. Average sugarcane productivity and sugar recovery in India.

Period	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})	Recovery (%)	Cane crushed ('000 t)	Sugar production ('000 t)	Crushing capacity (t day^{-1})
1931-40	1443	51,289	35.36	9.08	7091	653	573
1941-50	1431	49,288	34.49	9.95	10,088	1004	774
1951-60	1846	74,703	40.38	9.89	17,155	1683	998
1961-70	2443	110,458	45.14	9.74	30,269	2944	1237
1971-80	2758	140,097	50.67	9.81	45,709	4472	1506
1981-90	3126	185,659	59.32	9.99	78,532	7824	1840
1991-98	3826	255,789	66.81	9.79	130,513	12,853	2431

The average annual production of sugar increased sharply from less than 2 Mt in the 1950s to 12.85 Mt in the 1990s. However, the moderate increase in sugar recovery is a matter of concern among policy makers, industrialists and researchers.

The prominent sugarcane varieties developed and released for commercial cultivation in the tropics and subtropics are presented in Table 2. During the pre-independence period, “Co” varieties ruled the cultivation scene in the subtropics whereas in the tropics, Java variety PoJ 2878 was also grown besides “Co” varieties. Co 419 was the most popular variety in the tropics for more than four decades, followed by Co 740 and Co 975. A series of improved “Co” varieties such as Co 312, Co 313, Co 1148, Co 1158 and CoJ 64 were cultivated for many decades. This continuous cultivation resulted in their becoming susceptible to red rot, smut, wilt and insect pests. To overcome new problems, the breeding thrust was shifted towards developing varieties with high sucrose content, resistance to diseases and wider adaptability. During the 1970s, breeding research was further strengthened in collaboration with SAUs and state departments. The emphasis shifted towards selection and identification of location-specific varieties to maximize productivity as well as the crushing duration of sugar mills. This led to the development of several promising varieties with varying maturity levels such as CoS 687, CoS 767, CoJ 64, Co Lk 8001, Co Lk 8102, Co Pant 90223, BO 120 and CoM 88121. It is however difficult to quantify the contribution of improved sugarcane varieties on productivity, sucrose content, and sugar recovery due to improved varieties, and crop production and protection techniques. Some studies have revealed that 50 to 70% of the gain in productivity was due to improved varieties (Sreenivasan and Bhagyalakshi 1997).

Ever since Schultz (1953) attempted the first major quantitative evaluation of agricultural research investment, literature on it has grown to over 200 studies (Schwartz et al. 1993). Governments in many countries are now emphasizing the need to evaluate agricultural research investment in order to set future research priorities. The Indian Council of Agricultural Research (ICAR) has completed a study on national level priority setting (Jha et al. 1995). Recently, the World Bank, while funding under the NATP project to SAUs and ICAR institutes, insisted on a prioritized research agenda. Different approaches were used to evaluate returns from research investment. In India, government departments, ICAR institutes, SAUs, and NGOs are involved in the research and development of sugarcane and sugar industries. The

Table 2. Important sugarcane varieties in India from 1930 to 1997.

Period	Subtropical region	Tropical region
1931-40	Co 205, Co 213, Co 223, Co 224, Co 281, Co 285, Co 290, Co 312, Co 313	Co 213, Co 243, Co 281, Co 290, Co 313, PoJ 2878
1941-50	Co 213, Co 312, Co 313, Co 331, Co 356, Co 453, CoJ 46	Co 213, Co 419, HM 320, PoJ 2878
1951-60	Co 312, Co 313, Co 421, Co 527, Co 453, Co 951, CoS 245, CoS 510, CoL 29	Co 419, Co 449, Co 527, HM 320
1961-70	Co 312, Co 975, Co 1007, Co 1148, BO 17, Co 1158, CoS 245, CoS 510	Co 419, Co 527, Co 658, Co 740, Co 853, Co 975, Co 997
1971-80	Co 312, Co 1148, Co 1158, BO 17, CoS 510	Co 419, Co 517, Co 658, Co 740, Co 975, Co 997, Co 62175, Co 6304, Co 6806
1981-90	Co 1148, Co 1158, Co 7717, BO 91, Co 99, CoJ 64, CoS 687, CoS 767	Co 419, Co 740, Co 975, Co 62175, Co 6304, Co 6907, Co 7219, CoC 671, Co 8021
1991-97	Co 1148, BO 91, BO 99, CoJ 64, CoJ 81, CoS 687, CoS 767, CoS 802, CoS 7918, CoS 8436, CoS 95255, CoS 92423, Co Lk 8001, Co Lk 8102, Co Pant 84211, Co Pant 90223	Co 740, Co 62175, Co 6304, Co 7219, CoC 671, Co 7508, Co 8011, Co 8014, Co 8021, Co 8208, Co 8338, Co 85004, Co 87263, Co 8603, CoM 88121, CoC 86062, CoC 92061, CoC 91061

nonavailability of relevant time series data on investment incurred and technologies developed by these organizations is the main limiting factor in assessing the impact of investment in technologies, adoption level, and performance in farmers' fields.

Developing a cane variety requires rigorous effort of a multidisciplinary team of scientists, and a research lag of 8 to 10 years. In India, mainly two research institutions, the SBI and the Indian Institute of Sugarcane Research (IISR), Lucknow, are involved in diverse areas of sugarcane research. Using their data on research resource allocation, it was estimated that a rupee invested

Table 3. Budget of ICAR institutes involved in sugarcane R&D and crop productivity.

Plan period	IISR, Lucknow (in lakh Rs)	SBI, Coimbatore (in lakh Rs)	Average productivity (t ha^{-1})
I (1952-56)	4.57	-	39.10
II (1956-61)	41.03	-	42.70
III (1961-66)	36.82	-	44.00
IV (1969-74)	66.84	61.36	49.40
V (1974-79)	166.71	202.99	51.90
VI (1979-84)	384.90	429.47	54.70
VII (1984-89)	788.81	716.21	59.16
VIII (1992-97)	1825.00	1689.80	67.30

Sources: IISR 1997 and SBI 1997.

in sugarcane research and development yielded an input-output ratio of 1:21 at 1977-78 prices (IISR 1997). The relationship between investment in sugarcane research and productivity (Table 3) reveals that investment increased from Rs 128.2 lakh in the IV Five-Year Plan to Rs 3514.8 lakh in the VIII Five-Year Plan. A steady and positive growth in sugarcane productivity can be seen since 1950-51, explaining the positive association between research investment and productivity. Besides improved varieties, expenditure on R&D has resulted in many crop production, protection, and farm mechanism techniques for cane growers.

Status of Improved Varieties

Important sugarcane varieties with high sugar content were released in 1928, when Co 313 was released to serve the industry in subtropical India. Cane growers and the industry as a whole commercially exploited several varieties such as Co 527, Co 658, CoL 29, Co 957 and Co 997. Even in climatically unfavorable locations, varieties like CoC 671 with a high recovery rate changed the situation as in Maharashtra. Similarly, CoJ 64 created a revolution in Punjab during the 1980s when the state was rated as number one in terms of high sugar recovery. The potential of improved varieties was fully exploited in states where there was a greater awareness among cane growers to adopt improved varieties. A statewise status of improved varieties (Table 4) shows that CoC 671 occupies 70.0% of the area in Gujarat, 41.6% in Tamil Nadu, 10.5% in Andhra Pradesh, 9.6% in Maharashtra and 5.1% in Karnataka. The share of CoS 767 in the total cane area was about 15.3% in Bihar. The area under improved cultivar CoJ 64 was the highest in Punjab, followed by Haryana, West Bengal and Uttar Pradesh. Sugar recovery in Punjab, which was static at 8.5% increased to 10.6% in 1983-84.

Recovery rates of up to 11% have been observed from sugar mills in Gurdaspur and Batala. This significant achievement in Punjab has been possible due to adoption of CoJ 64 (Kanwar 1989). Though high sugar varieties reduced the cost of production, they did not achieve the desired results mainly due to the sugarcane pricing policy, which was based on cane weight rather than sucrose content. Cultivators basically prefer high tonage to high quality cane due to its good economic returns. The major constraint resulting in the low adaptability of these varieties was poor ratoonability. Most of the sugarcane growers possess small and medium landholdings and depend heavily on ratoons, which give a higher benefit-cost ratio compared to the parent crop. Farmers desist from adopting these varieties because of their susceptibility to insect pests and diseases. Most high sugar varieties are susceptible to diseases, especially red rot. The most popular varieties, CoC 671 and CoJ 64 in Punjab and Haryana, are susceptible to red rot, smut, wilt and insect pest like the Gurdaspur borer.

Quality of Sugarcane Juice in Tropical and Subtropical India

Subtropical India has seen an improvement in sucrose content in sugarcane juice (3.68%) and cane yield (52.6%) from the pre-release period to 1918-20 (Table 5). However, sucrose content (%) in juice remained more or less static from 1941-50 till 1991-98, though there was an improvement of 54% in cane yield. In the tropical region, there was an improvement of 1.26% in sucrose content from 1931-40 to 1941-50; it decreased to 16.35% in 1961-70, and then again increased to 19.28% during 1991-98. Cane productivity has however registered a decelerating trend in this region.

Table 4. Current status of improved sugarcane varieties (in percentage area) in different states of India.

Variety	Andhra Pradesh	Gujarat	Karnataka	Maha-rashtra	Tamil Nadu	Orissa	Madhya Pradesh	West Bengal	Uttar Pradesh	Bihar	Haryana	Punjab
Co 62175	9.70		32.65			17.88						
Co 6907	25.65							20.6				
Co 7219	17.25		8.16	17.27								
CoC 671	10.51	70.0	5.10	9.61	41.58			7.31				
Co 6304		12.0			38.96	6.73	19.04					
Co 8338		11.0										
Co 419			40.82	8.45	6.23							
Co 740				6.40	5.42	6.15	6.53					
Co 997						13.65						
Co 7318							18.98					
CoS 767							10.25			15.34	6.4	
BO 91									8.30	55.91		
BO 120									15.6	8.30		
CoJ 64								15.98	7.60		21.3	24.78
CoJ 83								7.41	8.60		15.6	26.4
CoJ 87									6.80		29.4	12.6
CoS 91269									10.2			9.86
CoS 95255									8.10			
BO 110										7.95		
Others	47.09	7.00	13.17	58.29	7.81	56.74	44.2	48.7	6.6	12.50	27.3	26.3

Table 5. Sucrose content (%) in sugarcane juice and cane yield in India.

	Subtropical region		Tropical region	
Period	Sucrose % juice	Cane yield (mt ha^{-1})	Sucrose % juice	Cane yield (mt ha^{-1})
Pre-release	15.38	36.27	-	-
1918-20	19.06	55.35	-	-
1921-30	19.02	49.97	-	-
1931-40	17.00	-	18.00	-
1941-50	16.60	55.00	19.26	105.00
1951-60	18.40	67.95	17.84	85.08
1961-70	17.00	53.00	16.35	111.20
1971-80	17.14	72.08	18.09	111.79
1981-90	17.43	83.01	18.97	102.30
1991-98	18.47	84.67	19.28	107.58

Impact of Improved Varieties on Sugar Production

It is very important to increase sugar recovery during the early crushing period and maintain it during the summer season. Variety Co 658 improved sugar recovery in the subtropical belt during the 1960s. In the tropical belt, Co 6304 maintained sugar recovery for more than two decades. The variety was released for cultivation in the late 1970s. Another improved variety CoC 671, with a 1.5- 2.0% greater recovery rate over the existing cultivar, was also released, though it is susceptible to drought and insect pests in some areas. Another promising variety, CoC 86062, gives 2.5% more yield in parent crops and 23.4% more yield in ratoon crops and has a recovery rate of 9.36% as against 8.65% in the case of CoC 671. In Andhra Pradesh, Co 527 was the most popular variety. However in the 1960s, Co 997 replaced it due to the superior quality of its juice, nonarrowing habit, nonspiny foliage and drought-resistant characteristics. Later on, CoA 7701 was developed as a superior substitute to Co 997 for its cane and sugar yield. Variety Co 6907 gives 18.52% sucrose in juice at maturity compared to 18.16% in Co 997. Besides higher sugarcane yield, it gives 15.37 t sugar ha^{-1} as compared to 11.26 t ha^{-1} by Co 997. Some of the promising improved varieties recently developed and released for tropical regions are CoC 90063, CoC 91061, CoC 92061 and CoA 88081 as a substitute for existing cultivar CoC 671.

Co 214 was used as parent material for the production of improved varieties for the subtropical region. Varieties Co 508 and Co 513 were found useful in improving sugar recovery during the early crushing season in north India. During the 1950s, the recommended varieties Co 312, Co 453, CoJ 39 and CoJ 46 in Punjab were replaced by CoL 29. During the 1960s, sugar recovery was the highest (9.60%) due to CoL 29 which occupied 35% area. In the subtropical belt, which is occasionally prone to frost, the release of frost-tolerant variety CoJ 46 with good ratoonability sustained recovery for some time. Variety CoJ 64 developed by the Sugarcane Research Station, Jalandhar, was released for commercial cultivation in 1976. Cultivars CoC 671 and CoJ 64 which have sustained the sugar industry for a long period, are now showing signs of declining productivity because of their susceptibility to wilt, smut, and red rot. In the subtropical belt, promising varieties such as CoP 84211, CoS 92253, CoS 95255, Co 87263 and CoJ 83 were released for commercial cultivation.

Conclusions

A stagnation or decline in sugarcane yield has been observed in high productivity areas in recent years. The yield potential can be further enhanced by exploiting hybrid vigor and biotechnological research. Technologies and cultural practices need to be utilized in an integrated manner in order to achieve the desired goals of efficiency, equity and sustainability in sugar production. There is a need to develop low-cost and resource neutral technologies easily adaptable by small farmers. Genetic resistance to insects and disease pathogens offers several advantages like increase in productivity and decreased dependence on insecticides, thereby minimizing health hazards and economic losses associated with chemical pesticides.

At present, research investment is thinly spread on need-based priority areas, and often missing is a critical minimum limit of resource allocation for key sugarcane research projects. Studies on the economic feasibility of research investment will provide feedback to the research community in order to justify future funding. This would also provide a framework for short-and long-term investment strategies for sugarcane research and draw the attention of policymakers.

References

IISR (Indian Institute of Sugarcane Research). 1997. *Vision 2020, Perspective Plan*. Lucknow, Uttar Pradesh, India: IISR. 57 pp.

Jha, D., Kumar, P., Mruthyunjaya, Pal, Suresh, Selvarajan, S. and **Singh, Alka.** 1995. *Research priorities in Indian agriculture*. Policy Paper 3. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 84 pp.

Kanwar, R.S. 1989. *Early-maturing high sugar varieties of sugarcane*. Paper presented at the National Seminar, 25-26 Mar 1989, Indian Institute of Sugarcane Research, Lucknow. 183 pp.

Ram, G.S. 1998. Doubling food production — targets, implications and strategies. *Agricultural Situation in India* 54(5):267-272.

SBI (Sugarcane Breeding Institute). 1997. *Vision 2020, Perspective Plan*. Coimbatore, Tamil Nadu, India: SBI. 54 pp.

Schultz, T.W. 1953. *The economic organization of agriculture*. New York, USA: McGraw Hill Book Company. 374 pp.

Schwartz, Lisa, Sterns, A.J.A. and **Oehmke, J.F.** 1993. Economic returns to cowpea research, extension and input distribution in Senegal. *Agricultural Economics* 8(2):161-171.

Sreenivasan, T.V. and **Bhagyalakshi, K.V.** 1997. Genetic improvement of sugarcane. *Indian Journal of Sugarcane Technology* 12(2):1-10.

Socioeconomic Impact of Investments in Potato Research and Development in India

P S Dahiya[1]

Introduction

Though organized agricultural research in India began much before independence, the scale of its activities and investments has increased tremendously over the past five decades. The generation of HYVs of crops and production technologies coupled with concomitant diffusion and adoption have been instrumental in ushering self-sufficiency in food. The benefits of the green revolution in India have been widely acclaimed the worldover and the returns to investment have reportedly been quite handsome. The annual rate of return in India has been 40-70% or even more in some cases at the aggregate level (Dahiya 1997).

However, it is believed that the green revolution and agricultural advances only benefited areas with superior agroclimatic conditions and infrastructure. The beneficiary was the large landholding community. This left the small landholder out in the cold, thereby causing further income inequalities and social tensions. The impact of agricultural research in various areas needs to be assessed in order to reorient agricultural policy given the increasing resource crunch and globalization.

This paper makes a critical assessment of the impact of investments made in potato R&D in India. According to Horton et al. (1993), impact assessment

---

Dahiya, P.S. 2005. Socioeconomic impact of investments in potato research and development in India. Pages 165-174 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Central Potato Research Institute, Shimla 171 001, Himachal Pradesh, India.

of research covers: (i) economic impact assessment in terms of costs and benefits of agricultural research; (ii) environmental impact assessment in terms of food safety; and (iii) social impact assessment in terms of the effects of research activity on the income, health and nutritional status of different social groups, particularly the effects on pollution, natural resource conservation, nutritional quality of products and disadvantaged groups. This paper confines itself to socioeconomic impact assessment.

Achievements in Potato Research

The potato was brought to India by Portuguese traders in the 1600s. Prior to 1700, it used to be grown in parts of Western India. By 1900, its spread increased. Thus the first half of the twentieth century (1900-1949) can be called the transitional phase of potato development in India. It was only in April 1935 that the then Imperial (now Indian) Agricultural Research Institute, New Delhi, set up three seed potato production stations — at Shimla, Kufri (both Shimla hills), and Bhowali (Kumaon hills). However, multifaceted scientific research on breeding varieties resistant to late blight and suitable for the subtropical agroclimate received a big fillip in 1949 when the Central Potato Research Institute (CPRI) was set up at Patna. In 1956, it was shifted to Shimla (Shekhawat 1999).

The Institute's contribution to crop improvement has been commendable. Thirty-five HYVs suitable for the eight potato growing zones have been released. These varieties are resistant to late blight, give economic yields under short growing periods, are tolerant to viruses, and have wide adaptability. Five varieties — Kufri Jyoti, Kufri Chandramukhi, Kufri Lauvkar and Kufri Chipsona-I and II are suitable for processing.

A True Potato Seed (TPS) technology for the commercial production of potato has been developed. Two high-yielding TPS hybrids, TPS C-3 and HPS 1/13, have been recommended for commercial cultivation. Seed is the most critical input in potato cultivation. Therefore, the Seed Plot Technique (SPT) that exploits the low aphid period identified in the Indo-Gangetic plains for healthy seed production, enabled the growing of disease-free seeds in the plains and the hills. This was the basis on which the National Seed Potato Production Program began during the mid-1960s; it now produces about 2600 t of breeder seed annually. This can adequately meet the country's needs if multiplied and utilized properly.

Since agrotechniques and nutrient management are crucial to tap the yield potential of potato varieties, fertilizer needs in eight different potato-growing zones have been standardized. Application of farmyard manure (FYM) @ 30 t ha^{-1} can meet the crop's P and K needs. In case FYM falls short of 30 t, P and K should be reduced accordingly. About 2.5-3.5 t ha^{-1} seed is recommended, depending on the size of the tubers. Irrigation should be applied at 8-9-day intervals in light soils and at 12-15-day intervals in heavy soils. The CPRI has developed efficient methods of testing soil and spotting nutrient deficiencies and also identified profitable potato-based cropping systems.

Pests and diseases affect potato crops in India. Diseases like late blight and bacterial wilt can cause up to 75-80% economic losses in a single crop season. Viral diseases cause the degeneration of seed stocks over the years. On the plant protection front, forecasting late blight, developing modified ELISA procedures, and identifying biocontrol agents for Potato Tuber Moth (PTM), bacterial wilt, and late blight have been the major achievements.

Technology Adoption and Constraints

The success of technology generation lies in its adoption by the farming community. A comprehensive study in Farrukhabad district (Uttar Pradesh) revealed that marginal farmers had 78% of their area under HYVs, small farmers 83%, medium farmers 73%, and large farmers 92% during 1983-84 (Gupta et al. 1989). Potato varieties released by CPRI occupy more than 90% of the area in the Indo-Gangetic region, India's potato bowl. However, the impact of HYV adoption is not noticeable in the northeastern region.

The rates of fertilizer application were 183 kg ha^{-1} N, 80 kg ha^{-1} P, and 85 kg ha^{-1} K against the recommended doses of 120-150 kg ha^{-1} N, 80-100 kg ha^{-1} P, and 800-100 kg ha^{-1} K. Small and marginal farmers do not use the recommended doses of fertilizer and manure in rainfed areas like Himachal Pradesh, the UP hills, and the northeastern hills. There has been only a partial adoption of plant protection technology due to lack of resources, ignorance, and nonavailability of chemicals for ready use in certain parts of the country. Seed rate was found to be 2700 kg ha^{-1} for small and marginal farmers and 2400 kg ha^{-1} in the case of medium and large farmers. It was reported to be 3200-4000 kg ha^{-1} under the Operational Research Project (ORP) in Bihar and 1600 kg ha^{-1} in Himachal Pradesh.

Impact of R&D in Potato

Impact assessment evaluates the effects of agricultural research in terms of changes in yield, production, income, employment generation, food security, social welfare, environment, etc. The impact of the technologies developed by CPRI has been quite marked as revealed by adoption studies and other economic analyses. The impact can be related to various parameters.

Growth in Area, Production and Yield

During the past 50 years, growth in potato area, production, and yield has been quite phenomenal. India harvested 25 Mt of potatoes from 1.34 Mha, with a yield of 18.6 t ha^{-1} in 1999-2000, as compared to 1.54 Mt harvested over 0.234 Mha with an average yield of 6.6 t ha^{-1} in 1949-50, the year CPRI was set up. This translates into an increase of 5.7 times in area, 16.2 times in production, and 2.8 times in yield. Potato has outdone both rice and wheat in terms of registering the highest rates of growth in area, production, and yield from 1967-68 to 2000-2001. The annual compound growth rates (ACGRs) are 3.31 for potato area, 5.61 for production and 2.22 for yield whereas the corresponding figures for rice are 0.68 (area), 2.80 (production) and 2.16 (yield), and for wheat they are 1.40 (area), 4.41 (production) and 2.96 (yield). Increase in wheat yield was greater than that of potato yield (Table 1).

Table 1. Annual compound growth rates (%) in area, production and yield of rice, wheat, potato, foodgrains and principal crops from 1967-68 to 2000-2001.

Crop	Area	Production	Yield
Rice	0.68	2.80	2.16
Wheat	1.40	4.41	2.96
Potato	3.31	5.61	2.22
Total foodgrains	0.01	2.53	2.10
All principal crops	0.36	2.82	1.92

Source: GOI 2001.

Potato registered a significant growth compared to all the foodgrains and principal crops put together (GOI 2001). It is generally agreed that varieties and technology developed by CPRI, setting up the National Seed Production Program and the adoption of the technology by the farming community (CPRI 1997a), have been the main factors contributing to the growth.

Self-sufficiency in Seed Production

The CPRI produces seed at its regional stations located at Gwalior, Jalandhar, Kufri, Modipuram and Patna. Modern biotechnological techniques have been used to eliminate viruses from seed stocks of commercial cultivars. India enjoys self-sufficiency in seed production while our neighbors continue to import seed from Europe. The current price of Dutch seed potatoes in Pakistan and Sri Lanka ranges between US$56 and 60 for 50 kg, i.e., US$1120-1200 t^{-1}. CPRI produces 2600 t of seed potatoes and supplies 2000 t to the states and other agencies. Indigenously-produced seed is available at Rs 5000-7000 t^{-1}, i.e., US$139-194 t^{-1} as against US$1120-1200 t^{-1} for neighboring countries (at 1996 prices). The CPRI has also evolved innovative techniques like rapid multiplication and micro tuber production using tissue culture to augment seed stocks (CPRI 1997a).

Contribution to Intensive Cropping and Employment Generation

Potato being a short-duration crop, it fits well into multiple and relay cropping systems. Adoption of rice-potato-wheat and other cropping systems has increased cropping intensity and land productivity, particularly in the Indo-Gangetic region. Intercropping potato with sugarcane in Maharashtra and potato with maize in Bihar has increased both cropping intensity and profitability. Potato is a capital and labor-intensive crop. While it requires 250 man-days to cultivate a hectare of potatoes, rice and wheat need only 101 and 48 man-days, respectively (Shekhawat and Dahiya 1997). The increase in potato area during the last five decades has added 275 million more man-days of employment annually. In experiments conducted by ICAR's All India Co-ordinated Agronomic Research Project, it was observed that the man-day requirement per hectare in different sequences was the highest when potato was included in a crop rotation. It ranged from 313 man-days ha^{-1} in a rice-potato-okra rotation in the central region to 488 man-days ha^{-1} in a maize-potato-green gram rotation in the northwestern region (Swaminathan 1978). Potato also adds to employment generation in the postharvest phases of production of processed products, marketing and utilization, thus having a good socioeconomic impact on the economy.

Adoption of Potato Technology and its Impact

A comprehensive study of farmers' perceptions on the adoption and impact of potato technology conducted in Bihar (Dahiya and Sharma 1988) had revealed that 52% of the respondents felt it had the highest impact in terms of knowledge gained while 59% of the respondents thought it had medium impact (Table 2). Increase in income, addition to assets, improvement in social status, and extension contacts were rated medium by more than 50% of the sample. Only 9-33% of the farmers perceived the impact as poor in terms of various parameters.

Table 2. Farmers' perceptions about the impact of the Operational Research Project in Bihar.

Parameters	Percent of farmers		
	High impact	Medium impact	Poor impact
Gain in knowledge	52	59	9
Seed quality	39	39	22
Increase in yield	41	45	14
Increase in income	33	50	17
Addition to assets	17	50	33
Employment generation	14	45	23
Improvement in social status	26	51	23
Extension contacts	26	51	23
Training	32	47	21
Seed certification	36	44	20

Source: Dahiya et al. (1988).

Investments in Potato Research and Contribution to the National Economy

Agricultural research calls for considerable investment. While developed countries invest 2-4 % of their GDP on it, in India the figure is less than even 1%. As regards potato research, the total allocation for research went up from Rs 5.47 crore during the V Five-Year Plan (1974-75 to 1978-79) to Rs 56.02 crore during the IX Plan period (1997-98 to 2000-2001; four-year period only). In absolute terms, it is more than a tenfold increase but in terms of net value of output, the investment scenario for potato is stagnant at about 0.18% (Table 3).

Table 3. Allocation of resources to potato research relative to the net value of potato output in India (1974-75 to 2000-2001).

Plan	Period	Net value of output of potato (in crore Rs)	Total allocation for research (in crore Rs)	Internal resources generated by CPRI (in crore Rs)	Net allocation of resources (in crore Rs)	Allocation to research relative to potato output (%)
V	1974-75 to 1978-79	2325	5.47	1.13	4.34	0.18
VI	1980-81 to 1984-85	4514	9.83	1.87	7.96	0.17
VII	1985-86 to 1989-90	8335	15.10	2.79	12.31	0.14
VIII	1992-93 to 1996-97	17,152	34.68	7.49	27.19	0.15
IX	1997-98 to 2000-2001[1]	22,900	56.02	11.00	45.02	0.20
	Total	55,226	121.10	24.28	96.82	0.18

[1] Four-year period. Three annual plan periods, 1979-80, 1990-91, and 1991-92 have not been considered.

Potato has done exceedingly well in terms of contribution to the national economy. Its contribution increased from Rs 787 crore in 1980-81 to Rs 4845 crore in 1999-2000 at current prices, marking a 516% increase during the past two decades. As against this, rice contributed Rs 9688 crore in 1980-81 and 51,002 crore in 1999-2000, while wheat's share was Rs 5233 crore in 1980-81and Rs 90,891 crore in 1999-2000, registering increases of 838% and 874% respectively. In relative terms (area vs contribution), potato has surpassed both rice and wheat. Potato is cultivated over 0.6% of total cropped area but it contributes about 2% of the gross value of output from agriculture, i.e., thrice the percentage of area under potato cultivation. However, potato's contribution declined to 1.2% in 1999-2000 due to a glut and a price crash. As against this, rice occupied 23.5% of total cropped area but contributed only 22.4% to the gross value of output from agriculture. The corresponding figures for wheat are 14.4% and 12.6% (Table 4).

Table 4. Share (%) of rice, wheat and potato in the total value of agriculture.

	Rice		Wheat		Potato	
Year	Area[1]	Value[2]	Area[1]	Value[2]	Area[1]	Value[2]
1970-71	22.7	26.2	11.0	10.4	0.3	1.4
1980-81	23.3	20.9	12.9	11.3	0.4	1.7
1990-91	23.0	20.4	13.0	11.5	0.5	1.9
1991-92	23.4	21.9	12.8	12.4	0.6	2.1
1992-93	22.5	21.3	13.2	11.9	0.6	1.5
1993-94	22.8	20.7	13.5	11.0	0.6	1.6
1994-95	22.8	20.0	13.7	10.8	0.6	1.6
1995-96	23.0	18.7	13.4	10.3	0.6	2.1
1996-97	23.3	18.3	13.9	12.1	0.7	1.8
1997-98	23.3	18.4	14.3	10.8	0.6	2.0
1998-99	23.5	19.2	14.4	10.8	0.7	2.9
1999-2000	23.5	22.4	14.4	12.6	0.6	1.2

[1] Figures are percentages of total cropped area in India.

[2] Figures are percentages of total value of output from agriculture as per CSO estimates.

Profitability from Potato Production

Unlike cereal crops which enjoy the benefits of price support, potato cultivation is subject to the vicissitudes of market forces. In the case of horticultural crops, public policy focuses only on market intervention. Yet potato production in India has made unprecedented strides, thanks to achievements in research and their impact.

Prior to the release of HYVs in 1958 and the development of other components of technology, potato cultivation used to be a losing enterprise. For instance, according to Farm Management Studies, potato cultivation caused a loss of Rs 369 ha^{-1} in West Bengal (1955-56 and 1956-57 put together) with an output-input ratio of 0.85. A comprehensive study in Farrukhabad showed the output-input ratio to be 1.40, with net returns of Rs 4676 ha^{-1} (1983-84) and estimated net returns of Rs 13,654 ha^{-1} in 1997-98. The country has invested only 0.18% of the net value of potato output on research. Crop research has yielded handsome returns.

Food Security

Potato, one of the major food crops in the world, enjoys the status of a vegetable crop in the developing world. Its potential in ensuring food security is not fully recognized. In this context, it is pertinent to add that "although most of the published projections of future global demands for food focus on cereal consumption, in many regions of the world non-cereal staples such as roots, tubers, and plantains are also of great importance in the diets and income of the poor. For example, it has been estimated that these non-cereals supply as much as 40% of the food in the developing countries. Crops like potatoes, sweet potatoes, cassava, taro, bananas, and coconuts play a highly significant part in the lives of the poor people in many parts of Asia, the Pacific and Latin America as well as in Africa. Greater efforts to accelerate the productivity of these crops need to be an integral part of future effort to secure global food security" (Tribe 1994).

Though India used to import seed potatoes and table potatoes till the 1950s, it is now fully self-sufficient. Globally too, India is the third largest producer of potatoes, after China and the Russian Federation. Per capita potato consumption has drastically increased from 2.69 kg year^{-1} in 1952-53 to 15 kg year^{-1} now. Potato plays a vital role in ensuring food security. Out of the country's total vegetable production, the potato's share is over 30%.

Conclusion

Rising incomes, growing urbanization, and consumers' desire to branch out from a strictly cereal-based diet have increased the demand for potato as a fresh food, and, more recently, in processed form too. Impact simulations indicate that R&D will play an economically important and increasingly diversified role in the food systems of developing countries over the next two decades (Scott et al. 2000). The CPRI has projected potato output to reach 49 million tons and per capita consumption to be 31.3 kg year^{-1} by 2020, making a great impact on the farm economy and food security in India (CPRI 1997b).

References

CPRI (Central Potato Research Institute). 1997a. *Social impact of potato research and development in India*. Report of the Mehboob Zahedi

Committee on Social audit of potato improvement and breeders' seed production. Shimla, Himachal Pradesh, India: CPRI. 56 pp.

CPRI (Central Potato Research Institute). 1997b**.** *Vision 2020, CPRI Perspective Plan*. Shimla, Himachal Pradesh, India: CPRI. 42 pp.

Dahiya, P.S. 1997. Food security - Key issues and investment strategies. *Political Economy Journal of India* 7(3&4):168-175.

Dahiya, P.S. and **Sharma, Hoshyar Chand.** 1988. *An impact study report on operational research project in Bihar*. Shimla, Himachal Pradesh, India: Central Potato Research Institute. 135 pp.

GOI (Government of India). 2001. *in Agricultural statistics at a glance*. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi, India: GOI. Pages 210-211.

Gupta, S.S., Raheja, S.K., Srivastava, A.K., Dahiya, P.S. and **Malhotra, V.P.** 1989. *Sample survey for cost of cultivation, agronomic practices, area and yield rates of potato*. New Delhi, India: Indian Agricultural Statistics Research Institute, and Shimla, Himachal Pradesh, India: Central Potato Research Institute. 119 pp.

Horton, D., Ballantyne, P., Peterson, W., Uribe, B., Gapasin, D. and **Sheridan, K. (eds.)** 1993. *Monitoring and evaluating agricultural research. A sourcebook*. Wallingford, Oxon, UK: CAB International. 240 pp.

Scott, G.J., Rosegrant, Mark, W. and **Ringler, Claudia**. 2000. *Roots and tubers for the 21st century —Trends, projections and policy options*. Washington, DC, USA: International Food Policy Research Institute. 73 pp.

Shekhawat. G.S. 1999. 50 years of the Central Potato Research Institute. *Indian Farming* December 1999. 49(9):4-9.

Shekhawat, G.S. and **Dahiya, P.S.** 1997. Potato: Emerging paradigms. Pages 57-71 *in The Hindu survey of Indian agriculture 1997*. Chennai, India: Kasturi and Sons.

Swaminathan, M.S. 1978. Potato has great potential in India**.** *Agricultural Situation in India* 33(9):583-587.

Tribe, Derek E. 1994. *Feeding and greening the world — The role of international agricultural research*. Wallingford, Oxon, UK: CAB International. 288 pp.

15

Impact Assessment of Watershed Technology in India

Ram Babu and B L Dhyani[1]

Introduction

About 52% (173.65 million ha) of India's total geographical area is subjected to various forms of degradation, resulting in soil losses to the tune of 16.35 t ha^{-1} per year (Narayana et al. 1983). High volumes of runoff, soil loss, sedimentation, and increasing loss through natural calamities such as floods and drought are the indirect effects of irrational utilization of natural resources. The direct and indirect losses in terms of sedimentation and nutrient depletion are estimated to be valued at Rs 100,000 million per year, which is equal to 10% of the country's agricultural production.

Watershed Management Models

The Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun, and its regional research centers have been in the forefront of popularizing the watershed approach through research, demonstration, extension and training programs. An integrated watershed management approach was first demonstrated in the mid-1970s through model Operational Research Projects (ORPs) on watersheds at Sukhomajri (Haryana)

Babu, Ram and **Dhyani, B.L.** 2005. Impact assessment of watershed technology in India. Pages 175-186 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Central Soil and Water Conservation Research and Training Institute, 218 Kaulagarh Road, Dehradun 248 195, Uttaranchal, India.

representing the Shivalik foothills; Fakot (Uttar Pradesh hills) representing the middle Himalayas; and G.R. Halli (Karnataka) representing red soils in a low-rainfall region. Later, these were replicated in different regions in the country. The achievements and benefits of these model (ORPs) and 47 other watersheds were well established in different agroecological regions of the country during 1983-84 (Narayana et al. 1987). Subsequently, huge schemes such as the National Watershed Development Project for Rainfed Agriculture (NWDPRA), Integrated Watershed Development Project (IWDP), Drought Prone Area Programme (DPAP), Integrated Wasteland Development Projects (IWDP), and Desert Development Programmes (DDP) were launched for the sustainable development of rural areas in the country. To accomplish this, various modules pertaining to planning (from the sectoral to the integrated approach), implementation (by state/central governments to NGOs), coordination (formal and informal), institution building (private to cooperative bodies), equity, community empowerment, and a system of distribution (mandatory to voluntary) were adopted (Samra 1997).

Up to 1993-94, India spent Rs 35,915 million to treat 37.34 Mha land (about 22% of the problem area). During the VIII Five-Year Plan, Rs 8000 million were spent on soil and water conservation works on a watershed scale. Under the NWDPRA launched during 1990-91, Rs 11,285 million was sanctioned to treat 3.84 Mha in 2495 micro-watersheds. World Bank-assisted watershed development projects have been in operation since 1991-92 to treat 0.5 Mha at a cost of Rs 7560 million. Further, the European Economic Community (EEC)-assisted integrated watershed management project and Germany's Kreditanstait fur Weideraufbau (KFW)-assisted projects are in operation at a cost of Rs 1740 million. A sum of Rs 60,000 million was allocated in the IX Five-Year Plan (1997-2002) by the central and state governments, and foreign agencies to launch nationwide watershed management programs. The Government of India provided Rs 2500 million to the National Bank for Agriculture and Rural Development (NABARD) for the year 1999-2000 to provide loans to develop watersheds.

This paper discusses the issue of sustainability through watershed management programs in India, considering their economic feasibility, employment potential, equity in terms of responsibility and sharing of benefits, community empowerment, and protective benefits such as reduction in runoff, soil loss and groundwater recharge.

Description of Watersheds

Fourteen OPRs were selected representing six agroecological zones and seven states in the country (Table 1). These watersheds, with long-term data pertaining to operational and after-withdrawal phases required to analyze sustainability, varied in size (from 90 ha in Nada to 1120 ha in Chinnatekur), and annual rainfall (528 mm to 3000 mm), and were located at elevations ranging from 120 to 2015 meters above sea level (msl). Eight soil groups were represented in the study: alluvial, black cotton, red, red lateritic, red yellow, silty loam, loam, and black red. The problems were unique to each region: denudation and mass wasting in the Himalayan region; denudation, flash floods, high sedimentation and drought in the Northern plain; sheet, rill, gully and ravines in the Northern plain and Central highland; rill and drought in the Central highland; sheet, rill and high sedimentation in the Western ghats; and drought in the Deccan plateau.

Watershed Management Plans and Activities

A unique and comprehensive watershed management plan comprising foundation structures and production systems compatible with the physiography, hydrology, soil, land capability, vegetation, irrigability and socioeconomic conditions of the region was developed for each watershed.

Foundation Structures

These included tanks, small dams, water distribution systems, spillways, gully plugs, check dams, silt detention basins, trenches, embankments, leveling, bunding, terracing, and dug-out ponds, which were constructed in order to ensure technical feasibility and economic viability. More than 60% of the expenditure on the watershed was utilized for this purpose (Ram Babu and Dhyani 1997).

Structures of Production System

Conserved resources were used efficiently by putting the land to the most sustainable productive use. A large number of demonstrations were conducted on farmers' fields to reveal the efficiency and efficacy of available technologies. These were held in a participatory mode to make them "a people's program". Since strengthening local institutions is important for sustainable development, community participation was ensured by involving the users in the processes of

Table 1. Basic resources and major problems faced by watersheds.

Watershed	Rainfall (mm)	Area (ha) Arable	Area (ha) Nonarable	Major soil groups[1]
Western Himalayas				
Fakot, Uttar Pradesh	1900	80	290	RY
Northern plain				
Sukhomajri, Haryana	1120	50	85	A
Nada, Haryana	1116	35	55	A
Bunga, Haryana	1116	336	127	A
Northern plain & Central highland				
Bajar Ganiyar, Haryana	640	820	270	A
Siha, Haryana	640	424	236	A
Tejpura, Uttar Pradesh	940	526	250	Lo
Navamota, Gujarat	819	218	95	R
Central highland				
Rebari, Gujarat	960	370	200	SL
Chhajawa, Rajasthan	874	453	—	B
Deccan plateau				
Joladarasi, Karnataka	528	509	61	B
Chinnatekur, Andhra Pradesh	654	815	306	BR
G.R. Halli, Karnataka	601	151	169	R
Western ghats				
Khumbhave, Maharashtra	3000	121	89	La

[1] A - Alluvial, B - Black cotton, BR - Black red, La - Lateritic, Lo - Loam, R - Red, RY - Red yellow, and SL - Silty loam.

planning, implementation, and sharing of costs and benefits, for which Resource Management Societies were formed with required legislative support.

Watershed Responses

Production in conjunction with protection on a sustained basis and generation of gainful employment within the watershed were two objectives of the programs. The outcome of the watersheds on production sustainability, economic viability, employment generation, equity, community empowerment and protection is given below.

Production Sustainability

Implementing the watershed management programs enhanced irrigation potential by 40-300%, improved *in-situ* moisture conservation, and increased cropping intensity to the tune of 12-110% (Table 2). This increased the productivity of arable land by 0.44 - 2.16 t ha^{-1} and that of nonarable land by 0.05-1.3 t ha^{-1} in various agroclimatic regions. Milk production also increased significantly due to the substitution of low-yielding local animals with high-yielding breeds and the availability of good quality fodder.

Economic Viability

An economic evaluation of these programs (Table 3) revealed that their benefit-cost ratio (BCR) varied from 1.07 in Nada to 3.42 in Tejpura considering the productive benefits alone. The Internal Rate of Return (IRR) was higher than 16%, indicating the economic soundness of the projects.

Employment Generation

Watershed management programs may yield productive and protective benefits in perpetuity if they are economically sound, provide gainful employment, and become an integral part of the farming system. Enhanced productive potential owing to a change in land and animal husbandry practices — from extensive to intensive and traditional to improved — generated regular employment opportunities ranging from 6 to 45 man days ha^{-1} $year^{-1}$ (Table 4), indicating that such programs may be helpful in checking the migration of the local workforce and provide better opportunities in the rural areas.

Table 2. Impact of watershed management on irrigation, cropping intensity and productivity.

Watershed	Irrigated area (ha)		Increase in cropping intensity (%)	Increase in productivity of land ($kg\ ha^{-1}$)	
	Pre-project	Post-project		Arable	Non-arable
Western Himalayas					
Fakot, Uttar Pradesh	11.0	24.0	56	1050	13000
Northern plain					
Sukhomajri, Haryana	-	29.0	82	1450	7400
Nada, Haryana	-	31.5	78	2160	4200
Bunga, Harayana	-	243.0	110	2100	3600
Northern plain & Central highland					
Bajar Ganiyar, Haryana	125.0	395.0	21	870	4000
Siha, Haryana	115.0	302.0	23	1040	4600
Tejpura, Uttar Pradesh	20.0	510.0	97	2000	24300
Navamota, Gujarat	17.7	35.0	26	900	1000
Central highland					
Rebari, Gujarat	9.0	55.3	20	900	600
Chhajawa, Rajasthan	32.5	260.3	26	560	600
Deccan plateau					
Joladarasi, Karnataka	Na	3.0	18	1300	3300
Chinnatekur, Andhra Pradesh	217.0	354.0	25	1100	13000
G.R. Halli, Karnataka	12.0	52.0	12	Na	Na
Western ghats					
Khumbhave, Maharashtra	Na	Na	40	440	3500

Na= Not available.

Table 3. An economic evaluation of the watershed management programs.

Watershed	Project life (years)	Discount rate (%)	Benefit-cost ratio	Net present value (in million Rs)	Internal Rate of Return (%)
Western Himalayas					
Fakot, Uttar Pradesh	25	10	1.92	0.5	24.0
Northern plain					
Sukhomajri, Haryana	25	12	2.06	-	19.0
Nada, Haryana	30	15	1.07	-	12.3
Bunga, Haryana	30	12	2.05	-	-
Northern plain & Central highland					
Bajar Ganiyar, Haryana	20	15	1.58	-	17.0
Tejpura, Uttar Pradesh	10	10	3.42	-	-
Navamota, Gujarat	30	12	2.00	0.8	-
Central highland					
Rebari, Gujarat	2.0	12	2.65	0.9	37.5
Chhajawa, Rajasthan	20	10	2.24	13.17	-
Deccan plateau					
Joladarasi, Karnataka	15	15	1.45	1.7	-
Chinnatekur, Andhra Pradesh	15	15	1.81	18.5	-
G.R. Halli, Karnataka	15	15	1.48	0.9	-
Western ghats					
Khumbhave, Maharashtra	20	15	2.10	-	-

Table 4. Employment generated through various watershed management programs.

Watershed	Employment generated: Casual (man days ha^{-1})	Employment generated: Regular (man days $ha^{-1} year^{-1}$)	Region
Fakot	203	32	Western Himalayas
Navamota	240	11	Western Himalayas
Rebari	88	6	Western Himalayas
Chinnatekur	268	45	Deccan plateau

Equity

An analysis of Fakot (Uttar Pradesh hills) and Bunga (Haryana) watersheds revealed (Dhyani et al. 1997; Arya and Samra 1995) that the programs reduced the degree of inequality (Figs. 1 and 2).

Environmental Protection

Watershed management plays a protective role by maintaining/restoring soil productivity by reducing runoff volume, sediment yield, and recharging groundwater. There is very little information on these due to the lack of gauging stations. Data from watersheds indicate the success of such programs (Table 5). The reduction in runoff and soil loss helped reduce sedimentation in ponds and reservoirs, moderating flood peaks and increasing groundwater recharge (Table 6).

Community Empowerment and Management Societies

Community empowerment by strengthening local institutions is the new paradigm of sustainable development of rural areas in general and for watershed management in particular. Local institutions such as Resource Management Societies created at the watershed level were entrusted with the responsibility of protecting natural resources, ensuring equal distribution of benefits from Common Property Resources (CPRs) and maintaining their own resources. The societies have a set of by-laws that can only be amended and modified by the general body. For instance, in the Bunga watershed (Haryana), the society generated an income of Rs 368,578 over a 9-year period (1984-92) from the

Figure 1. Lorenz curves for farm and family income, Fakot watershed.

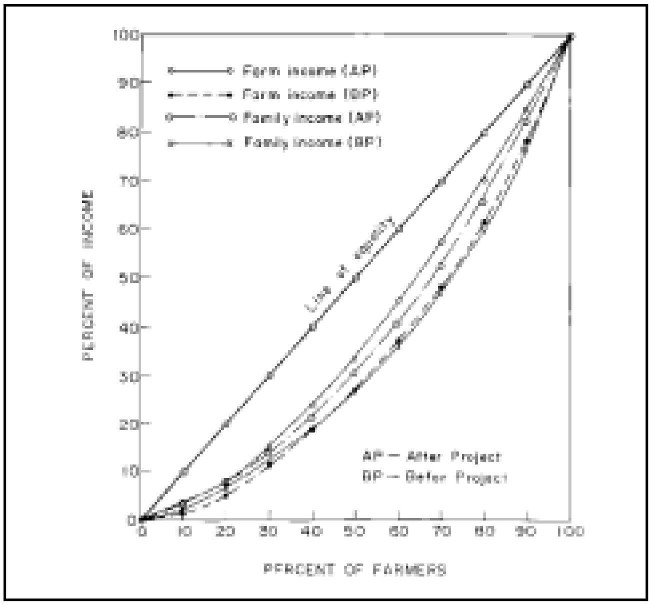


Figure 2. Lorenz curves for income distribution, Bunga watershed.

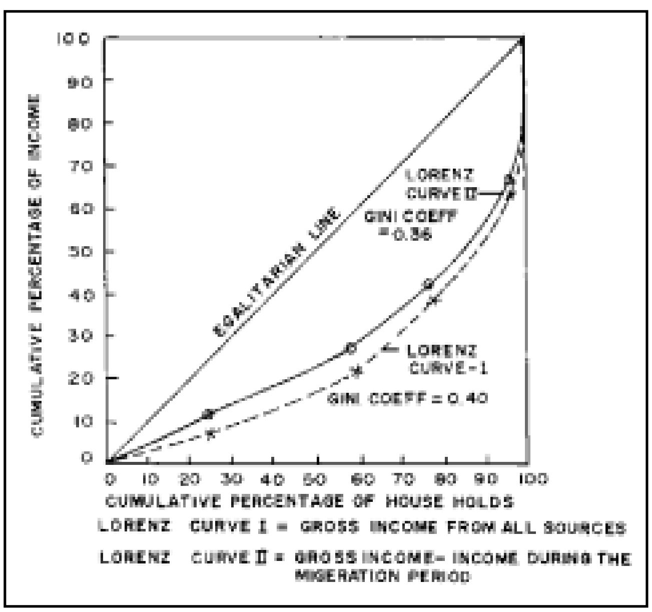


Table 5. The impact of watershed management programs on runoff and soil loss.

Watershed	Runoff (%)		Soil loss (t ha^{-1} $year^{-1}$)	
	Pre-project	Post-project	Pre-project	Post-project
Western Himalayas				
Fakot	42.0	14.2	11.0	2.0
Northern plain				
Bajar Ganiyar	7.3	3.5	NA	NA
Navamota	2.2	1.0	NA	1.1
Central highland				
Chhajawa	34.5	10.1	NA	NA
Deccan plateau				
Joladarasi	NA	6.7	12.0	2.3
Chinnatekur	5.2	3.5	2.2	1.2

NA= Not available.

Table 6. The effect of watershed management strategies on groundwater recharge in select watersheds, India.

Watershed	Surface storage capacity created (ha m^{-1})	Rise in ground-water table (m^1)
Bunga	60.0	1.8
Chhajawa	20.0	2.0
Chinnatekur	5.6	0.8
G.R. Halli	6.8	1.5

The difference between with and without project water table.

sale of stored water for irrigation, lease of catchment areas for grass, and lease of reservoirs for fish culture (Arya and Samra 1995). Sukhomajri watershed society generated Rs 92,437 from the sale of grass from the catchment area and water for irrigation and fish (Table 7). The income generated by the societies was invested in the development of new CPRs and the maintenance of old ones (Grewal et al. 1995). Thus, the concept of 'social fencing' is being propagated. The results of a similar project at Fakot (Uttar Pradesh hills) were also quite encouraging. The impact of the participation in this watershed on various

Table 7. Total income (Rs) accruing to resource management societies in Bunga and Sukhomajri watersheds, India, 1984-92.

Year	Bunga	Sukhomajri
1984	5,722	2,600
1985	13,112	5,157
1986	9,093	4,265
1987	46,399	19,374
1988	24,213	7,441
1989	31,809	14,060
1990	40,250	9,382
1991	43,051	10,475
1992	154,929	19,683
Total	**368,578**	**92,437**

Table 8. The impact of participating at different stages of development of the Fakot watershed management program.

	Average level of attributes		
Product	**During pre-project (1974-75)**	**During interventions (1975-86)**	**After withdrawal of external interventions (1987-95)**
Food crops (t)	88.2	401.5	584.3
Fruit (t)	Neg.	62	1,962
Milk (liters)	57,000	185,000	237,000
Floriculture (Rs)	Neg.	Neg.	120,000
Cash crops (Rs)	6,500	24,800	202,500
Animal rearing method	Heavy grazing	Partial grazing	Stall feeding
Dependency on forest (%)	60	46	18

activities, especially after the withdrawal of CSWCRTI's intervention, is evident from Table 8. Production of foodgrains, fruits, milk, flowers and cash crops continued to increase after the withdrawal of active support due to the participatory management of the watershed (Dhyani et al. 1997).

References

Arya, S.L. and **Samra, J.S.** 1995. Socioeconomic implications and participatory appraisal of integrated watershed management project at Bunga. *Bulletin No. T-27/C-6*. Chandigarh, India: Central Soil Water Conservation and Training Institute, Research Centre. 112 pp.

Dhyani, B.L., Samra, J.S., Juyal, G.P., Ram Babu, and **Katiyar, V.S.** 1997. Socio-economic analysis of a participatory integrated watershed management in Garhwal Himalaya — Fakot watershed. *Bulletin No. T-35/D-24*. Dehradun, India: Central Soil Water Conservation and Training Institute, Research Centre. 113 pp.

Grewal, S.S., Samra, J.S., Mittal, S.P. and **Agnihotri, Y.** 1995. Sukhomajri concept of integrated watershed development. *Bulletin No. T-26/C-5*. Chandigarh, India: Central Soil Water Conservation and Training Institute, Research Centre. 157 pp.

Narayana, V.V., Dhruva, and **Ram Babu**. 1983. Estimation of soil erosion in India. *Journal of Irrigation and Drainage Engineering*, ASCE 109:419-433.

Narayana, V.V., Dhruva, Bhardwaj, S.P., Sikka, A.K., Singh, R.P., Sharma, S.N., Vittal, K.P.R. and **Das, S.K.** 1987. Watershed management for drought mitigation. *Bull., ICAR*, New Delhi. 54 pp.

Ram Babu, and **Dhyani, B.L.** 1997. Watershed management programmes in India - An overview. *Land Husbandry* 2 (1):27-44.

Samra, J.S. 1997. *Status of research on watershed management*. Presented at the 173rd meeting of the Governing body of the Indian Council of Agricultural Society, New Delhi. Dehradun, India: Central Soil Water Conservation and Training Institute. 44 pp.

Economic and Environmental Sustainability through Participatory Watershed Management Program in the Garhwal Himalayas

B L Dhyani and R Babu[1]

Introduction

The Himalayas are characterized by a young and fragile ecosystem, diminishing biodiversity, marginalized land resource, inaccessibility, and resource-poor inhabitants. Of the nearly 24 million hectares covered by the Garhwal Himalayas, about 34% is severely degraded and more than half of it is facing natural resource degradation in one form or the other. About 20% of it is permanently under snow. Agriculture is practised on 22.5% of the reported area and a majority of the population (84%) depends on agriculture and the forest for its livelihood. Since there is no secondary sector, male migration and disguised unemployment are prevalent in the region. Agricultural productivity is very low owing to traditional crop production technologies, rainfed farming and faulty land-use practices. Hence a watershed approach was considered to be most effective in improving the economic and environmental suitability of the region.

This paper attempts to assess the role of watershed activities in meeting the multiple objectives of stakeholders who are heavily dependent on agriculture, forests, remittances made by male members who have migrated and the conservation of natural resources to maintain intergeneration equity.

Dhyani, B.L. and **Babu, R.** 2005. Economic and environmental sustainability through participatory watershed management program in the Garhwal Himalayas. Pages 187-197 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Central Soil and Water Conservation Research and Training Institute, 218 Kaulagarh Road, Dehradun 248 195, Uttaranchal, India.

Materials and Methods

Experimental Watershed

To demonstrate sustainable production through participatory resource conservation, an Operational Research Project (ORP) on watershed management was taken up in Fakot (Tehri Garhwal district of Uttaranchal) by the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun, during 1974-75. The watershed covered 370 ha with an average slope of 72% and elevation range of 650-2015 metres above sea level. The average annual rainfall in the area is about 1900 mm. The watershed forms part of river Hiul, a tributary of the river Ganga. The watershed supported a population of 818 people and 555 livestock with an average productivity of 700 kg ha^{-1} of arable and 1500 kg ha^{-1} of nonarable land. Most of the land (92-98%) was found unsuitable for cultivation; however 22% of it was under agronomical crops. Even though the watershed was suitable for horticultural crops and permanent vegetation, a baseline survey revealed that fruit trees occupied only 0.5 ha. The rest of the watershed comprised mostly of uneconomic bushes, except for some area under the Forest Department (Anonymous 1978). Various soil and water conservation works such a terracing, water harvesting and recycling, improved crop demonstration, planting horticultural and forest trees, setting up gully plug structures, etc., were undertaken between 1975 and 1986, where farmer's participation was in the form of family labor, supply of locally-available materials, and FYM. Various watershed management activities were carried out by the locals with the objectives of generating casual employment opportunities for them, for training and capacity building so that they could sustain the program, and to maintain transparency in the program.

Data Collection and Analysis

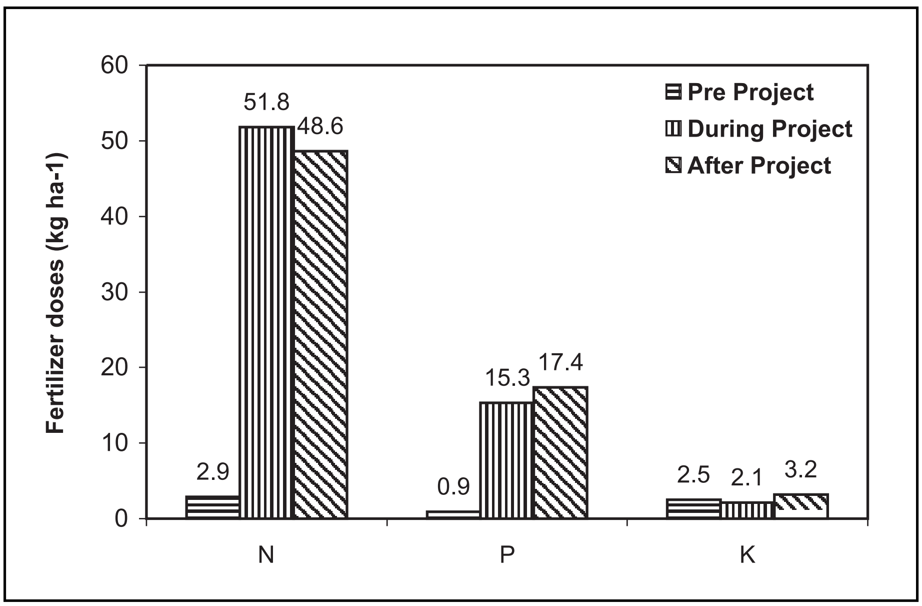
Time series data were collected from records pertaining to the watershed from 1974-75 to 1995-96 and categorized under three phases: Pre-Project Phase (PPP), 1974-75; Active Operational Phase (AOP), 1975-86; and Financial Withdrawal Phase (FWP), 1987-96. A budgeting technique was employed to estimate the impact of the watershed management program on income patterns and production, changes in land resource-use, and emigration. Compound growth in agricultural production during two phases of the project was estimated from linear time trend equations using the statistics suggested by Rao (1980).

Results and Discussion

Application of Chemical Fertilizer

Prior to the watershed project, farmers used to apply 2.9 kg ha^{-1} N, 0.9 kg ha^{-1} P and 2.5 kg ha^{-1} K. The dosage increased to 51.8 kg ha^{-1} N and 15.3 kg ha^{-1} P during AOP. After the FWP, N application fell marginally (to 48.6 kg ha^{-1}) while there were increases in P (17.4 kg ha^{-1}) and K (3.2 kg ha^{-1}) applications (Fig. 1).

Figure 1. Application of chemical fertilizers (kg ha^{-1}).



Adoption of Improved Varieties

A persistent participatory demonstration of improved crop production technologies from 1975-76 to 1985-86 yielded encouraging results. Before the project, improved varieties of irrigated paddy and wheat used to be cultivated by 5% and 12% of the farmers respectively; this increased to 70% and 82% during

AOP. At present, all the farmers use improved varieties. Further, the area under improved varieties increased from the pre-project level to AOP, and this trend continued after FWP (Table 1).

Table 1. Adoption of improved varieties of major crops during three phases[1] of the watershed management project, Fakot, Uttaranchal.

	Adoption by farmers (%)			Area under improved varieties (%)		
Crop	**PPP**	**AOP**	**FWP**	**PPP**	**AOP**	**FWP**
Paddy (irrigated)	5	70	100	3	60	100
Paddy (rainfed)	Nil	20	Discontinued	Nil	40	Discontinued
Maize (rainfed)	10	60	55	7	40	62
Finger millet (rainfed)	Nil	68	70	Nil	60	73
Jhingora (rainfed)	Nil	72	76	Nil	56	71
Ginger (rainfed)	Nil	10	60	Nil	4	56
Wheat (rainfed)	3	45	60	1	66	75
Wheat (irrigated)	12	82	100	2	70	100
Tomato (irrigated)	Nil	10	60	Nil	2	63

[1] PPP=Pre-Project Phase (1974-75); AOP = Active Operational Phase (1975-86), and FWP = Financial Withdrawal Phase (1987-96).

Average Yield of Major Crops

The average yield of various crops grown in the watershed during PPP, AOP and FWP periods are given in Table 2. A remarkable improvement was observed in the yield of various crops during the project, ranging between 225% in the case of ginger to 676% in the case of maize. However, a marginal reduction in yield was observed during FWP compared to AOP. Due to the adoption of improved crop production technology, uncertainties in crop yields were reduced by 40% in finger millet (mandua) and 60% in wheat (irrigated). The magnitude of uncertainty fell from 450% (PPP) to 40-69% after FWP. It boosted agricultural production in the watershed on a sustained basis.

Resource-use Diversification

Land, livestock, labor, and capital are the major resources of an agrarian community. The development of farming communities depends on the resource-

Table 2. Average yield (kg ha^{-1}) of major crops during three phases[1] of the Fakot watershed project.

Crops	PPP	AOP	FWP
Paddy (irrigated)	650	4820	3950
Maize (rainfed)	500	3380	3230
Finger millet (rainfed)	450	1080	890
Jhingora (rainfed)	400	940	840
Chillies (rainfed)	150	580	760
Ginger (rainfed)	3500	7870	11460
Pulses (postrainy season-rainfed)	360	1080	1260
Wheat (rainfed)	450	1860	1640
Wheat (irrigated)	1060	3140	2850
Gram (rainfed)	Not cultivated	1730	1680
Oilseed (rainfed)	Not cultivated	670	750

[1] PPP=Pre-Project Phase (1974-75); AOP = Active Operational Phase (1975-86); and FWP = Financial Withdrawal Phase (1987-96).

use pattern at the farm level. The extent and composition of their use in the watershed at three points of time (Table 3) reveals many interesting patterns in resource allocation. In the case of land, the area under horticulture increased from 0.5 ha in 1974-75 to 21.8 ha in 1985-86 and 25.3 ha after financial withdrawal (1994-95). The area under fuel, fodder and grasses under community-managed land (*Civil Soyam*, the land owned by the revenue department but managed by villages for common use) increased from almost nil to 22.6 ha and then to 28.5 ha during the same period. Land under horticulture, fuel and fodder was diverted from wasteland and rainfed agriculture use. There was a maximum increase in livestock population in the watershed in 1988-89 but this declined slightly after FWP. This was due to a drastic and favorable shift from low-quality animals (local cow) to improved buffaloes. As a result, grazing went out of the picture and stall feeding became common. Good grasses developed on pasture land and total milk production increased.

The available labor force in the watershed increased from 177 to 247 during 1985-86 and further to 274 in 1994-95 (after FWP). A major achievement of the program was the drastic fall in seasonal migration from the watershed —

from 47 (26.7%) in 1974-75 to 23 (9.3%) in 1985-86, and 2 (0.7%) in 1994-95 (Dhyani et al. 1997). This was possible mainly through the development of horticulture and off-season vegetable cultivation, besides the intensive use of land and the adoption of improved crop production technology.

Table 3. Resource-use diversification in the treated watershed.

Resource	Pre-Project (1974-75)	During financial support (1985-86)	After withdrawal of financial support (1994-95)
Land			
Land (ha)	370.0	370.0	370.0
Net cultivated area	79.9	74.0	71.8
Gross cropped area	120.7	146.5	134.9
Cropping intensity (%)	151.0	198.0	188.0
Orchard plantation	0.5	21.8	25.3
Fuel, fodder and grasses	Nil	22.6	28.5
Wasteland	157.1	122.2	112.3
Livestock composition (Nos.)			
Cow	68	40 *	6
Sheep and goats	250	272 *	35
Buffaloes	109	289 *	350
Bullocks	128	212 *	238
Total	555	813 *	629
Labor work force (Nos.)			
Seasonal migrant	47 (26.7[1])	23 (9.3)	2 (0.7)
Own-farm employment	116 (65.9)	206 (83.4)	256 (93.4)
Service	14 (8.4)	18 (7.3)	16 (5.9)
Total work force	177 (100)	247 (100)	274 (100)

[1] Figures within parentheses are percentages of the work force.

* Figure relates to 1988-89.

Growth in Production

Improved resource use coupled with the adoption of modern agronomic practices through watershed management enhanced agricultural production in the watershed. Estimated linear trend equations indicate that the annual total crop production increased at 2.68% per year from 1975-76 to 1985-86 and increased further at 1.65% from 1985-86 to 1993-94 (Table 4). The growth rate during the second phase of the project was achieved despite the withdrawal of 7.2 ha of cultivable land for the development of horticulture.

The increase in agricultural production at the rate of 1.65% during the FWP is an indicator of the program's sustainability. A noteworthy feature of the analysis is the greater increase in the production of spices and vegetables during the second phase compared to the first phase. Vegetable production increased at the rate of 34.1 t per year during the FWP. This was possible only when farmers gained confidence and attained self-sufficiency in foodgrains. These activities, mainly taken up to generate cash income, gave an impetus to the watershed management program during the FWP. Apart from enhancing grain production by more than 4-6 times, the program also diversified farming activities. Fruit production, almost non-existent before the project, reached 19,000 kilograms during 1985-86 and increased to 201.500 kilograms during 1994-95. Similarly, a shift from the low-yielding local cow to high-yielding buffaloes helped boost annual milk production from 57,000 liters (1974-75) to 185,000 liters (1988-89) and further to 260,000 liters (1994-95).

Table 4. Agricultural production and income from the Fakot watershed.

Crops	PPP	AOP	FWP
Food crops (kg)			
Cereals + millets	68,330	284,810	26,1000
Pulses	1400	13,820	25,360
Oilseed	Neg.	850	3050
Vegetables	7160	98,050	207,000
Spices	5300	20,830	73,050
Total	88,180	418,360	569,460
Fruit (kg)	Neg.	18,900	201,500
Milk ('000 liters)	56.6	184.8*	260.8
Income from sale of cash crops (in '000 Rs)	6.5	62.2	525.5**

* Figure relates to the year 1988-89.
** Figure relates to 1995-96. The community diversified into horticulture from 1994.
Neg. = Negligible.

Protection Impact

The watershed management program yielded tangible as well as intangible benefits. The tangible benefits were in the form of increase in the quantity of utility products such as crops, milk, fruits and cash income. The environmental benefits included easing of burden on reserve forests due to stall feeding and a reduction in runoff and soil loss from the watershed owing to adequate vegetative cover well supported by a series of mechanical measures (Table 5). Adequate vegetative cover reduced the dependency on fodder from reserve forests by 60% after financial withdrawal. Runoff and soil loss from the watershed also showed a significant reduction during the same period, with rates being within permissible limits. A higher level of productivity from all farm resources with improved or enhanced soil fertility, labor, capital, and environment on a sustained basis indicated there was balanced and equitable development.

Table 5. Production and protection impact of the treated watershed management program during three phases[1] of the project.

Crops	PPP	AOP	FWP
Food crops (kg ha^{-1})			
Cereals + millets	683.3	2848.1	2610.0
Pulses	14.0	138.2	253.6
Oilseeds	Neg.	8.5	30.5
Vegetables	71.6	980.5	2070.0
Spices	53.0	208.3	730.5
Total	881.8	4183.6	5694.6
Fruit (kg ha^{-1})	Neg.	189	2015.0
Milk ('000 liters)	56.6	184.8[2]	260.8
Income from the sale of cash crops (in '000 Rs)	6.5	62.2	525.5[3]
Animal rearing method (grazing)	Heavy grazing	Partial feeding	Stall feeding
Dependency on forest for fodder (%)	60	40	20
Runoff (%)	42	15	130
Soil loss (t ha^{-1} year^{-1})	11.1	2.7	2

[1] PPP=Pre-Project Phase (1974-75); AOP = Active Operational Phase (1975-86); and FWP = Financial Withdrawal Phase (1987-96).
[2] Figure relates to 1988-89.
[3] Figure relates to 1995-96. The community diversified into horticulture from 1994.

Drought Mitigation

One of the objectives of the watershed management program was to provide resilience in production under unfavorable weather conditions. This is more important in hill agriculture, where more than 2/3 of arable land is rainfed. The region witnessed a severe drought in 1987, when the total rainfall in the watershed was 44.5% less than the long-term average (from previous records). During the rainy season (July to September), there was about 58% rainfall. Further, there were four dry spells lasting for more than 15 days during the rainy season. The whole region faced an acute shortage of water; therefore a significant decline in the production of foodgrains and fodder was expected.

The impact of the watershed management program in mitigating drought was quantified in terms of net sown area and the productivity of arable and nonarable land compared to the comparative watershed. Data collected from the experimental and control watersheds in 1987 are presented in Table 6. Various soil and water conservation measures adopted in the Fakot watershed helped farmers sow a large percentage of their arable land. On the other hand, there was an 18% reduction in net sown area outside the watershed. There was a 5% reduction in the average productivity of arable land in the Fakot watershed as compared to 40% outside it. The productivity of nonarable land was badly hit by the severe drought. However, small water harvesting structures (trenches, pits, gully plugs, vegetation, check dams etc.) adopted on nonarable land in the watershed helped produce good fodder. Fodder production within the watershed declined by 7% as against 80% outside it. From the analysis, it is clear that sustainable production from arable as well as nonarable land could be obtained from the treated watershed even in a climatically unfavorable year.

Table 6. Performance of the Fakot watershed during the 1987 drought.

Indicators	Reduction (%)
Rainfall	44.5
Rainy-season rainfall	58
Net sown area inside the watershed	4
Net sown area outside the watershed	18
Decline in average crop yield inside the watershed	5
Decline in average crop yield outside the watershed	40
Decline in average fodder yield inside the watershed	7
Decline in average fodder yield outside the watershed	80

Source: Dhyani et al. (1997).

Constraints

The Fakot watershed has a ruggedness measuring 13.85 with a dendritic drainage pattern. In addition to constraints like inaccessibility, marginality, fragility of fragmented holdings, resource-poor farmers, women-dependent agriculture and male migration, there are others like weak community organization, poor infrastructural facilities, and lack of proper legislative support. Since the watershed has wide variations in microclimate owing to differences in elevation, a wide range of technologies were required to suit it. Available technological interventions are limited due to poor research efforts.

Conclusion

Nearly one-third of the Garhwal Himalayas are severely degraded. In order to ensure the prosperity of people living there and in the foothills, immediate efforts are needed to adhere to the watershed program. An analysis of the Operational Research Project revealed that balanced and sustained development can be achieved in the region given the available technology is planned and implemented with peoples' participation. The program led to a favorable, self-sustainable, economically viable, socially acceptable, and environmentally-desirable resource-use pattern in the watershed. The benefits were in the form of water harvesting, storage, recycling and active participation by the local community.

Acknowledgement

We express our gratitude to JS Samra, Director, CSWCRTI, Dehradun, for his guidance and Minakshi Pant for typing the manuscript.

References

Anonymous. 1978. *Report on Operational Research Project on watershed management* - Fakot (Bhaintan Watershed) District - Tehri Garhwal. Dehradun, India: Central Soil and Water Conservation Research and Training Institute. 86 pp.

Dhyani, B.L., Samra, J.S., Juyal G.P., Ram Babu, and **Katiyar, V.S.** 1997. Socio-economic analysis of a participatory integrated watershed management in Garhwal Himalayas –Fakot. *Watershed Bulletin T-35/D-24*. Dehradun, India: Central Soil and Water Conservation Research and Training Institute. 113 pp.

Rao, V.M. 1980. Methodological issues in measuring agricultural growth: lessons of recent Indian researchers. *Indian Journal of Agricultural Economics* 35(12):1-20.

17

Technological Options for Salinity Management in Agriculture: Scope and Prospects

K K Datta[1]

Introduction

Irrigation enjoyed a favored status during the 1970s in terms of investment in Indian agriculture. With more than 75% of the World Bank's assistance being allocated to it, the outcome was an unprecedented rise in agricultural productivity. This was followed by a decline in investment, one of the reasons being the disillusionment with its poor economic performance which was largely due to poorly-managed operations, inadequate supplies at the tail ends, and untimely and unreliable water delivery.

There is a constant threat of water scarcity due to the overuse of water in a fresh groundwater zone and the consequent decline in the water table. However, farmers generally prefer not to use saline groundwater. This results in the nonexploitation of poor quality groundwater and the mismanagement of surface canal water which creates waterlogging and secondary salinization. Due to this, about 15-20% of the command area, which is mostly underlain with marginal and poor quality groundwater, has become waterlogged and saline. Northwestern Indian states like Haryana, Punjab, Rajasthan, and Gujarat face problems of waterlogging and salinity. In Gujarat, about 9% of the total geographical area is affected by salinity and sodicity. About 20-30% of the area in the Chambal Command of Madhya Pradesh is no longer under cultivation for the same reasons.

Datta, K. K. 2005. Technological options for salinity management in agriculture: scope and prospects. Pages 199-204 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1]Central Soil Salinity Research Institute, Karnal 132 001, Haryana, India.

A survey of acquifers in different states reveals that about 32-84% of groundwater is of poor quality. The Central Groundwater Board, New Delhi, India, reported in 1994 that the percentage of area under saline groundwater was 4% in Haryana, 3% in Punjab, 82% in Rajasthan, 10% in Gujarat, and 1% in Uttar Pradesh. According to the VIII Five-Year Plan, 17.61 Mha are affected by waterlogging, 8.53 Mha by alkalinity, 3.58 Mha by salinity, and 95.50 Mha by sandy area (GOI 1991). Recent estimates show that 8.6 Mha of soils in India are salt-affected and that 4.5 Mha are waterlogged (Singh 1994).

Keeping this in view, this paper suggests the scope and prospects of different technological options and forms of institutions needed to promote equity among all stakeholders and devolve powers and autonomy to local institutions with effective powers of regulation, legislation, and enforcement for the sustainable development of agriculture in saline environments.

Technological Options

Better water management, conjunctive use of canal and groundwater, improved surface drainage, on-farm development, introduction of forestry, amending soils and shallow groundwater management have been suggested as remedial measures to tackle salinity. Of these, the adoption of vertical drainage where groundwater quality is good and the water table is at a reasonable level; skimming well/*doruvu* technology where shallow groundwater management is needed, the water table is high and the quality of groundwater is poor; and subsurface drainage (SSD) have been suggested. Several strategic approaches were adopted at various times, and it was observed that all of them fetched good returns and were financially and economically viable in farmers' fields.

Subsurface Drainage in Haryana

In Haryana, subsurface drainage was installed over 589 ha at 13 different locations in order to prevent, or enable the reclamation of areas which were already waterlogged and saline, and over about 2000 ha at two different locations were selected for SSD under Indo-Dutch collaboration. In the Chambal Command area in Rajasthan, SSD was installed on 10,000 ha under a Canadian-funded project. In Gujarat, the Central Soil Salinity Research Institute (CSSRI) in collaboration with the Water and Land Management Institute (WALMI), Gujarat, installed SSD over 200 ha at four locations. The cost of installing SSD depends on soil type, depth and spacing of drains, location under drainage, and type of material used. At 1994-95 prices, the cost of a manually-installed SSD varied between Rs 22,310 and Rs 18,525 ha^{-1} in Haryana (Datta et al. 2002)

The SSD enabled the control of the water table level and the desalinization of soils by leaching, either with irrigation water or with monsoon rains. Operational research at Sampla farm showed that topsoil salinity decreased rapidly after drainage, from about 50 dSm^{-1} in Jun 1984 to about 5 dSm^{-1} in Nov 1985, in spite of low rainfall during these years. In all the small-scale pilot projects in Haryana, most of which were operated by farmers, SSD showed the following effects:

- considerable increase in cropping intensity;
- shift in cropping pattern towards more remunerative crops;
- significant increase in crop yields;
- increase in the efficiency, or productivity of fertilizers;
- increase in gainful employment;
- timeliness in planting and harvesting; and
- increase in land value.

These changes resulted in a substantial increase in farm income. It is well-known that SSD sustains or restores the productivity of agricultural land (Datta and de Jong 1997). The cost of installing SSD was about Rs 35,000 ha^{-1} at 1997-98 prices. Installing SSD calls for collective action for which an institutional set-up is needed. Attempts in this direction have already been made in Haryana, Rajasthan, and Gujarat. A positive coordination was observed in some of the small-scale SSD areas (Datta and Joshi 1993).

Doruvu Technology in Coastal Andhra Pradesh

Nonavailability of canal water, poor recharging, and the prevalence of clayey soils in deeper layers are the major constraints to installing tubewells. Rainwater and good quality shallow groundwater are the major sources of irrigation. Though the coastal area in Andhra Pradesh receives high rainfall but with very high permeability of coastal sands, almost all the rainwater percolates into the soil. The infiltrated rainwater having lesser density, floats over the subsurface saline water, which itself is underlain by impervious soil layer. Therefore, farmers are forced to draw shallow groundwater that collects in dugout conical pits locally called *doruvus*. As the water-retention capacity of the old system is negligible, this 20% land is wasted due to high evaporation in summer and its maintenance cost is high. Therefore, the AICRP's Bapatla Center improvised the traditional *doruvu* into an improved subsurface water harvesting system (SSWHS). The immediate impact was:

- a change in cropping sequence from rainfed groundnut to paddy;
- a reduction in fallow land;
- increase in cropping intensity due to sufficient and good quality water;
- increase in irrigated area during the postrainy season; and
- increase in irrigated area using sprinklers or drip irrigation for plantation crops.

The cost of installing a SSWHS system at 1997-98 prices was about Rs 48,000. It can irrigate about 3-4 ha. However, it is essential to consolidate landholdings in order to derive the maximum benefit from this technology. Though individual farmers may be able to install the system, resource-poor farmers of the coastal area require government intervention to do so.

Management Practices for Saline Water Use in Uttar Pradesh

The AICRP's Agra center had adopted Karanpur village in Uttar Pradesh under the Operational Research Project program in 1993-94. Recommended doses of gypsum (1.25 t ha^{-1}) along with 2 t ha^{-1} of FYM were applied where alkaline waters were used for irrigation. Conjunctive use of canal and saline waters, gypsum, conservation of rainwater, and sprinkler and drip irrigation were suggested as strategies for using saline water for irrigation. Following were the effects of these strategies:

- drastic reduction in fallow land during the rainy season;
- increase in average yields in both rainy and postrainy seasons;
- increase in crop stability in both the seasons;
- increase in labor requirement; and
- increase in annual income of farm families.

Economic studies show that if the share of good quality irrigation water is limited, it is possible to produce wheat by using saline drainage water, with yields higher than the break even level of output (Datta et al. 1998). Subsidy is needed to encourage the comparatively disadvantaged farmers. It is also essential to make their production frontier stronger (Datta and Dhayal 2000).

Policy intervention in the form of ensuring timely availability of canal water in the saline groundwater zone during sowing is an essential component of a saline environment. This would encourage farmers to bring more area under crop production. Even if less canal water is available during tillering and flowering, it will encourage farmers to bring more area under crop production, and will help them use their saline groundwater through either conjunctive use or subsequent irrigation as per the crop's requirement.

Constraints and Policy Needs

From the institutional point of view, irrigation's poor performance arises mainly due to larger systems, lack of reliable and responsive management, and no management in terms of deliberate water allocation in response to actual circumstances. The inherent lacuna in the institutional set up in irrigation systems is resulting in increased irregularity, uncertainty, favoritism and exploitation. To overcome these problems, the 1970s and the 1980s saw a major shift in emphasis towards improving irrigation performance through on-farm development (OFD), involvement of water users, and strengthening of irrigation agencies. However, no effort was made to harness the synergistic benefits of the options. As a result, no progress was made on testing the strategies together. From the 1990s onwards, it was contemplated to transfer the responsibility and authority of irrigation management from government to non-governmental agencies. Such a transfer would help water users maintain transparency, accountability, and support incentives by managing, operating, and maintaining irrigation systems. The IX Five-Year Plan (1997-2001) approach paper proposed an improvement in the efficiency of the end-use of water through the adoption of water-efficient devices and the promotion of conjunctive use of surface and groundwater. This initiative was on for a long time. However, there have been calls for an organized solution with public intervention. Those solutions are not thought to require testing and modification for long-term sustainability. Though these solutions may be effective in the short run, in the long run, SSD is the only way to reclaim waterlogged saline lands, where salts accumulate in both the soil and the groundwater.

References

Datta, K.K. and **Dhayal, Bhu.** 2000. Irrigation with poor quality water: an empirical study of input use, economic loss, and coping strategies. *Indian Journal of Agricultural Economics* 55(1):26-37.

Datta, K.K. and **de Jong, C.** 1997. Economic consideration of agricultural land drainage for managing waterlogged saline soils. *Indian Journal of Agricultural Economics* 52(2):260-270.

Datta, K.K., de Jong, C. and **Singh, O.P.** 2002. Feasibility of subsurface drainage for salinity control in the Trans-Gangetic Region of India. *Irrigation and Drainage* 51(4):275-292.

Datta, K.K. and **Joshi, P.K.** 1993. Problems and prospects of cooperatives in managing degraded lands: Case of saline and waterlogged soils. *Economic and Political Weekly* 28(12&13):16-24.

Datta, K.K., Sharma, V.P. and **Sharma, D.P.** 1998. Estimation of a production function for wheat under saline conditions. *Agricultural Water Management* 36 (1998):85-94.

GOI (Government of India)**.** 1991. *Waterlogging, soil salinity and alkalinity*. Report of the Working Group on problem identification in irrigated areas with suggested remedial measures, New Delhi, India: Ministry of Water Resources.

Singh, N.T. 1994. Land degradation and remedial measures with reference to salinity, alkalinity, waterlogging and acidity. *In Salinity management for sustainable agriculture* (Rao, D.L.N., Singh, N.T., Gupta, Raj K. and Tyagi, N.K., eds). Karnal, Haryana: Central Soil Salinity Research Institute.

18

Total Factor Productivity of the Livestock Sector in India

A Kumar,[1] D Jha[1] and U K Pandey[2]

Introduction

Livestock makes a significant contribution to the growth and development of India's rural economy. It accounts for about 6% of GDP and employs 5% of the labor force. Livestock contributes to food and nutritional security by providing milk, meat, and eggs; it provides draught power and manure for crop production, raw materials (wool, hides, and skins) for industries, and acts as insurance during bad crop years.

The livestock sector has undergone several changes since the early 1970s, most of them being direct or indirect consequences of Operation Flood, the Green Revolution, and an upsurge in the demand for livestock products. These changes have important implications for the future growth of the sector, diversification of agriculture, and the economic development of the country.

However, this sector has not received as much attention as the crop sector. Studies on the livestock sector deal largely with issues relating to livestock numbers, resource-use efficiency, marketing, institutions, employment and income generation, and feed and fodder (George 1996). There is no empirical evidence on sources of growth in the livestock sector, particularly relating to productivity

Kumar, A., Jha, D. and **Pandey, U.K.** 2005. Total factor productivity of the livestock sector in India. Pages 205-216 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

[2] Choudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, 125 004.

changes, unlike the crop sector (Jha and Evenson 1973; Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; Rosegrant and Evenson 1995; Bhalla and Hazzel 1998; Desai and Namboodiri 1998). For example, though it has been argued that technology has contributed to the growth and expansion of this sector, there is no empirical evidence to support this contention. This paper attempts to measure the contribution of technology to the growth of the livestock sector.

Methodology

Data

The study is based on information compiled from various sources from 1950-51 to 1995-96, which include Livestock Censuses, National Accounts Statistics, Report of the Technical Committee for Direction and Improvement of Animal Husbandry and Dairying Statistics, Indian Poultry Industry Yearbook, Agricultural Prices in India, and Agricultural Wages in India. However, data not readily available in the published sources are estimates (Appendix).

Computing Total Factor Productivity (TFP)

Total Factor Productivity measures the growth in total output which is not accounted for by growth in total inputs. The TFP index is the ratio of the index of aggregate output to the index of aggregate inputs. Growth in TFP is, therefore, the growth rate in total output less the growth rate in total inputs. Tornqvist-Theil TFP indices (Copalbo and Vo 1988) were computed at the aggregate level for the period between 1950-51 and 1995-96. Growth rates in output, input, and TFP indices were also calculated for subperiods to make the trends more revealing.

The output index covered milk and milk products, meat and meat products, animal draught power, dung (fuel + manure), eggs and poultry meat, hides and skins, wool and hair, and some other unspecified byproducts. To estimate the input index, feed, labor, and livestock populations were considered. Livestock feed comprises roughage and concentrates including salt, medicines, and other miscellaneous feed. Roughage includes cane trash, grass, fodder (green + dry), stalk, straw, etc., while concentrates include oilcakes, crushed pulses, grains, rice bran, husk, oilseeds, *gur*, etc. The data adjustments and assumptions are described in the Appendix.

Structure, Growth, and Importance

Composition and Growth of Population

Livestock population increased from 212 million adult cattle units (ACUs) in 1951 to about 313 million ACUs in 1992, at an annual rate of 0.98% (Table 1). The absolute number of all animal species increased during this period. Of the total livestock population, bovines constituted the lion's share, followed by ovines and pigs. Among bovines, cattle outnumbered buffaloes, which is why the Indian livestock economy is often referred to as the cattle economy. However, over the years there has been a slow but perceptible change in favor of buffaloes. The share of cattle declined from 78.2% of the total bovine population in 1951 to 71% in 1992. In the ovine category, goats outnumbered sheep. In 1951, goats comprised 55% of the ovines and this increased to 69% by 1992. The poultry population has increased tremendously. These changes clearly reveal the predominance of cattle in the livestock population. However, the importance of buffalo, goat, and poultry is gradually increasing.

Table 1. Composition of livestock population (in million adult cattle units).

Species	1951	1972	1982	1987	1992
Cattle	155.30 (73.11[1])	178.30(70.66)	192.45(67.77)	199.69(66.76)	204.53(65.27)
Buffalo	43.40 (20.43)	57.40(22.75)	69.78(24.57)	75.97(25.40)	83.50(26.65)
Bovine	198.70 (93.55)	235.70(93.41)	262.23(92.34)	275.66(92.16)	288.03(91.92)
Sheep	3.91 (1.84)	4.00 (1.59)	4.88 (1.72)	4.57 (1.53)	5.08 (1.62)
Goat	4.72 (2.22)	6.75 (2.67)	9.53 (3.35)	11.02 (3.68)	11.53 (3.68)
Ovine	8.63 (4.06)	10.75 (4.26)	14.40 (5.07)	15.59 (5.21)	16.61 (5.30)
Camel	0.60 (0.28)	1.10 (0.44)	1.08 (0.38)	1.00 (0.33)	1.03 (0.33)
Horses and ponies	1.50 (0.71)	0.90 (0.36)	0.90 (0.32)	0.80 (0.27)	0.82 (0.26)
Donkeys	1.30 (0.61)	1.00 (0.40)	1.02 (0.36)	0.96 (0.32)	0.97 (0.31)
Mules	0.06 (0.03)	0.08 (0.03)	0.13 (0.05)	0.17 (0.06)	0.20 (0.06)
Pigs	0.88 (0.41)	1.38 (0.55)	2.01 (0.71)	2.12 (0.71)	2.56 (0.82)
Yaks	NC[2]	0.04 (0.02)	0.13 (0.05)	0.04 (0.01)	0.06 (0.02)
Subtotal	4.34 (2.04)	4.50 (1.78)	5.27 (1.86)	5.09 (1.70)	5.64 (1.80)
Poultry	0.74 (0.35)	1.39 (0.55)	2.08 (0.73)	2.75 (0.92)	3.07 (0.98)
Livestock	212.41 (100)	252.34 (100)	286.98 (100)	299.10 (100)	313.35 (100)

[1] Figures in parentheses are percentages of the total.

[2] NC = Not conducted.

There are significant variations in the population growth rates of different species (Table 2). For instance, buffalo population recorded a faster growth rate than that of cattle. Similarly, goat numbers grew faster than those of sheep. Poultry witnessed a spectacular growth and the numbers increased over fourfold, i.e., from 0.74 million to 3.07 million between 1951 and 1992. The overall compound annual growth rate in poultry population was 3.64%. This growth was mainly due to the fact that among farm animals, poultry birds are one of the quickest and most efficient converters of plant products into food of high biological value. Further, they require a small area and low initial capital investment, are easily manageable by women and children, the byproducts unfit for human consumption can be used as feed, the returns are quick, and there is a well distributed turnover throughout the year. All these make poultry farming remunerative in both rural and urban areas. Most of the species recorded highest growth during the 1977-82 inter-census period, and a declining trend thereafter. The population of other animals (camels, equines, and pigs) witnessed a mixed trend.

Table 2. Growth rates of livestock population in India.

Species	1951-72	1972-92	1951-92
Cattle	0.69	0.69	0.69
Buffalo	1.41	1.89	1.65
Sheep	0.11	1.20	0.66
Goat	1.80	2.71	2.26
Camel	3.08	-0.33	1.36
Horses and ponies	-2.52	-0.46	-1.50
Donkeys	-1.30	-0.15	-0.73
Mules	1.45	4.69	3.06
Pigs	2.28	3.13	2.70
Yaks	-	2.05	-
Poultry	3.22	4.06	3.64
Livestock	**0.87**	**1.09**	**0.98**

Contribution of Livestock

The combined contribution of agriculture and allied sectors to the GDP has been declining. On the other hand, livestock's contribution to it improved from 5.70% in 1980-81 to 6.06% in 1995-96 (at 1980-81 prices). Its share in agricultural

GDP increased significantly from 16.76% in 1980-81 to 22.96% in 1995-96 (Table 3). This was largely due to a sustained annual growth of over 4% in milk, meat, and eggs during the last two and a half decades.

Table 3. Share[1] of livestock in the national GDP and AgGDP (average at 1980-81 prices).

	Triennium ending averages			Livestock GDP as % of		
Triennium averages ending year	Livestock GDP (in crore Rs)	AgGDP (in crore Rs)	GDP (in crore Rs)	AgGDP factor (in crore Rs)	GDP	AgGDP as % GDP
1950-51	Na[2]	21,382	43,953	-	-	48.65
1960-61	Na	28,157	62,168	-	-	45.29
1970-71	Na	34,785	89,291	-	-	38.96
1980-81	6,968	41,573	1,22,184	16.76	5.70	34.02
1990-91	13,707	59,652	2,09,230	22.98	6.55	28.51
1995-96	15,528	67,645	2,56,389	22.96	6.06	26.38

[1] The percentage share varies from official estimates due to the inclusion of the contribution of draught power in the GDP.

[2] Na = not available.

Source: *National Accounts Statistics* (various issues) published by the Central Statistical Organization, Department of Statistics, Government of India, New Delhi.

Value of Output from the Livestock Sector

The componentwise value of outputs from the livestock sector is given in Table 4. Milk and milk products, meat and meat products, eggs and poultry meat, animal draught power, dung, hides and skins, wool and hair are the major outputs of the livestock sector. The absolute values of these components at constant prices increased from 1951-52 to 1995-96, except for wool and hair and draught power. The value of outputs from milk and milk products increased by about 4 times, meat and meat products 2.7 times, eggs and poultry meat over 6 times, hides and skin 1.75 times, and dung 1.5 times. The value of draught power and wool and hair remained almost constant. There was a trebling of the overall value of outputs from the livestock sector.

Milk and milk products constituted the lion's share in the value of outputs from this sector. Its share in the total value (at 1980-81 prices) rose from around 49% in 1950-51 to over 63% in 1995-96. The share of draught power was around 16% in 1950-51; it declined to a mere 6% in 1995-96. Similarly, the share of dung too declined from 15 to 7% during this period. Next to milk and milk products, eggs and poultry meat have emerged in recent years as major contributors to the output of the livestock sector. The contribution of eggs and poultry meat was 4.47% in 1950-51; it reached a little over 9% in 1995-96. Meat and meat products (excluding poultry) are also an important contributor with a share of 8.55%. Hides and skins, and wool and hair are relatively less important. The share of wool and hair fell from 1.04 to 0.34%, while that of hides and skins declined from 2.49 to 1.43%.

The declining share of draught power and dung in the total value may be attributed to the mechanization of agriculture and the relatively faster growth registered by ovine and poultry groups.

Table 4. Total value of output from the livestock sector (in crore Rs) and its composition.

(triennium average ending)

Items	**1950-51**	**1970-71**	**1980-81**	**1995-96**
Milk group	3463 (48.89[1])	4877 (52.93)	7070 (57.87)	13814 (63.35)
Meat and meat products	695 (9.81)	757 (8.28)	903 (7.40)	1862 (8.55)
Eggs and poultry meat	317 (4.47)	498 (5.42)	839 (6.87)	1872 (9.05)
Dung	1090 (15.39)	1176 (12.82)	1367 (11.19)	1608 (7.38)
Draught power[2]	1128 (15.92)	1335 (14.56)	1366 (11.19)	1313 (6.03)
Hides and skin	176 (2.49)	184 (2.02)	205 (1.68)	312 (1.43)
Wool and hair	74 (1.04)	81 (0.89)	65 (0.53)	74 (0.34)
Others	142 (1.99)	282 (3.04)	401 (3.27)	845 (3.87)
Total	7085 (100.00)	9190 (100.00)	12215 (100.00)	21801(100.00)

[1] Figures in parentheses are percentages of the total.

[2] Authors' estimates.

Source: *National Accounts Statistics* (various issues), published by the Central Statistical Organization, Department of Statistics, Government of India, New Delhi.

Annual compound growth rates in the value of output of the livestock sector by components for the period 1950-51 to 1970-71 (Period I), 1970-71 to 1995-96 (Period II), and 1950-51 to 1995-96 (overall) are presented in Table 5. Except for wool and hair, the value of output of all components registered positive and significant growth rates. There was an increase in the growth during Period II, except in the case of draught power which registered a negative growth. Growth rates for food items (milk, meat, eggs, and poultry) were in the range of 4 to 6% from this period. However, the most notable growth among the livestock products has been recorded by eggs and poultry meat. Since 1970-71, their output has grown at 5.87% per annum. The growth rates for dung, draught power, hides and skins, and wool and hair were in the range of -0.12 to 1.34% during 1970-71 to 1995-96. The agriculture sector performed better than the livestock sector during Period I but the situation changed in favor of the livestock sector during Period II. During this period, the livestock sector witnessed an annual growth of 3.62%, while the agriculture sector grew at 3.17%.

The spectacular growth of livestock products, especially milk, meat, eggs, and poultry meat is attributed to the initiatives taken by the organized sector and the rising demand for these products in response to rising per capita incomes in both urban and rural areas. The expenditure elasticities for livestock products are high, averaging 1.47 and 1.01 for milk in rural and urban areas, respectively (Bhalla and Hazzel 1998). Further growth in per capita income would lead to acceleration in demand for livestock products and is expected to give a boost to the growth of this sector.

The efforts of the government, particularly the departments concerned with dairying, animal husbandry, and veterinary services, have played a vital role in raising the productivity of livestock. The contribution of dairy cooperatives has also been of great importance, in both creating markets as well as supporting farmers with technical inputs like feed, breeding, and veterinary services. These technical inputs, made available under programs like Operation Flood, provided an impetus to the growth of this sector.

The declining trend in animal draught power is attributed to the mechanization of agriculture. The share of draught animals in farm power was almost 72% in 1961. It came down to 23% by 1991, and most of the farm operations switched over to electrical and mechanical sources of power. Further, a shift in the priority of the farming community from the production of work animals to that of milch animals has been observed since 1970-71. Likewise, rising expectations and

Table 5. Growth trends of the livestock sector and its components, and the agricultural sector.

Items	Period I (1950-51 to 1970-71)	Period II (1970-71 to 1995-96)	Overall (1950-51 to 1995-96)
Milk group	1.38	4.21	3.39
Meat and meat products	0.82	4.34	1.99
Eggs and poultry meat	2.14	5.87	4.22
Dung	0.48	1.34	0.90
Draught power	1.04	-0.14	0.32
Hides and skin	0.55	2.27	0.88
Wool and hair	-0.44	0.48	-0.01
Value of output from livestock sector	-	3.62	2.61
Value of output from agricultural sector (excluding livestock)	2.32	2.95	2.60
Value of output from agricultural sector (including livestock)	2.13	3.17	2.66

migration have reduced the scope of draught animal power, which is labor intensive. It is the pressure arising out of such economic trends that explains falling trends in animal draught power. It reflects a major structural change that's taking place in the Indian livestock sector. In future too, it is expected that the declining trend in the population of bullocks and local cows will gather momentum and mechanical power and rural electrification will provide the bulk of power to the farm sector.

Total Factor Productivity

Results of output, input, and TFP growth over different time-spans are presented in Table 6. Between 1950-51 and 1995-96, the livestock sector output grew at 2.59% per year. While the input index increased by 1.79% per year, TFP grew at about 0.8%. However, subperiod-wise results are more revealing.

There was no TFP growth during Period I (till 1970-71), implying no technical change. Output growth proceeded along the traditional production function and was entirely driven by growth in measured inputs. Not surprisingly, the resulting growth in output was a modest 1.3% per year. There was concern about nutritional implications as population and demand growth were substantially higher. There was a sharp uptrend since then. Input as well as TFP growth picked up significantly. Output growth increased to 3.6%. The real upswing started during the 1980s when output growth touched nearly 4% per year and TFP growth jumped to 1.8% per year.

Table 6. Compound annual growth rate (%) of output, input, and TFP indices.

Item	1950-51 to 1970-71	1970-71 to 1995-96	1950-51 to 1995-96	1970-71 to 1980-81	1980-81 to 1995-96
Output index	1.28	3.59	2.59	2.80	3.98
Feed	0.97	1.57	1.18	1.13	1.74
Labor	0.37	0.44	0.42	0.54	0.28
Population stock	0.16	0.19	0.18	0.20	0.17
Total input index	1.32	2.25	1.79	1.87	2.19
TFP index	-0.04	1.39	0.81	0.93	1.79

These results indicate that technical change has gradually become the driving force imparting dynamism to the livestock sector. It was not at all a factor in the pre-1970 period when growth of inputs was the only determinant. During the 1970s, technical change accounted for 33% of the output growth, rising to about 45% in the post-1980 era. Labor and population stock, which together accounted for over 40% of output growth during Period I, contributed only 11% in the post-1980 phase. Better feeding and technology contributed nearly 89%. Growth and technical change have thus prompted substitution of production factors, mostly reflected in the composition of livestock feed consumption over the years. It is interesting to note that feed accounted for more than 60% of the input index (Table 7). The relative factor shares over the period changed slightly in favor of feed. However, the composition of livestock feed consumption has undergone a significant change. In 1970-71, dry fodder accounted for around 58% of the total livestock feed. This came down to 35% in 1995-96 (Table 8). The share of green fodder increased from 40% to 57% during this period. The percentage share of concentrates was around 2% in 1970-71 and it remained almost constant up to 1980-81, but since then it increased significantly and reached 7.6% in 1995-96. This implies that during the ’70s, the shift in feeding pattern of livestock took place in favor of green fodder while during the ’80s and afterwards, it was more pronounced in favor of concentrates.

Higher TFP growth in the latter periods implies that the livestock economy of India has gathered momentum only during the past two and a half decades, having come out of its sluggish past. The mild trend underlying the livestock economy for decades was accelerated by modern marketing (along the Amul model) and determined measures for the protection of health and breed improvement.

Table 7. Relative factor shares (in %).

Item	1950-51 to 1970-71	1970-71 to 1995-96	1950-51 to 1995-96	1970-71 to 1980-81	1980-81 to 1995-96
Feed	60.69	60.57	62.93	61.72	61.39
Labor	23.39	24.13	23.54	23.92	23.60
Population stock	15.92	15.30	13.53	14.36	15.01

Table 8. Composition (%) of livestock feed in India.

Item	1950-51	1970-71	1980-81	1995-96
Dry fodder	59.74	57.76	46.75	35.38
Green fodder	37.74	40.19	50.62	56.98
Concentrates	2.52	2.05	2.63	7.63

Conclusion

At the macro level, the livestock sector's growth prospects in India look bright. The land-man ratio is quite low and the distribution of land is skewed. Diversifying the crop-based rural economy into an animal husbandry mixed farming system must be encouraged for rapid economic development and for generating equitable income and employment in the country.

References

Bhalla, G.S. and **Hazzel, Peter.** 1998. Foodgrains demand in India to 2020: A preliminary exercise. *Economic and Political Weekly* 32 (52):A150-154.

Copalbo, S.M. and **Vo, T.T.** 1988. A review of the evidence of agricultural productivity and aggregate technology in Susan. Pages 17-95 *in Agricultural productivity: measurement and explanation* (Copalbo, S.M., and Antle, J.M. eds.). Washington, D.C., USA : Resources for the Future.

Desai, Bhupat M. and **Namboodiri, N.V.** 1998. Determinants of total factor productivity in Indian agriculture. *Economic and Political Weekly* 32 (52):A165-170.

George, P.S. 1996. Dairying and livestock economy of India. *Indian Journal of Agricultural Economics* 51(1 and 2):288-300.

Jha, Dayanatha and **Evenson, R.E.** 1973. The contribution of agricultural research system to agricultural production in India. *Indian Journal of Agricultural Economics* 28 (4):212-230.

Kumar, P. and **Mruthyunjaya.** 1992. Measurement and analysis of total factor productivity growth in wheat. *Indian Journal of Agricultural Economics* 47 (3):451-458.

Kumar, P. and **Rosegrant, M.W.** 1994. Productivity and sources of growth for rice in India. *Economic and Political Weekly* 29 (52):A183-188.

Mishra, S.N. and **Sharma, R.K.** 1990. *Livestock development in India — An appraisal*. New Delhi, India: Vikas Publishing House Pvt. Ltd. 203 pp.

Rosegrant, M.W. and **Evenson, R.E.** 1995. Total factor productivity and sources of long-term growth in Indian agriculture. *EPTD Discussion Paper No. 7*, Washington, D.C., USA: International Food Policy Research Institute.

Appendix

Data Adjustments and Assumption

Estimation of value of draught power use: One draught animal was assumed to be equal to 0.5 HP. The working days per animal were assumed to be 100 days a year. The quantum of draught power was converted into the fuel equivalent required by a tractor to do the same amount of work. The value at current price was obtained by multiplying current average prices of diesel oil with the quantity of draught power for the respective years.

Estimation of labor use: Data on workforce engaged in the livestock sector was taken from different rounds of National Sample Surveys (NSS) on Employment and Unemployment. Two hundred mandays were assumed per unit of labor in a year. Wage rates were taken from Agricultural Wages in India to quantify the value of labor used.

Estimation of livestock value: To work out the value of livestock population, all species of livestock were converted into adult cattle units (ACUs). These ACUs were multiplied by prices. The conversion ratios suggested in the National Commission on Agriculture (NCA) 1976, have been used to convert all species of livestock into ACUs. An interest rate of 12% per year has been charged on this value to work out the share of population in the input cost.

Estimation of value of inputs: It is generally agreed and there is no evidence to the contrary that the nutritional requirement of India's livestock is greater than the availability of feed and fodder. On the other hand, the actual consumption of feed and fodder by stock in any year cannot exceed the net of carry over to the following year. Considered *ex-post* consumption must equal availability. Therefore, the estimates for cakes/concentrates, dry fodder, and green fodder availability have been used for constructing input indices. Mishra and Sharma (1990) have given a detailed estimation procedure.

Assessment of Crossbreeding Technology in India: A Macro Perspective

S Sirohi[1]

Introduction

Increasing milk production has been one of the major goals of India's livestock development policy. In order to achieve this, emphasis has been laid on improving the productivity of low-yielding Indian cattle by crossbreeding them with exotic breeds. Although isolated cases of crossbreeding have been known in India for long (Amble and Jain 1969), systematic research on it started during the mid-1960s. Several crossbreeding projects — Indo-German in Himachal Pradesh, Indo-Swiss in Kerala and Punjab, Indo-Danish in Karnataka, Indo-Australian in Haryana and Assam, and Indo-New Zealand in Tamil Nadu — were initiated under bilateral collaborations. An All India Co-ordinated Research Project on crossbreeding of cattle was launched by ICAR with research units located in different agroclimatic regions of the country.

Significant technological advances have been made in breed improvement. However, their adoption in the field has been limited and regionally concentrated even though micro-level evidence rarely disputes their technical and economic performance (Bhat et al. 1978; Bhatnagar et al. 1976; Katpatal 1977; Nair 1974; Puri 1963; Kumar and Gupta 1988; Sharma and Singh 1994; Khemchand 1998). This paper assesses the performance of crossbreeding technology in a macro framework, focusing on its adoption across regions and farms, and its impact on milk production. It also attempts to identify the factors that could accelerate the pace of technology adoption.

Sirohi, S. 2005. Assessment of crossbreeding technology in India: a macro perspective. Pages 217-228 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Dairy Research Institute, Karnal, Haryana, India.

Data

The study is based on secondary data collected from various published and unpublished sources. The adoption of crossbreeding in 17 major states was studied using Livestock Census data for 1982 and 1992. Although information was also available for the year 1987, it was not included in the analysis since it was a year of severe drought in many parts of the country. State- and district-level data was adjusted for discrepancies in enumeration timing and incomplete coverage in order to maintain comparability across regions. Data on ownership of milch animals across landholding categories was from NSSO's decennial Land and Livestock Holding Survey.

Official estimates of state-level cow and buffalo milk production in 1972 and 1992 have been used to study sources of growth in milk production and the impact of crossbreeding on milk production. The year 1972 was chosen as the base year since it was during that year that the entire milk production could be attributed to local cows in all the states.

Information on the productivity of indigenous cattle in 1992 and infrastructure related to dairy development, such as amount of semen, artificial insemination, veterinary healthcare centers, dairy co-operatives, etc., was taken from the *Basic Animal Husbandry Statistics* published by the Department of Animal Husbandry and Dairying, Ministry of Agriculture, Government of India, New Delhi.

Adoption of Crossbreeding Technology

Regional Pattern of Adoption

After three decades of research and extension, by 1982 only about 5% of the breedable zebu cattle could be hybridized in India (Table 1). However, the extent of technology diffusion varied considerably across states. The proportion of crossbred cattle in milch cattle ranged from a minuscule 0.27% in Rajasthan to 48% in Kerala. Punjab ranked second in transforming local cattle into crossbred ones (37%), followed by Haryana (13%), Tamil Nadu (10%), and Uttar Pradesh (9%). On the other hand, in Rajasthan, Madhya Pradesh, and Gujarat, the percentage of crossbred cattle was less than one till 1982.

During the subsequent decade (1982-92) at the all-India level, rapid growth in adult crossbred females (compound annual growth rate: 6.30%) and a marginal decline in breedable indigenous cows (annual growth rate: -0.02%) led to a doubling (9.8%) of the share of the former in total milch cattle population in 1992. In a majority of the states too, the population of breedable cattle increased significantly. It was interesting to observe that in all the states except Uttar Pradesh and Bihar, the share of crossbreds increased not only in milch cattle population but also in total milch bovines, due to their quicker growth compared to buffaloes.

Table 1. Adoption (%) of crossbreeding across states: select indicators.

	Share of crossbred cows in milch cattle stock		Share of crossbred cows in milch bovines		Growth rate of population (1982-92)		Share of states in the increase in crossbreds during 1981-92	
States	1982	1992	1982	1992	Cross-bred	Indige-nous	Buffalo	Cows
Andhra Pradesh	1.17	7.64	0.59	2.80	14.22	-5.12	0.92	5.34
Assam	2.78	4.46	2.55	4.07	7.94	3.03	3.70	2.41
Bihar	1.22	1.21	0.82	0.82	1.96	2.02	2.00	0.41
Gujarat	0.82	5.96	0.35	2.40	21.72	0.23	1.94	3.79
Haryana	12.71	22.73	3.88	5.47	5.52	-1.31	2.98	2.38
Himachal Pradesh	6.93	16.97	4.34	10.32	9.38	-0.65	1.15	2.58
Jammu & Kashmir	6.56	25.31	4.74	17.86	16.67	0.42	3.37	7.24
Karnataka	5.88	7.14	3.93	4.47	1.47	-0.51	1.39	1.35
Kerala	48.08	52.28	44.05	49.16	2.11	0.49	-2.14	6.13
Madhya Pradesh	0.30	1.03	0.22	0.73	12.85	0.30	2.14	2.20
Maharashtra	3.97	15.54	2.76	10.00	15.05	-0.19	3.29	23.82
Orissa	2.05	5.94	1.88	5.39	10.45	-0.57	0.80	5.56
Punjab	36.64	61.86	9.28	15.34	7.79	-2.29	2.83	13.70
Rajasthan	0.27	0.99	0.17	0.52	11.57	-1.50	2.68	1.06
Tamil Nadu	10.26	20.36	6.87	13.65	5.89	-1.92	-0.82	10.16
Uttar Pradesh	8.79	9.28	4.01	3.81	0.95	0.38	2.22	2.09
West Bengal	4.98	6.36	4.76	6.12	5.16	2.59	1.31	5.34
India	5.39	9.79	3.41	5.81	6.30	-0.02	2.01	—

During the 1980s, crossbreeding spread rapidly in Gujarat and Jammu & Kashmir, which saw a fivefold increase in the number of crossbred females between 1982 and 1992. Maharashtra, Madhya Pradesh, Rajasthan, Orissa, and Himachal Pradesh too registered high rates of growth in breedable crossbreds. However, despite high growth rates in Rajasthan and Madhya Pradesh, adoption of crossbreeding technology continues to be very low; only about 1% of the female cattle population is crossbred.

The share of states in the increase in crossbred cows between 1982 and 1992 reveals the extent of the concentration of change across states. Maharashtra, Punjab, and Tamil Nadu together accounted for nearly half (47.68%) of the total increase in crossbred milch cattle in India. Maharashtra's share alone was as high as 23.82%. In contrast, the share of a majority of the states was below 5%.

An investigation into the pattern of adoption of crossbreeding technology at the district level (Figure 1) will reveal that in 1992, crossbred cows comprised half or more than half of the milch cattle stock in only 5% of the districts, most of which were in Punjab and Kerala. At the state level, the maximum proportion of crossbred females was found in Punjab and at the district level, in Jalandhar (88%).

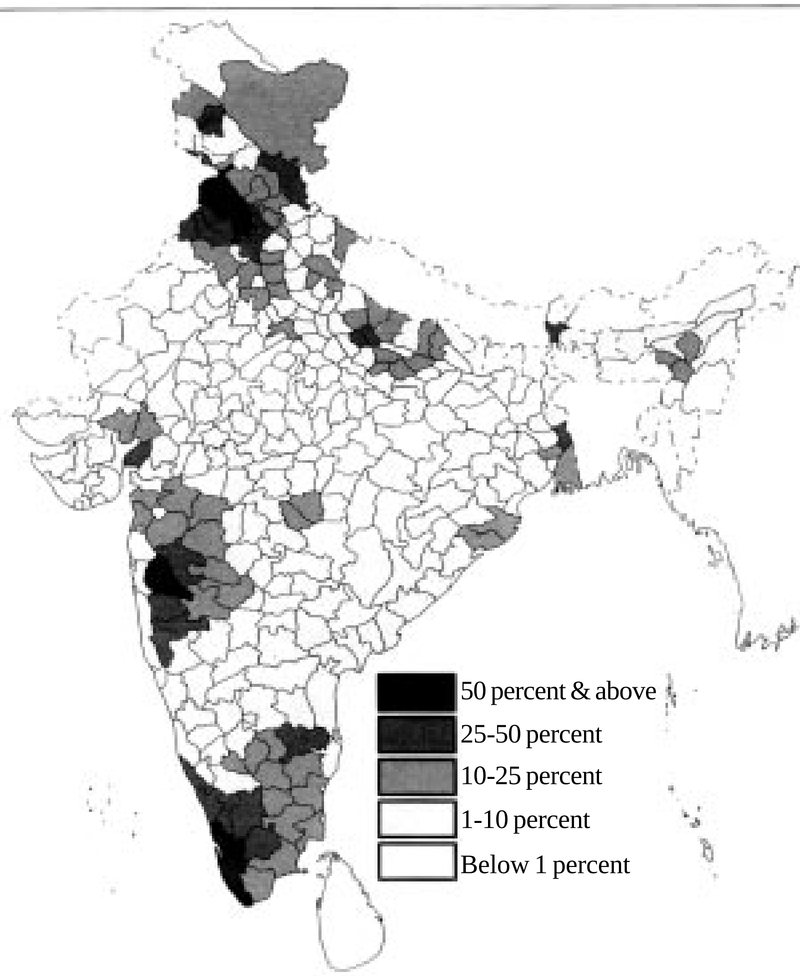
In 68.69% of the districts, not even 10% of the female cattle population is crossbred. In fact, in about 21% of the districts, largely from the states of Rajasthan, Madhya Pradesh, Bihar, and Gujarat, the proportion of crossbred cows is less than even 1%. The proportion ranged from 25 to 50 % in three regions — northwestern India, inland western Maharashtra, and southern India. Districts falling in the 10-25% range were also largely around these areas. However, some of them were also from central Uttar Pradesh, southern Bengal, Assam hills, coastal Orissa, and northeastern Gujarat.

It may be noted that northeastern Gujarat, where the Anand pattern of dairying originated, has more indigenous female cows than crossbred cows. Interestingly, the phrase Anand pattern is associated with recommendations on crossbred cows in policy documents. Even though Operation Flood resulted in an increasing acceptance of crossbred cows, indigenous cows and buffaloes continue to dominate the milch stock in Kaira district, of which Anand is a tehsil.

Farm Size

An analysis of the variation in adoption across households, categorized according to the size of the operational holding (Table 2) shows that the proportion

Figure 1. Share of cross bred cows in milch cattle population at the district level, 1992.



Share of cross breds in milch cattle	Percentage distribution of districts
50% & above	5.11%
25-50%	8.63%
10-25%	17.75%
1-10%	47.60%
Below 1%	21.09%

of crossbreds was highest in the milch cattle stock of the landless (22%) and marginal (19.25%) farm households. Medium and large households owned a relatively lower percentage of crossbred cattle (13.85 and 13.41%, respectively). This suggests that crossbred cows are not exclusively owned by the upper strata of farm households. Similarly, statistics on interfarm size across states broadly indicate the absence of size bias in the adoption of crossbreeding technology.

However, it is surprising how landless or marginal farmers who can barely maintain their families, could afford to support crossbred cows, which require better feeding and management. Why was there a relatively lower adoption of crossbreeding technology on larger holdings where financial/feed resources were presumably not a constraint? Such issues need further probing through extensive surveys.

Table 2. Proportion (%) of crossbred females in total milch cattle across farm sizes, 1992.

	Farm size categories				
States	**Landless (<0.2 ha)**	**Marginal (0.2-1.0 ha)**	**Small (1.0-2.0 ha)**	**Medium (2.0-4.0 ha)**	**Large (> 4.0 ha)**
Andhra Pradesh	0.00	12.50	11.11	11.90	19.34
Assam	59.26	27.91	24.55	11.01	20.08
Bihar	36.08	20.06	15.91	16.22	14.28
Gujarat	0.00	18.07	11.11	14.89	6.07
Haryana	0.00	7.56	43.24	18.37	13.51
Himachal Pradesh	28.47	31.54	32.41	33.33	30.71
Jammu & Kashmir	0.00	29.31	15.89	29.52	21.11
Karnataka	34.83	14.10	15.52	23.44	12.06
Kerala	22.22	61.95	71.43	68.29	64.20
Madhya Pradesh	23.71	8.32	5.68	7.58	12.42
Maharashtra	6.07	21.73	18.18	19.05	16.65
Orissa	27.80	11.70	4.81	15.00	13.59
Punjab	61.90	31.93	49.15	36.54	55.17
Rajasthan	0.00	6.33	11.34	9.09	1.55
Tamil Nadu	0.00	31.24	27.66	30.56	35.82
Uttar Pradesh	23.64	8.82	9.76	15.56	15.33
West Bengal	39.77	19.91	15.05	16.44	23.18
India	22.13	19.25	13.90	13.85	13.41

Gains from Crossbreeding: Impact on Milk Production

Bovine milk production in India was 205,83 thousand tons in 1972. It increased by two and a half times to 55,382 thousand tons in 1992, registering a growth rate of 5.07% per year (Table 3). The rate of increase in cow milk production (6.36%) was higher than that of buffalo milk (4.25%). Similarly, in 12 of the 17 major states in the country, the growth of cow milk was substantially higher. In three states — Andhra Pradesh, Madhya Pradesh, and Orissa — milk production of both the bovine species increased at roughly same rates.

Taking a cue from a study by Dhas (1990), reasons for growth in milk production during 1972-92 was split into population effect, productivity effect, and interaction effect. The results show that at the all-India level, the maximum increase in milk production (28.63%) occurred due to increase in yield of cattle (Table 3). The contribution of increased population was only about 9% in the case of cows, primarily because the increase in the population of in-milk crossbred cows was accompanied by a decline in the population of in-milk indigenous cows.

In Assam, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, and West Bengal, productivity was the dominant factor in the growth of cow milk. Its contribution ranged from 28 to 50%. The number of crossbred cattle increased, while that of indigenous cattle declined or remained stagnant everywhere during 1982-92, except West Bengal. However, in Andhra Pradesh, Gujarat, Haryana, Orissa, Punjab, and Rajasthan, where similar trends were observed in the population of crossbred and local cattle, productivity was not the major source of growth in milk production. Instead, it was the population of cows in Orissa, and increase in the population of buffaloes in other states that drove the growth. These results coupled with the decline in indigenous cattle and increase in crossbred cattle during 1982-92, seem to suggest that crossbreeding technology has made an impact on milk production in a number of states. However, it needs to be emphasized that although the population of local cattle has declined over time, there has been an improvement in their productivity, as is indicated by the positive growth rate of the average daily yield of in-milk local cattle (Table 3). Except in Orissa, the yield from local cattle increased, and in most of the states this increase was at a modest rate of over 3% per year. It would therefore be erroneous to attribute only productivity effect to crossbreeding technology.

Table 3. Growth in milk production (%), sources of growth, and estimated contribution of crossbred cows to milk production.

States	Growth rate of milk production (1972-92)			Reasons for change in milk production between 1972-92						Estimated growth	
				Productivity effect		Population effect		Interaction effect		in milk yield of local cattle (1972-92)	gain in milk production in 1992 due to cross-
	Bovine	Cow	Buffalo	Cow	Buffalo	Cow	Buffalo	Cow	Buffalo	(%)	breeding
Andhra Pradesh	5.26	5.34	5.23	26.62	24.65	0.75	28.98	1.28	17.73	3.41	8.32
Assam	7.65	8.19	5.19	39.56	1.82	18.12	7.47	30.94	2.09	5.02	1.50
Bihar	2.62	3.28	2.11	14.26	14.29	32.89	26.45	7.76	4.34	0.13	8.17
Gujarat	3.76	4.87	3.29	18.95	0.27	11.14	60.74	8.65	0.25	2.51	2.92
Haryana	4.55	3.73	4.75	13.01	20.62	1.67	45.97	1.45	17.28	2.84	1.22
Himachal Pradesh	4.12	5.02	3.49	28.30	15.26	11.56	26.14	10.75	7.98	2.46	9.31
Jammu & Kashmir	6.81	8.00	5.30	30.63	10.18	13.57	14.70	22.73	8.19	2.98	22.82
Karnataka	6.37	7.08	5.65	35.19	29.08	7.63	6.08	13.86	8.16	3.74	15.16
Kerala	9.86	10.84	3.20	49.78	4.36	10.37	-0.46	36.47	-0.53	3.34	56.54
Madhya Pradesh	7.19	7.32	7.07	28.98	22.08	5.64	14.71	11.11	17.49	4.99	5.09
Maharashtra	6.52	10.26	4.23	37.46	6.29	5.39	25.75	19.56	5.56	4.91	24.82
Orissa	2.59	2.67	2.27	12.05	4.95	63.89	10.90	6.47	1.74	-1.33	25.96
Punjab	4.90	7.09	4.28	23.08	13.10	3.19	43.04	6.57	11.02	2.82	12.32
Rajasthan	2.86	2.38	3.25	33.46	-4.05	2.38	71.02	1.29	-4.10	1.49	5.55
Tamil Nadu	6.89	7.73	5.85	39.79	24.59	7.37	5.10	15.96	7.19	4.34	17.05
Uttar Pradesh	4.39	5.62	3.96	22.68	14.29	4.72	41.50	6.30	10.51	3.74	3.32
West Bengal	9.91	10.82	4.64	40.79	2.87	13.52	1.71	39.87	1.24	5.93	19.05
India	5.07	6.36	4.25	28.63	13.26	8.71	27.70	12.24	9.47	3.15	10.93

For isolating the impact of crossbreeding on milk production, estimates of milk production in 1992 have been generated on the assumption that none of the in-milk cattle in the country had been hybridized in 1992. The difference between the cow milk production thus estimated and the reported actual cow milk production in 1992, gives the magnitude of increase in milk production from crossbred animals, i.e.

$CBCM = CM^R - CM^E$

$CM^E = (IMIC^R + IMIC^E) \times YIC^R \times 365$

$IMIC^E = MCBC^R \times (IMIC^R/MIC^R)$

where, CBCM is increase in milk production exclusively due to crossbred cattle,
CM^R is actual cow milk production in 1992,
CM^E is estimated cow milk production,
$IMIC^R$ is number of in-milk indigenous cattle according to 1992 census,
$IMIC^E$ is the estimated number of in-milk indigenous cattle if no crossbreeding was undertaken
YIC^R is average daily milk yield of local cattle in 1992
$MCBC^R$ is number of milch crossbred cattle in 1992, and
MIC^R is number of milch indigenous cattle in 1992.

Estimates of crossbred milk production arrived at in this manner indicate that milk production in India would have been 6053.35 thousand tons lower in 1992 in the absence of crossbreeding. In other words, crossbred cattle have contributed about 11% to milk production in the country. However, there is considerable inter-state variation in the technology's contribution to milk production. The impact of crossbreeding on milk production was found to be maximum in Kerala, where milk production would have been less than half of its present level in the absence of this technology. Interestingly, data indicates that even in the agriculturally backward state of Orissa substantial gains in milk production were achieved through crossbreeding. The other two states which gained substantially from crossbreeding were Maharashtra with a contribution of 25% and Jammu & Kashmir with 23%. The technology's contribution in West Bengal, Tamil Nadu, Karnataka, and Punjab ranged between 12 and 20%. In the remaining states, less than 10% of growth in milk production could be attributed to crossbreeding. In fact, in Assam, Haryana, Gujarat, and Uttar Pradesh the contribution was less than 4%.

It is imperative to emphasize here that the gains from the improved genetic potential of crossbred cows (i.e. pure breed effect) were much lower than the total gains reported here. The adoption of crossbred animals was accompanied by an improvement in input use, especially feed and fodder, since their full genetic potential can only be realized with a concentrate-based feeding system. Field evidence (Kumar and Singh 1980; Lalwani 1989; Gaddi and Kunal 1996; Dixit 1999) indicates that of the total increase in milk production resulting from the adoption of crossbred cow, the pure breed effect ranged from 25 to 40%; the remaining increase was attributed to the use of better inputs and the interaction of input and breed effects.

Correlates of Crossbreeding

Adoption of crossbreeding technology started picking up during the 1980s, and the gains from it have not been very remarkable in most parts of the country. A number of constraints in the adoption and transfer of the technology at the field level have been responsible for its unimpressive performance in India. Several micro-level studies have reported lack of adequate breeding and health infrastructure as potential constraints (Balasubramanium and Knight 1982; Sharma 1980; Sohal 1985). Empirical evidence at the macro level emphasizes the role of infrastructure in adoption. The percentage share of crossbred cows in total milch cattle was positively and significantly correlated with density of semen banks, semen producing centers and liquid nitrogen plants (r = 0.87), artificial insemination centers (r = 0.67), and veterinary institutions (r = 0.55).

The importance of an efficient milk marketing network in motivating farmers to increase milk production by adopting more crossbred cattle is reflected in the positive correlation between the density of working dairy co-operative societies and the proportion of crossbred cows across the states (r = 0.74). Another important factor which was seen to constrain the adoption of crossbred cows was the prejudice against the draught capacity of crossbred male progeny. Therefore, in regions where the dependence on draught animals for field operations continues, crossbreeding cannot take-off effectively till mechanization reduces the requirement of draught animals. This is substantiated by the positive correlation between the mechanization index and percentage of hybridized zebu cattle (r = 0.60).

One of the most important reasons for the slow adoption of crossbreeding technology is the quantitative and qualitative inadequacy of feed fodder. In 1991, feed fodder deficit was 47.1% for concentrates, 40.4% for dry fodder, and

24.7% for green fodder (Ranjhan 1994). Therefore, crossbred cows were unable to express their full genetic potential of milk production on low nutrition.

Conclusions

After about three decades of research on crossbreeding, its impact on the structure of the cattle population and milk production has been slow and regionally skewed. Strengthening the requisite infrastructure and extension services can stimulate adoption of crossbred cattle. However, unless adequate quantities of quality feed and fodder are made available, returns to investment in the research and dissemination of crossbreeding technology would be far from remunerative. Therefore, instead of adopting a blanket strategy of crossing zebu cattle with exotic sires to increase milk production, there is an urgent need to incorporate the much desired but consistently missing regional dimension in dairy development strategy.

References

Amble, V.N. and **Jain, J.P.** 1969. Review of crossbreeding work in cattle in India. *Seminar on Animal Breeding,* 7-9 Dec 1966, Haringhatta, Calcutta. New Delhi, India: Indian Council of Agricultural Research.

Balasubramanium, R. and **Knight, J.** 1982. Bottlenecks in modern dairying. *Indian Journal of Extension Education* 18 (1&2):102-105.

Bhatnagar, D.S., Sharma, R.C. and **Sundresan, D.** 1976. Crossbreeding of cattle for increased milk production. National Dairy Research Institute, Karnal Extension. Press Bulletin Pub. No. 143. 18pp.

Bhat, P.N., Taneja, V.K. and **Garg, R.C.** 1978. Effects of crossbreeding on reproduction and production traits. *Indian Journal of Animal Sciences* 48 (2):71-78.

Dhas, A.C. 1990. Structure of milk production in Tamil Nadu: An analysis of trends and sources of growth. Pages 196-226 *in Resources, institutions and strategies: Operation flood and Indian dairying* (Doornbos, M. and Nair, K.N., eds.). Indo-Dutch studies on development alternatives No.4. New Delhi, India: Sage Publications Pvt Ltd.

Dixit, P.K. 1999. *Bovine economy of Mandya district in Karnataka: A sustainability-oriented analysis*. Ph.D. Thesis, NDRI (Deemed University), Karnal, Haryana. 178 pp.

Gaddi, G.M. and **Kunal, L.B.** 1996. Sources of output growth in new milk production technology and some implications to returns on research investment. *Indian Journal of Agricultural Economics* 51(3): 389-395.

Katpatal, B.G. 1977. Dairy cattle crossbreeding in India. *World Animal Review* 22:15-21.

Khemchand. 1998. *Economic analysis of commercial dairy herds in Bikaner (Rajasthan)*. Ph.D. Thesis, NDRI (Deemed University), Karnal, Haryana. 100 pp.

Kumar, P. and **Gupta, J.N.** 1988. Comparative cost of milk production from different species of milch animals. *Indian Journal of Dairy Science* 41(4):411.

Kumar, P. and **Singh, R.P.** 1980. Dynamic feed-milk relationship and technical change in milk production. *Indian Journal of Agricultural Economics* 35 (3):126-132.

Lalwani, M. 1989. Technological change in Indian dairy farming sector: Distribution and decomposition of output gains. *Indian Journal of Agricultural Economics* 44(1):55-56.

Nair, P.N.R. 1974. Cattle improvement through crossbreeding. Paper presented at the *XIXth International Dairy Congress*, 2-6 Dec 1974, New Delhi.

Puri, T.R. 1963. Economics of cost of milk production. *Indian Journal of Agricultural Economics* 18(2):42.

Ranjhan, S.K. 1994. *Consultant's report on the availability and requirement of feed and fodder for livestock and poultry*. Ministry of Agriculture, Government of India, New Delhi. Department of Animal Husbandry & Dairying.

Sharma, R.K. 1980. *A study of socio-psychological and infrastructural constraints in the efficient execution of ICDP*. Ph.D. Thesis, Kurukshetra University, Kurukshetra.

Sharma, V.P. and **Singh, R.V.** 1994. An economic analysis of milk production by different breeds of milch animals in humid-temperate zone of Himachal Pradesh. *Indian Journal of Dairy Science* 47(9):749-755.

Sohal, T.S. 1985. Constraints in transfer of technologies. Pages 69-72 *in Transferable technologies for enhancing milk production* (Kherde, R.L. and Rao, S.V.N., eds.). NDRI Publication No. 217.

20

Meat Production and Productivity Trends: Some Issues for Research and Development

P S Birthal and A Ravishankar[1]

Introduction

The role of animals as a source of food is well documented. They provide milk, meat and eggs that are rich in proteins and energy. Among these, milk occupies a prominent place in the diet of the majority of Indians. The consumption of meat is inhibited by sociocultural and religious factors; moreover, its demand is constrained by its high price and the low income of a majority of the population. Even among the high-income population, meat often does not constitute the regular diet.

With rising per capita incomes, urbanization and changing lifestyles, food habits are gradually veering towards meat and eggs. Demand for meat and meat products is income elastic and has been rising continuously (Kumar 1998). This has fostered rapid growth in meat production in the country in recent decades. Since 1970, total meat production has been growing at about 4.6% per year. Production of beef, buffalo meat, and chevon has witnessed faster growth. Future growth in demand is likely to be greater, and it is believed that if these production trends are sustained, domestic supplies can adequately meet the demand for meat (Kumar 1998).

Birthal, P.S. and **Ravishankar, A.** 2005. Meat production and productivity trends: some issues for research and development.Pages 229-240 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

Indian livestock produces less meat compared to the world average. For instance, beef and pork yields are about half that of the world average. Mutton and chevon yields are about 25% less. The situation is worse compared to developed countries such as the USA, UK, Canada, and Germany. However, yields are better in neighboring Pakistan. This indicates the considerable scope of raising meat productivity in India.

Conditions of production and the state of technology determine productivity growth. The current production environment in India has several constraints — feed and fodder scarcity have been major limiting factors in addition to the deteriorating common grazing resources.

This paper examines meat production and productivity trends, and derives some implications for research and development.

Data and Method

Information was compiled from reports of the Integrated Sample Surveys for Estimation of Milk, Egg, Meat and Wool conducted by the Directorate of Animal Husbandry and Veterinary Services, Government of Karnataka. Information from the Livestock Censuses conducted by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi, has also been used.

Growth rates in output and yield have been estimated using the semi-log form of production function. The contribution of yield to output growth has been calculated as the ratio of yield growth to output growth. To ascertain changes in growth over time, the entire period was divided into two sub-periods: 1975-76 to 1986-87 and 1987-88 to 1995-96. The demarcation was because of the sudden spurt in certain livestock outputs after 1986-87.

Population Dynamics

According to the 1992 Livestock Census, Karnataka accounts for 6.4% of the country's cattle, 5.1% of buffaloes, 10.9% of sheep, 5.4% of goats, 3% of pigs and 5.3% of poultry. Population trends of different species are given in Table 1.

The livestock production system in Karnataka is predominantly cattle-based. Indigenous stock accounts for more than 90% of the total cattle stock because of its dual role as milk producer and supplier of draught power. Between 1972 and 1992, cattle population increased from 101to132 lakhs at an annual rate of 1.31%. Growth slowed down during 1972-82. Further, the male cattle population increased at a slower rate compared to the female population.

Buffalo is the other species raised primarily for milk. The buffalo population has been growing steadily — from 32.7 lakhs in 1972 to 42.4 lakhs in 1992, at an annual rate of 1.31%. The highest growth was recorded during 1982-92. The sex ratio has remained adverse to males since it is not an efficient source of

Table 1. Trends in livestock population in Karnataka, 1972-1992.

	Population (in lakhs)			Annual compound growth rate (%)		
Species	**1972**	**1982**	**1992**	**1972-82**	**1982-92**	**1972-92**
Cattle	101.5	113.0	131.6	1.10	1.54	1.31
Indigenous	101.5	107.5	125.4	0.58	1.55	1.06
Male	50.9	52.7	61.5	0.36	1.56	0.95
Female	50.6	54.0	63.9	0.64	1.70	1.17
Sex ratio	1004	976	962	-	-	-
Crossbred	Na[1]	5.5	6.2	-	1.21	-
Male	Na	1.3	1.5	-	1.44	-
Female	Na	4.2	4.7	-	1.13	-
Sex ratio	Na	310	319	-	-	-
Buffalo	32.7	36.4	42.4	1.08	1.54	1.31
Male	7.2	6.3	7.4	-1.29	1.62	0.15
Female	25.5	30.1	35.0	1.68	1.52	1.60
Sex ratio	282	209	211	-	-	-
Sheep	46.6	48.0	54.3	0.29	1.24	0.77
Indigenous	46.6	46.7	52.8	0.02	1.24	0.63
Crossbred	Na	1.3	1.5	-	1.44	-
Goat	37.3	45.5	62.9	2.09	3.29	2.62
Pigs	2.6	3.2	3.8	2.10	1.73	1.92
Indigenous	2.6	2.9	3.4	1.10	1.60	1.35
Crossbred	Na	0.3	0.4	-	2.92	-
Poultry	101.6	121.0	157.3	1.76	2.66	2.21

[1] Na= not applicable.

Source: Computed from data in *Livestock Censuses*.

draught power compared to male cattle. The male population increased at a rate of just 0.15% per year. The annual growth rate has however been erratic. Between 1972-82, it declined to 1.29% a year, with a considerable recovery during 1982-92.

Goats are mainly valued for their meat while sheep are reared for both meat and wool. Crossbred sheep comprise about 3% of the total sheep population. During 1972-92, the sheep population increased steadily at a rate of 0.77% per year. The pattern of increase has not been steady. Total population increased by 0.29% during 1972-82, while that of the crossbred population increased faster than that of its indigenous counterpart in subsequent years. The goat population has grown rapidly between 1972 and 1992 (annual rate of 2.62%), most of it during 1982-92.

Pigs are raised for their meat mainly by the socially and economically backward sections of society. Pig rearing is not a popular enterprise in Karnataka. The system of production is limited to scavenging, with hardly any inputs. The state's pig population has been hovering between 3 and 4 lakhs over the past two decades. Crossbreds account for 10% of the total population.

Poultry is raised under both traditional and intensive systems of production. Traditional backyard poultry is predominant in rural areas. Data from the Integrated Sample Survey, 1995-96, indicates that only about 5% of the poultry units in the state have more than 20 birds. Between 1972 and 1992, the poultry population grew at a rate of 2.21% a year. The rate of increase was however higher during1982-92. The share of improved poultry is low; in 1992 it accounted for 18% of the state's total poultry population.

Meat Production and Productivity

ProductionTrends

Small ruminants contribute more than 70% of the total meat production in the state of Karnataka (Table 2), with sheep being the dominant contributor. Of the 6.4 lakh tons of meat produced in the state during the triennium ending 1995-96, sheep contributed 40%, cattle 13% and buffalo 11%.

Over time, wide fluctuations have been observed in the contribution of different species to meat output. The share of cattle, buffaloes and pigs declined between TE 1980-81 and TE 1986-87, but increased during the succeeding period. On the other hand, the share of goat increased from 28% in TE 1980-81

Table 2. Trends in meat production in Karnataka, 1978-96.

Year/period	Cattle	Buffalo	Sheep	Goat	Pig	Total
			Meat output (t)			
TE 1980-81	2002	1516	5374	3552	469	12913
	(15.50[1])	(11.74)	(41.62)	(27.51)	(3.63)	
TE 1986-87	2832	1843	13342	13019	679	31715
	(8.93)	(5.81)	(42.07)	(41.05)	(2.14)	
TE 1995-96	8389	7312	25634	19844	3175	64355
	(13.04)	(11.36)	(39.83)	(30.84)	(4.93)	
			Annual growth (%)			
1978-79 to 1986-87	5.27	2.20	16.03	22.99	7.17	15.36
1987-88 to 1995-96	4.64	9.74	2.64	3.09	11.11	4.06
1978-79 to 1995-96	4.95	5.97	9.33	13.04	9.14	9.17

[1.] Figures in parentheses are percentages of total.

Source: *Integrated Sample Survey Reports.*

to 41% in TE 1986-87, and dropped to 31% in TE 1995-96. However, sheep has consistently maintained its share of about 40%.

Meat production increased drastically in 1987-88, and this trend continued. The increase was mainly on account of drought conditions that forced livestock owners to dispense with nonproductive and unwanted stock . The trend continued even after 1986-87 due to increases in the internal and external demand for different types of meat. Meat demand is highly income elastic; as per capita income increases, the consumption pattern of the masses undergoes a distinct shift. Once social/consumption taboos are broken, they have a propensity to persist, the post-1987-88 trend in meat production being an indicator.

The export demand for meat has grown in recent years. Between 1987-88 and 1995-96, meat exports increased by 188%, with variations depending on the type of meat exported. Data reveals a negative trend in sheep and goat meat exports during 1984-89, which was subsequently reversed. The export of mutton is constrained by its high domestic demand. The export of bovine meat increased sharply in 1987-88 and thereafter maintained a sustained rise mainly due to its competitiveness. A favorable trade policy regime during 1995-96 helped sustain growth in meat production.

Since 1978, total annual meat output has been growing at a rate of 9%, with substantial variations in the growth of different species. Between 1978 and 1996, goat and sheep meat production grew at an annual rate of 13% and 9%, respectively (Table 2). Cattle meat output grew at an annual rate of 5% and that of buffalo meat at 6%.

Growth in meat production started tapering off after 1986-87. It decelerated from 15% to 4%. However, this was not applicable to all species. Sheep and goat meat production decelerated sharply, while there was a marginal decline in the growth of cattle meat output. On the other hand, buffalo and pig meat output grew at an accelerated rate during the latter period, which was largely export-led.

Trends in Animal Slaughter

During TE 1980-81, an average of about 0.23 lakh cattle, 0.17 lakh buffaloes, 4.95 lakh sheep, 3.2 lakh goats and 0.11 lakh pigs were slaughtered (Table 3). The number of animals slaughtered increased substantially during TE 1995-96. In fact, there was a quantum jump after TE 1986-87. The rate at which sheep were slaughtered increased from about 11% during TE 1980-81 to 37% during TE 1995-96. The corresponding figures for goat were estimated to be 9% and 54%. This phenomenon which continued thereafter, was triggered off by a drought in 1987-88.

The total number of animals slaughtered in Karnataka increased at a rate of 10.4% per year (Table 3). Goat, sheep and pig slaughter however increased more rapidly compared to large animals. It may be noted that for most species, growth rates in slaughtering are comparable to growth rates in their outputs.

The growth rate in animal slaughter varied substantially over time. Growth in sheep and goat slaughter decelerated sharply while it almost doubled in the case of pigs. Growth in buffalo slaughter too accelerated. On the other hand, growth in cattle slaughter declined marginally. The current slaughter rates of sheep and goat are almost equivalent to their potential. There is considerable scope to raise the slaughter rates of buffaloes, pigs and cattle. The slaughter rate of both cattle and buffaloes in the state has never exceeded 2%. In many Indian states including Karnataka, cattle slaughter is banned on account of sociocultural and religious sentiments. However, buffalo slaughter is not subject to restrictions, yet the slaughter rate is low.

Table 3. Growth in the number of animals slaughtered in Karnataka, 1978-96.

Year/period	Cattle	Buffalo	Sheep	Goat	Pig	Total
			Number of animals slaughtered (lakhs)			
TE 1980-81	0.23	0.17	4.95	3.20	0.11	8.66
	(0.21[1])	(0.49)	(10.81)	(8.80)	(3.58)	
TE 1986-87	0.35	0.21	12.34	10.65	0.14	23.69
	(0.33)	(0.54)	(24.50)	(24.95)	(4.95)	
TE 1995-96	0.98	0.78	20.45	16.00	0.63	38.84
	(1.14)	(1.70)	(36.69)	(53.96)	(27.04)	
			Annual growth (%)			
1978-79 to 1986-87	6.54	3.49	16.34	20.95	5.25	17.69
1987-88 to 1995-96	4.30	9.26	2.74	2.84	10.94	3.03
1978-79 to 1995-96	5.42	6.37	9.54	11.90	8.09	10.36

[1] Figures in parentheses are percentages of animals slaughtered.

Source: *Integrated Sample Survey Reports.*

Trends in Meat Yield

The meat sector's performance has been dismal in terms of productivity. Meat yields of almost all species have been stagnant (Table 4). There was a decline in the annual meat yield from cattle and buffaloes. However, the trend has not been uniform. During 1978-87, meat yield from cattle showed a decline but improved in the subsequent period, and turned out to be positive at the margin. Similar was the case with buffalo meat. Sheep meat yield showed a negative trend throughout. In the later period, the rate of decline was partially arrested. Goat meat yield increased at an annual rate of 2% during 1978-87. In the following years (1987-96), it showed a significant downward trend. An identical pattern was observed in the case of pig meat.

Growth in meat production has largely been due to the growth in the number of animals slaughtered (Table 4), especially in the case of large ruminants. In fact, output growth shrunk by 9.5% in cattle and 6.7% in buffaloes due to a decline in productivity. In the subsequent period, meat yields of both species improved and their shares in output growth turned marginally positive.

Yield has contributed negatively to output growth in sheep meat production while it has contributed positively and consistently (about 9%) to output growth of goat meat. The contribution of yield in the case of pig meat was maximum during 1978-87, while there was a sharp decline in 1987-96 on account of the slower growth in yield. The growth during 1978-87 could be partly attributed to the introduction of high meat-yielding crossbred pigs, whose share in the total pig population has not changed much since 1982.

Several socioeconomic factors have been responsible for poor growth in meat yields and their contribution to output growth. Large animals such as buffaloes and cattle are raised for their milk and provide meat as an adjunct. Generally, surplus male buffaloes and nonproductive cattle and buffaloes are used for meat production, and these are of poor quality. Cattle slaughtered are usually old, infertile and malnourished. Buffalo meat production is mainly sourced from the male young stock. This is confirmed by the highly adverse sex ratio of males. In 1992, the sex ratio for adults and young stock was 375 and 136, respectively, indicating that slaughtering young calves is a waste of meat.

Stagnating yields from small ruminants is a matter of concern. Quantitative and qualitative deterioration in common property resources, an extensive system of production and lack of appropriate technology are the major reasons for this. That common property resources in the state have deteriorated is evident from

Table 4. Growth in meat yield and its contribution to output growth in Karnataka, 1978-96.

Year/Period	Cattle	Buffalo	Sheep	Goat	Pig
	Meat output per slaughtered animal (kg)				
TE 1980-81	87.04	89.18	10.86	11.10	42.67
TE 1986-87	80.91	87.76	10.81	12.22	48.52
TE 1995-96	85.60	93.74	12.54	12.40	50.40
	Annual growth (%)				
1978-79 to 1986-87	-1.27	-1.29	-0.31	2.04	1.92
1987-88 to 1995-96	0.34	0.48	-0.10	0.25	0.17
1978-79 to 1995-96	-0.47	-0.40	-0.21	1.14	1.05
	Contribution of yield to output growth (%)				
1978-79 to 1986-87	-24.10	-58.64	-1.93	8.87	26.78
1987-88 to 1995-96	7.33	4.93	-3.79	8.09	1.53
1978-79 to 1995-96	-9.49	-6.70	-225	8.74	11.49

Source: *Integrated Sample Survey Reports*.

a study by Jodha (1991) of 12 villages in Karnataka, which showed that between 1950-51 and 1981-82, community grazing land declined by 40% and the number of watering points by 75%. Simultaneously, grazing pressure on land has been increasing due to increase in livestock population and intensification of agriculture.

The system of production is largely subsistence oriented. Only a small proportion of sheep and goat populations is raised under intensive or semi-intensive systems of production. In this context, it is important to note that unlike in northern and western India, where the small ruminant production system is characterized by nomadism, in southern India it is predominantly sedentary (World Bank 1996). Animals sustain mainly on grazing. The feedlot system is yet to develop.

Research on small ruminants has received relatively less attention in India. Evidence shows that the allocation of research expenditure to them is disproportionately low compared to their contribution to the gross value of livestock output (Jha et al. 1995). Breed improvement efforts to increase body weight have been underway in recent decades. However, their impact is yet to be realised. Paying attention to nutritional and health aspects can increase meat yields of existing stock in the short run. In this context, Devendra and Burns (1983) mention that "improved veterinary care, nutrition and other aspects of husbandry may achieve spectacular gains when first introduced, but sooner or later breeding policy will have to be considered, and the genetic potential of stock assessed." It is worth mentioning here that goat meat yield in Pakistan is about twice that in India, despite both having similar agroclimatic conditions. Though India is rich in animal genetic diversity, its potential is yet to be fully assessed (CIRG 1997; CSWRI 1997).

Determinants of Yield

Irrespective of whether past growth has been driven by numbers or productivity, the latter is crucial to sustain output growth in the long run. Productivity is mainly defined by the animal's genetic constitution. The extent to which the animal's potential is realized depends on factors such as quantity and quality of feed, management, healthcare, etc. Their role in improving the yield of major meat-producing animals such as sheep and goat is examined through a regression analysis of a cross-section of district-level data. Meat yields of sheep and goat are expected to be influenced by three main factors — access to grazing land, climatic conditions (mainly rainfall) and access to animal health facilities. The estimates of regression are presented in Table 5.

Explanatory variables accounted for 86% of the variation in yields of sheep meat. The association between mutton yield and grazing lands was positive and highly significant, underlining the role of common property resources. This has implications for short-run production growth, suggesting that sheep meat yields can be increased through proper management of grazing resources.

Evidence suggests that sheep perform better under arid and semi-arid conditions because of their adaptability to such environments (ICAR 1996). A negative and significant relationship between rainfall and sheep confirms this. Though access to health services had a positive influence on mutton yield, the association was not significant.

Table 5. Linear estimates of determinants of sheep and goat meat yields, 1995-96.

Explanatory variables	Sheep	Goat
Forests, pastures, and grazing lands	0.00034	-0.0000052
(ha 100 ovine^{-1})	(6.10[1])***	(0.14)
Number of veterinary institutions	0.0603	-0.01734
(100 sq km^{-1})	(1.09)	(0.47)
Annual rainfall (mm), 1994-95	-0.00073	-0.000046
	(9.75)***	(0.91)
Constant term	13.05	12.47
Coefficient of determination (R^2)	0.86	0.10
F value	31.94	0.57

[1] Values in parentheses are *t*-values.
*** Significant at 1% level.

On the other hand, goat meat yield was not significantly influenced by any of these variables. Though the availability of grazing lands had a positive and significant influence on meat yield, the coefficient turned out to be negative and nonsignificant. Rainfall had a negative but nonsignificant impact on the performance of goats. This was so because goats are hardier than sheep and can adapt to all types of climates and management conditions (CIRG 1997). Animal health services too did not have any significant influence on goat meat productivity.

Results indicate that arresting the degradation of common property resources would be critical in improving the meat yield of small ruminants. Though common grazing land does not appear to be an important determinant of goat meat yield in the regression model, the role of common property resources should not be undermined. Moreover, support to small ruminant farmers in terms of animal health services, extension, etc., is rather weak. The relationship between animal health services and meat yield bears testimony to this argument.

Conclusions and Implications

Meat production in Karnataka has been growing at an impressive rate of 9% per year, though there has lately been a slowing down of this momentum. The impressive growth has been largely because of the number of animals slaughtered. Meat yield has almost remained stagnant owing to a number of technological, socioeconomic and institutional factors. Nonetheless, yield trends clearly indicate a lack of technological breakthrough and an acute scarcity of feed and fodder.

The stagnating meat yield of small ruminants is a matter of concern since growth via the numbers route does not seem to be a practical option because of their high slaughter rates and the quantitative and qualitative deterioration of their grazing base. Proper management of common grazing lands can help improve yields in the short run. However, in the long run, improvement in productivity has to be technology-driven. Though India has a diverse range of breeds of sheep and goats, their genetic potential is yet to be assessed (CIRG 1997; CSWRI 1997). All this emphasizes the need to accord high priority to research on small ruminants.

Though an alternative would be to effect changes in the structure of meat production in favor of large ruminants, it seems to be an impractical option given the restrictions on cattle slaughter. However, doing away with the restrictions is considered to be Pareto-optimal as it is likely to improve the welfare of both vegetarians and non-vegetarians (Mishra 1995). This option remains unexplored due to sociopolitical and religious reasons. With this in view, Mishra (1995) raised an important question of whether India can benefit from the export of live bovines, if it cannot produce bovine meat for itself.

Unlike cattle, buffaloes are not subjected to a slaughter ban, and their meat production potential remains underutilized. Buffalo is raised for its milk and it is mainly the male young stock that finds its way to slaughterhouses. This is a potential waste of meat production. The prospects of exporting buffalo meat are good because of its competitive price in the world market.

Technology-led growth would necessarily demand more support in terms of extension, breeding, healthcare, etc. Support services to the livestock sector in general and small ruminants in particular, have been pathetic. Many technologies with proven economic viability do not reach farmers in the absence of an effective technology transfer mechanism and support services. The infrastructure for slaughtering and meat processing begs for considerable improvement in order to internalize the benefits of technology and the rising demand for meat and meat products.

References

CIRG (Central Institute for Research on Goats). 1997. *Vision-2020: Perspective Plan*. Makhdoom, Uttar Pradesh: Central Institute of Goat Research. 37 pp.

CSWRI (Central Sheep and Wool Research Institute). 1997. *Vision-2020: Perspective Plan*. Avikanagar, Rajasthan: Central Sheep and Wool Research Institute. 79 pp.

Devendra, C. and **Burns, M.** 1983. *Goat production in the tropics*. Commonwealth Agricultural Bureau, U.K. 183 pp.

ICAR (Indian Council of Agricultural Research). 1996. *Report of the Committee on Economics of Sheep and Goat Production*. New Delhi, India: ICAR.

Jha, D., Kumar, P., Mruthyunjaya, Pal, S., Selvarajan, S. and **Singh, A.** 1995. *Research priorities in Indian agriculture.* Policy Paper 3. New Delhi, India: National Centre for Agricultural Economics and Policy Research. 83 pp.

Jodha, N.S. 1991. *Rural common property resources — A growing crisis*. Gatekeeper Series 24, International Institute for Environment and Development. 35 pp.

Kumar, P. 1998. *Food demand supply projections in India*. Mimeo. New Delhi, India: Indian Agricultural Research Institute. 141 pp.

Mishra, S.N. 1995. India's livestock economy — A perspective on research. *Indian Journal of Agricultural Economics* 50(3): 255-263.

World Bank. 1996. *India livestock sector review: Enhancing growth with development*. Washington D.C., USA: The World Bank.

Potential Benefits of Disease Prevention in Goats

S Kumar, V S Vihan and P R Deoghare[1]

Introduction

The Royal Commission on Agriculture (1928) observed that, "in no sphere has scientific research conferred greater benefit on agriculture than by provision of means of controlling livestock diseases". Incidence of diseases and parasitic infestations are the major constraints to the development of goat enterprise in India. Diseases in goats result in very high mortality, ranging from 5 to 25% in adults and 10 to 40% in kids. In addition, they also cause morbidity losses in terms of low productivity of animals. In order to check mortality and morbidity losses, the Central Institute for Research on Goats in Uttar Pradesh, India, developed a health calendar to prevent diseases. This paper attempts to estimate the economic losses due to mortality that could have been avoided by adopting the suggested disease prevention measures.

Technology

Research efforts in goat health management have led to a technology to prevent common diseases. This has been standardized in the form of an annual goat health calendar (Table 1). Implementing this schedule would help prevent goat diseases under different agroclimatic conditions. A field survey was carried

Kumar, S., Vihan, V.S. and **Deoghare. P.R.** 2005**.** Potential benefits of disease prevention in goats. Pages 241-246 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Central Institute for Research on Goats, Makhdoom, P.O.Farah 281 122, Mathura, Uttar Pradesh, India.

out to ascertain the possible impacts of this technology and estimate the economic losses due to diseases.

Methodology

Data were collected from four villages — Fateha, Pingri, Mahuvan, and Ktirkunda — of Farah block in Mathura district of Uttar Pradesh. A sample of

Table 1. The annual preventive goat health calendar.

Operations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vaccination[1]												
FMD*						+						+
FMD**						+						
ET		+						+				
PPR	+											
HS						+	or +					
Drenching												
Coccidiosis				+			+					
Parasites						+	or+			+		
Dipping												
Lice				+						+		
Ticks												
Watch for												
Ecthyma				+	+						+	
Coccidiosis					+			+		+		
Tapeworm		+		+	+							
Haemonchus										+		
Ticks					+	+	+	+				
Pod toxicity					+	+	+					
Screen for												
Brucellosis				+	+	+					+	+
Johne's disease												+

[1] FMD = Foot and mouth disease; ET = Enterotoxaemia; PPR = *Peste des petits* ruminants; and HS = Haemorrhagic septicaemia.

*Immunity for 6 months; ** Immunity for one year.

61 goat-keeping households was randomly drawn from three categories of households — small (less than 5 goats), medium (5 to 10 goats), and large (more than 10 goats) — on the basis of probability proportional to the size of each category. Data relating to cost and returns, disease incidence, mortality, production losses due to diseases, consumption of goat products, etc, were collected for 1998-99. The general characteristics of the selected households are given in Table 2.

Estimates of losses due to animal deaths were based on the market price of the animals. Estimates of mortality loss in kids were based on the actual cost of rearing the kid; then its value at birth was added to the loss estimated for every kid. Thus, a value of Rs 100-150 was assigned to a kid, depending on its breed.

More than 50% of the goat-keepers were landless and goat rearing was mainly a subsidiary enterprise taken up at subsistence level. The size of the flock maintained was 2.2 in the small, 5.25 in the medium, and 16 in the large enterprise categories.

Economic Losses due to Diseases

In order to estimate economic losses due to diseases and parasitic infestations, disease incidence was observed in farmers' flocks throughout the year. Mortality and production losses due to each disease in adults and kids were ascertained (Table 3). Diseases inflicted heavy losses on poor goat-keepers. Diarrhoea and enterotoxaemia were the major causes of mortality. The mortality rate was as high as 15-33% in kids and 15-31% in adult goats. On an average, the annual loss per farm was Rs 1581 in small enterprises, Rs 2129 in medium enterprises and Rs 5253 in large enterprises. Economic losses due to diseases

Table 2. Characteristics of the goat-keepers.

	Distribution of goat-keepers (mandays)			Labor availability (adult)			Flock size		
Category	Total	Landless	Land owners	Male	Female	Child	Male	Female	Kid
Small	43	23	20	325.50	310.13	140.00	0.16	2.20	2.62
Medium	12	6	6	378.00	349.13	130.38	0.41	5.25	5.64
Large	6	2	4	756.00	217.88	82.00	0.16	16.00	21.32

Table 3. Annual mortality and production losses in goats due to diseases.

Particulars	Small enterprise		Medium enterprise		Large enterprise	
	Adult	Kid	Adult	Kid	Adult	Kid
Causes of mortality[1]						
ET	7	-	9	-	11	-
Diarrhoea	17	21	3	5	-	15
PPR	4	-	-	-	-	-
Overfeeding	-	1	-	-	-	2
FMD	-	-	1	-	-	-
Number of animals that died	46	55	17	32	17	24
Mortality (%)	31.20	32.82	19.94	32.12	14.90	15.80
Value of total dead animals (Rs)	533.50	13260	10100	6350	20000	11300
Mortality losses farm^{-1} (Rs)	1241	308	1592	529	3333	1883
Production loss farm^{-1} (Rs)	12	-	8	-	137	-
Total loss farm^{-1} (Rs)	1253	308	1600	529	3470	1883

[1] ET = Enterotoxaemia; PPR = *Peste des petits* ruminants; and FMD = Foot and mouth disease.

had a direct bearing on the profitability of goat enterprises, which in turn affected the food security of the farm family.

Income

Goat enterprises earned a family labor income of Rs 1972 per year and caused a direct income loss of Rs 1581 due to mortality and morbidity on small enterprises, Rs 7978 and Rs 2129 on medium enterprises, and Rs 17,500 and Rs 5253 on large ones, respectively. This could have been avoided by taking preventive measures.

Food Security

Goats contribute to a family's food security by providing food (milk), and generating employment and income that help assure access to other foods. Families of goat-keepers had access to 0.41- 4.0 liters of goat milk day^{-1} per family from 60 to 150 days a year. Goats are considered living banks to be used to acquire food and fulfil other needs. Diseases in goats had a direct bearing on the food security of goat-keeping families as a result of reduced milk supply and lower income from family labor.

Farm Women

Women, children and old men together contributed 83-92% of labor requirements in goat rearing. Women alone contributed 32-59% to it. This has helped women achieve financial independence. Therefore, any loss of income from goat enterprises will directly affect their financial independence.

Impact at the National Level

India had about 118 million goats in 1994, and nearly 50-60% of them were breedable females. Assuming that 90% of these go for kidding once a year, the total number of kids produced in a year can be estimated at 52-55 million. Assuming an average mortality rate of 20% in the case of kids and 10% in adults (Paliwal et al. 1978; Krishna et al. 1979; Chauhan et al. 1982; Vihan et al. 1986; Chatterjee and Dey 1992), the total mortality would be 10-12 million kids and 5-6 million adult females. Assigning a value of Rs 287 per dead kid and Rs 1000 per dead adult, the total annual loss due to disease mortality would be Rs 8602 million. Had the annual preventive goat health calendar been adopted, losses would have been reduced by about 70%, resulting in enhanced income and food security.

It is well known that the export demand for live animals is much higher compared to that for fresh or frozen meat. However, the export of live goats is impossible without obtaining a certificate stating that "the animals are free from all diseases". At present, it is very difficult to obtain such a certificate since disease incidence is high. Therefore, the answer lies in preventing diseases in order to promote the export of live animals.

Constraints to Adoption

The major constraints to adopting the annual preventive goat health calendar are:

- Farmers' lack of awareness about prophylactic measuresl;
- Nonavailability of vaccines and drugs on time; and
- Poor veterinary services.

Lessons for Future Research

Most of the common diseases in goats could be prevented by using available prophylactic measures. However, intensified research can help control and prevent diseases like PPR, Johne's disease and Brucellosis which are more prevalent in large flocks under intensive management systems. There should also be an emphasis on multidisciplinary research projects to develop package of practices which ensure low disease incidence in goats.

Conclusions

Research efforts in goat health management have been able to generate appropriate technology to prevent and control various diseases. If the annual preventive goat health calendar is adopted by goat farmers, huge economic losses can be avoided. This will raise the income of poor goat-keepers and ensure their food security.

References

Chatterjee, A. and **Dey, B.N.** 1992. Incidence of caprine brucellosis in West Bengal. *Vth International Conference on Goats*, New Delhi, India. 543 pp.

Chauhan, H.V.S., Jha, G.J. and **Singh, P.M.** 1982. Investigation on etiopathology mortality in goats. *Ist National Seminar on Sheep and Goat Diseases*, Avikanagar, India. 147 pp.

Krishna, L., Paliwal, O.P. and **Kulshreshtha, S.B.** 1979. Incidence of pre-natal mortality in lambs and kids. *Indian Veterinary Medicine Journal* 3:19.

Paliwal, O.P., Krishna, L. and **Kulshreshtha, S.B.** 1978. Studies on mortality in lambs and kids: incidence. *Indian Veterinary Medicine Journal* 2:1991.

Vihan, V.S., Saini, A.L. and **Khan, B.U.** 1986. Note on preliminary investigation of mortality in Jamunapari kids. *Indian Medical Journal* 10:166-169.

22

Impact of AICRP on Improvement in Production and Other Economic Traits of Pigs

C B Tiwari and R L Arora[1]

Introduction

Having achieved the goal of food security, the emphasis is now on improving the nutritional status of the population. This can be achieved by increasing the availability of animal products like milk, meat and eggs. According to the FAO, per capita animal protein availability in India is 7.6 g day^{-1} as against the world average of 24.7 g day^{-1}. This is the lowest figure for any Asian country, except Bangladesh. The deficiency in animal protein is next only to the deficiency of fruits in our diet. A good part of this gap can be met through increased supplies of pig and poultry products, as these species are prolific breeders, have short generation intervals, and are efficient feed converts.

Pigs are the only litter-bearing animals among meat-producing livestock having the shortest generation interval and a fast growth rate. Thus, they can play an important role in overcoming the deficiency in animal protein. Moreover, pig rearing fits well in mixed-farming systems and can be complimentary to intensive crop production. In rural India, pig rearing is a traditional occupation among the weaker sections of society.

India possesses around 12.5 million pigs, which comprises around 1% of the world's swine population. Pork production constitutes less than 10% of meat production in the country. Besides pork and pork products, the swine industry also produces bristles, a valuable export commodity.

Tiwari, C.B. and **Arora, R.L**. 2005**.** Impact of AICRP on improvement in production and other economic traits of pigs. Pages 247-253 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Indian Veterinary Research Institute, Izatnagar, India.

The number of pigs is concentrated in densely populated states (Andhra Pradesh, Bihar, Tamil Nadu, Uttar Pradesh, and West Bengal) or where popular food habits are favorably placed towards pork consumption (Assam, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, and West Bengal). Though the meat yield from pigs is low, it is possible to bring about rapid genetic improvements in the economic traits of pigs. Thus the main objectives of the All India Coordinated Research Project (AICRP) on pigs are to:

- Study the performance of indigenous pigs under optimum management conditions;
- Study the comparative performance of indigenous and crossbreds carrying 50 and 75% exotic inheritance in respect of their efficiency of feed conversion, production, and reproduction traits;
- Evolve economic pig rations with locally available feed ingredients (conventional and/or nonconventional);
- Select animals from within crossbreds with faster growth on economic rations to produce superior strains of improved pigs; and
- Study the incidence of various diseases in pigs and suggest areas for research to provide optimum health cover.

Technology Components

History of Technology Development

Except for a few imports of superior quality pigs of exotic breeds by some missionary organizations, no concerted efforts were made to improve pig production in India. During the II Five-Year Plan, however, a coordinated program for piggery development was taken up in different states. The scheme involved establishment of bacon factories, regional breeding stations, pig breeding farms/ units and piggery development blocks. The primary objective of the regional pig breeding stations was to acclimatize the exotic stock for distribution to the pig breeding units for further multiplication.

Systematic research on pig production in India was initiated with the launch of the All India Coordinated Research Project on pigs during the IV Five-Year Plan, with the initial mandate of studying purebred exotic breed at some selected centers. Landrace and Large White Yorkshire pigs were genetically and phenotypically evaluated for economic traits such as litter productivity, growth, efficiency of feed utilization, carcass characteristics, and reproductive efficiency.

Subsequently, in view of the direct economic importance of indigenous pigs to the rural poor, it was felt that work on indigenous pigs be brought under AICRP's ambit. Accordingly, the technical program was remodeled to include work on indigenous pigs.

Work during the VI Five-Year Plan was confined to studying the performance of indigenous pigs under improved management conditions and their genetic improvement through selection. During the VII Five-Year Plan, research was initiated on crossbreeding indigenous gilts with boars of landrace breed at Izatnagar; Hampshire at Khanapara; and Large White at Jabalpur and Tirupati. To decide about the optimum level of exotic inheritance test suited to Indian conditions, studies were undertaken during the VIII Five-Year Plan on indigenous and two grades of crossbreds (with 50% and 75% exotic inheritance) at each of the research centres. After 1994-95, research work on indigenous pigs was confined to the new centers at Mannuthy and Kattupakkam.

Specific Target Domain

India has a large number of rural poor who practise pig husbandry in the traditional way. Since pigs are mostly fed on scavenge, a good number of people desist from pork consumption. The ultimate aim is to involve all sections of society in this sector by introducing breeds with high litter size, litter weight, faster growth, disease resistance, and those fed on ration free from scavenge. This will attract people who do not like scavenge-fed pig meat and entrepreneurs who are reluctant to venture into this sector. Keeping improved breeds of pigs will definitely increase employment and income opportunities of economically weaker classes who are traditional pig farmers.

Methodology

The Exotic Phase of the breeding population at each center consists of 24 gilts and 8 boars. One farrowing is taken from each female. Each male is mated with three females at random avoiding half and full sib mating. Gilts are selected on the basis of litter size and weight at birth and weaning, and the individual body weight of gilts at 22 weeks.

In the Remodeled Phase, 30 sows and 8 boars of indigenous pigs are kept at each centre for pure breeding. Halfbreds are produced by crossing indigenous gilts with exotic boars. The halfbreds are bred *inter-se* to produce a superior strain of crossbred pigs. Twelve halfbred sows are mated with 6 boars of exotic origin to produce 75% of exotic and 25% of indigenous inheritance. Weaning is done at 8 weeks and males are castrated at this stage.

Nutritional experiments are conducted at each center to evolve economic ration from locally available crop residues/waste. Production and reproduction traits are recorded and statistically analyzed. Carcass characteristics are also studied.

Adoption of Improved Technology

More than 10,000 improved pigs for breeding purpose have been supplied from different centers of AICRP to interested farmers. This has improved herd quality. At Mammoth center, 6 castrated crossbred pigs were supplied to a farmer to be maintained exclusively on food waste collected from hotels and waste from slaughterhouses. This feeding program continued for five months (Nov 1998 to Mar 1999). The farmer who maintained this unit earned a profit of Rs 5651 and was satisfied with the program.

Impact of Improved Technology

The litter size at weaning during the Exotic Phase of the project increased from 6.02 to 7.80 in Landrace herds at Izatnagar and from 6.48 to 7.60 at Khanapara. The corresponding increase in Large White herds was 8.15 to 8.67 at Jabalpur and 7.6 to 8.28 at Tirupati. Litter weight at weaning at these locations during this period increased from 60.63 kg and 61.68 kg to 95.08 kg and 92.08 kg in Landrace and from 79.40 kg and 84.16 kg to 97.36 kg and 93.36 kg in Large White herds, respectively. Individual body weight at 8 weeks increased from 9.40 and 9.84 kg to 10.94 and 10.79 kg in Landrace and from 7.89 and 9.53 kg to 11.29 and 11.46 kg in Large White herds. Body weight at 28 weeks increased by 10.00 and 16.50 kg in Landrace and by 14-20 and 10.40 kg in Large White herds. In spite of this, the performance of exotic pigs in India is not comparable to that in their countries of origin.

Litter size of indigenous pigs at birth was highest at lzatnagar (6.82) followed by Mannuthy (6.40), Jabalpur (6.20), Tirupati (5.38), Kattupakkam

(4.90), and Khanapara (4.87). Litter weight at weaning averaged around 37.0 kg at Tirupati, Khanapara, Mannuthy, and Kattupakkam and around 33.0 kg at Izatnagar and Jabalpur. Individual body weight at birth averaged between 0.7 and 0.8 kg at all centers, except Kattupakkam where it was 0.43 kg. Body weight at weaning varied from 6.87 kg at Mannuthy to 8.12 kg at Tirupati. At 32 weeks, indigenous pigs were the heaviest at Tirupati (42.91 kg) followed by Izatnagar (40.43 kg) and Khanapara (38.05 kg). At Mannuthy, Kattupakkam, and Jabalpur, indigenous pigs at 32 weeks weighed between 31.3 and 33.0 kg, respectively. Varying level of growth rates and litter traits may be due to differences in strains (Table 1).

Table 1. Means of reproduction traits in different genetic groups.

Genetic group	Litter size at birth	Litter weight at birth (kg)	Litter size at weaning	Litter weight at weaning (kg)
		Jabalpur		
Desi	6.20±0.24	4.02±0.17	4.26±0.28	33.12±2.55
Halfbred	7.43±0.33	6.91±0.29	5.59±0.20	52.54±2.32
3/4-bred	8.75±0.32	8.08±0.29	5.78±0.35	56.40±3.34
		Tirupati		
Indigenous	5.38±0.36	5.21±0.34	4.30±0.31	37.81±3.21
halfbred	6.34±1.23	6.12±1.36	5.51±0.38	56.23±4.37
3/4-bred	6.69±0.82	7.98±0.89	6.04±0.43	66.37±4.85
		Izatnagar		
Indigenous	6.82±0.39	4.57±0.29	5.01±0.40	33.77±2.58
Halfbred	7.02±0.24	6.19±0.24	5.47±0.28	55.41±2.32
3/4-bred	5.99±0.39	5.6±0.33	4.12±0.29	50.12±3.15
		Khanapara		
Indigenous	4.87±0.28	4.33±0.19	4.60±0.23	36.80±1.83
Halfbred	5.84±0.30	6.05±0.25	5.33±0.27	53.31±3.15
3/4-bred	7.61±0.24	8.47+0.35	6.00±0.30	61.57±4.15

Efficiency of feed utilization in indigenous pigs, measured as feed consumed kg^{-1} gain in body weight, ranged between 4.80 at Izatnagar and 5.48 at Tirupati.

On crossbreeding indigenous gilts with exotic boars, there was a significant improvement in litter productivity, growth rate, efficiency of feed utilization, and lean meat production. There was an increase in litter size and weight at birth and litter size and weight at weaning from 6.20, 4.02 kg, 4.26 and 33.12 kg to 7.43, 6.91 kg, 5.59, and 52.54 kg in 50 % and to 8.75, 8.08 kg, 5.78 and 56.40 kg in 75% crossbreds at Jabalpur. Similar increases in litter productivity traits were observed at the remaining three centers. Crossbreds carrying 75% Large White or Hampshire inheritance were superior to 50% crossbreds in litter traits. In Landrace, 50 and 75 crossbreds did not differ in their growth rates and litter productivity traits.

Constraints to Technology Adoption

Significant improvements have been recorded in productivity levels of indigenous and crossbred pigs. Substantial information has also been generated on nutritional requirements of pigs. A large number of alternative sources of energy and protein have been identified and evaluated for their use in evolving economic rations. Pig husbandry is not popular among the general masses, mainly because of social taboos, nonavailability of cheap ration, high mortality, and lack of good marketing facilities. In rural areas, pigs are still considered as scavenge-fed animal. This impression deters even those who can invest in livestock from venturing into this field. Moreover, pig farmers are not trained in management practices and disease control measures to check high mortality, particularly high preweaning mortality. Also, there is no year-round demand for pork and there is a lack of pork processing facilities. The government should encourage entrepreneurs to venture into this sector and pork should be labeled as farm-bred and farm-fed while being marketed in order to attract those who shy away from consuming it.

Lessons for Future Research

The AICRP has made significant contributions to generating data on growth, prolification, efficiency of feed utilization, carcass quality and disease pattern in indigenous, exotic, and crossbred pigs under optimal levels of management. However, the following knowledge gaps have been identified for further research:

- Breeding and management technologies developed at research centers have not been tested under village conditions;

- Studies on behavioral and physiological attributes of various types of indigenous pigs, particularly in the northeastern region and tribal areas of Orissa and Bihar remain outside AICRP's scope;
- No scientific information is available on a suitable housing system;
- Information on recycling of pig farm wastes to cut down the cost of pig production is not yet available;
- A combination of pig farming and poultry and fish farming, i.e., mixed farming, has not been studied;
- Various marketing and transportation systems and their advantages have not been studied; and
- Research needs to be done on effective therapeutic and preventive measures against diseases like agalactia, swine fever, swine pasteurellosis, *E. coli* infection, etc.

23

Technological Change in Arid Agriculture: A Case of Leguminous Crops from Rajasthan

B Singh and B L Gajja[1]

Introduction

Rainfed agriculture in India accounts for two-thirds of the cultivated area, supports 40% of the population, and contributes 44% to total food production. Most of the coarse cereals, pulses, oilseeds, and cotton produce come from rainfed regions. However, productivity of rainfed crops is low and varies widely over time and space, depending on rainfall and its distribution.

Rajasthan is predominantly a rainfed state, with 81% of its total geographical area being represented by arid and semi-arid climate. The arid zone is characterized by sand dunes, high degree of soil erosion, low soil fertility, low and erratic rainfall, and meager irrigation facilities. As a result, only coarse cereals and leguminous crops that can withstand water stress are grown here. Pearl millet is the main food crop in arid Rajasthan and mung bean, moth bean, and cluster bean are the important leguminous crops. In order to provide resilience to the arid zone economy of the state, agricultural research efforts have been targeted towards evolving short-duration varieties with low water requirement and soil and water conservation technologies. In recent years, new varieties of moth bean (RMO-40) and cluster bean (RGC-936) have been identified for wider dissemination under arid conditions. This study attempts to evaluate their economic performance under field conditions and quantifies their potential contribution to yield changes following adoption.

Singh, B. and **Gajja, B.L.** 2005. Technological change in arid agriculture: a case of leguminous crops from Rajasthan. Pages 255-260 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Central Arid Zone Research Institute, Jodhpur, Rajasthan, India.

Data and Method

Sampling

The study was carried out in Bikaner district in the western arid zone of Rajasthan during 1996-97, where moth bean and cluster bean are widely grown during the rainy season. Moth bean occupies 10% of the area and cluster bean, 18%. Pearl millet is the main cereal crop covering 32% of the area.

A sample of 20 farmers growing moth bean variety RMO-40 was drawn from two villages adopted by the Central Arid Zone Research Institute, Jodhpur, under its Desert Development Programme/Transfer of Technology. An equal sample size was drawn from farmers growing local strains of moth bean. The same sampling procedure was adopted for selecting farmers growing cluster bean.

Decomposition of Output Gains

A production function approach was used to decompose the output gains due to technology and inputs (Bisaliah 1997; Thakur and Kumar 1984; Hussain and Young 1985; Joshi and Jha 1992). Separate production functions were estimated for high yielding and local varieties.

$$L_n Y_t = L_n A_t + a\, L_n FERT_t + b_l L_n HL_t + c_l L_n FL_t + d_l L_n OTHR_t + U_l \quad \ldots(1)$$

$$L_n Y_m = L_n A_m + a_2 L_n FERT_m + b_2 L_n HL_m + c_2 L_n FL_m + d_2 L_n OTHR_m + U_2 \quad \ldots(2)$$

where, Y is the crop yield (kg ha^{-1}), FERT is the value of fertilizer and manure (Rs ha^{-1}), HL is the hired labor (mandays ha^{-1}), FL is the family labor man days ha^{-1}, OTHR is the other expenses (ha^{-1}), A is the scale parameter, a, b, c, and d denote output elasticities of the respective inputs, and U is a random term independently distributed with zero mean and constant variance. Subscript t stands for local varieties and subscript m for high-yielding varieties. L_n is the natural log.

Taking the difference between Eqs (2) and (1) and rearranging the term yields:

$$L_n [Y_m/Y_t] = L_n [A_m/A_t] + [(a_2-a_1) L_n FERT_t + (b_2-b_1) L_n HL_t + (c_2-c_1) L_n FL_t + (d_2-d_1) L_n OTHR_t] + a_2 L_n (FERT_m/FERT_t) + b_2 L_n (HL_m/HL_t) + c_2 L_n (FL_m/FL_t) + d_2 L_n (OTHR_m/OTHR_t) + (U_2-U_1) \quad \ldots(3)$$

Equation (3) approximately decomposes the gains in output due to HYVs and input differences. The first bracketed expression measures change in output due to a shift in scale parameter A. The second bracketed expression measures the effect of change in slope parameters. Together, the two sum up the effect of HYVs on yield. The third bracketed term measures the contribution of the difference in input levels between high-yielding and local varieties.

Impact of Technology

Production Function Estimates

Cobb-Douglas production functions were used to examine the response of high-yielding and local varieties to inputs used. The estimated parameters are given in Table 1. The independent variables explained 91% the variations in yield of RMO-40 and 81% in the local moth bean. All the variables were positive, except for 'other expenses' in the case of RMO-40 which were significant at < 5% level. The dummy variable for HYVs in the pooled equation was positive and highly significant, indicating a structural break in moth bean yield on the introduction of a new variety.

Table 1. Estimated Cobb-Douglas production functions for moth bean and cluster bean in Rajasthan.

Explanatory variables	Moth bean			Cluster bean		
	RMO-40	Local	Pooled	RGC-936	Local	Pooled
Constant	0.1571	0.1059	0.1889	0.2078	0.1340	0.1779
Fertilizers and manure (Rs ha^{-1})	0.0361** (0.0109)	0.0126* (0.0071)	0.0937** (0.0232)	0.1306** (0.0317)	0.1159** (0.0302)	0.0956** (0.0391)
Labor (mandays ha^{-1})	0.0889** (0.0293)	0.0643** (0.0247)	0.3469** (0.1133)	0.1757** (0.0341)	0.1461** (0.0344)	0.2603** (0.0999)
Other expenses (Rs ha^{-1})	0.1778* (0.0802)	0.1579** (0.0667)	0.2063** (0.0877)	0.2605* (0.1286)	0.2161** (0.0917)	0.2086** (0.0913)
Dummy for variety HYV=1, otherwise=0	–	–	0.2744*** (0.0533)	–	–	0.1872*** (0.0417)
R^2	0.9126	0.8133	0.9413	0.8497	0.7137	0.9498
No of observations	20	20	40	20	20	40

*** Significant at 1%, ** Significant at 5%, and * Significant at 10%.
Figures in parentheses are standard errors.

In the case of cluster bean, independent variables accounted for 85% of the variation in yield of RGC-936 and 71% in the yield of the local variety. All the explanatory variables carried a positive sign and were statistically significant. The dummy variable for RGC-936 in the pooled equation was also positive and significant, implying that its widespread adoption would enhance the average yield.

Contribution of Technology

Table 2 presents the geometric means of yields and inputs used in the production of high-yielding and local varieties of moth bean and cluster bean. RMO-40 yielded 67.3% more than the local varieties, while RGC-936 yielded 60% more than the local variety. Though these were not high-yielding by themselves, they required greater quantities of inputs for a better response. In the case of RMO-40, the per hectare expenses on fertilizers and manure were 41% more and on labor 57.4% more compared to that on the cultivation of local varieties. Expenses on other inputs too were higher in the case of RMO-40. The cultivation of RGC-936 required 74.1% more expenses on fertilizers and manure and 47.6% more on labor.

Table 2. Geometric mean of inputs and productivity of moth bean and cluster bean.

Particulars	Moth bean		Cluster bean	
	RMO-40	Local	RGC-936	Local
Fertilizers and manure (Rs ha^{-1})	204 (+41.4[1])	145	278 (+74.1)	159
Labor (mandays ha^{-1})	41.3 (+57.4)	26.2	47.9 (+47.6)	32.4
Other expenses (Rs ha^{-1})	1037 (+24.3)	834	902 (+31.4)	690
Yield (kg ha^{-1})	460 (+67.3)	275	739 (+60.0)	462

[1] Figures in parentheses are percentage changes over local variety.

The relative shares of technology and inputs in enhanced yields of moth bean and cluster bean are given in Table 3. Varietal differences and accompanying input changes accounted for 67.6% of the observed difference in moth bean yield between growers and non-growers of RMO-40, and 63.5% of the difference in cluster bean yield between growers and non-growers of RGC-936. Varietal differences accounted for the bulk of the enhanced yield (58.6% in moth bean and 42.4% in cluster bean). Inputs contributed 9.1% to enhanced moth bean yield and 21.1% to cluster bean yield. These findings suggest that widespread adoption of HYVs can raise the production and productivity of these crops significantly.

Net Benefits of Technology

Since decomposition of productivity change helps in estimating returns to investment in research, additional costs and benefits accruing due to HYVs were estimated (Table 4). The value of additional inputs required per hectare to obtain the existing yield of moth bean variety RMO-40 was Rs 1211. The additional benefits accruing due to enhanced yield were to the tune of Rs 2328 ha^{-1}. Thus, the adoption of this variety resulted in net benefits worth Rs 1117 ha^{-1}.

Table 3. Relative shares of variety and inputs in yield gains accruing from the adoption of high-yielding varieties of moth bean and cluster bean.

Sources of difference	Moth bean	Cluster bean
Variety (%)	58.55	42.39
Inputs (%)		
Fertilizers and manures	1.25	7.24
Human labor	4.03	6.85
Other expenses	3.79	6.99
Total difference due to inputs	9.07	21.08
Total estimated difference	67.62	63.47

Table 4. Additional costs and benefits of adopting high-yielding varieties of moth bean and cluster bean.

Factors	Moth bean	Cluster bean
Yield (kg ha^{-1})		
High-yielding variety	460	739
Local variety	275	462
Operating expenses (Rs ha^{-1})		
High-yielding variety	3224	3000
Local variety	2013	2125
Additional cost (Rs ha^{-1})	1211	875
Additional benefits (Rs ha^{-1})	2328	3094
Net benefits (Rs ha^{-1})	1117	2219
Benefit-cost ratio	1.92	3.54

Replacing one hectare under local varieties of cluster bean with RGC-936 required additional inputs worth Rs 875. However, the additional returns due to its higher yield were estimated at Rs 3094 ha^{-1}, thus generating a net surplus of Rs 2219 ha^{-1}.

Conclusions

Moth bean and cluster bean productivity in the arid zone of Rajasthan can be substantially increased by introducing HYVs. Extension efforts coupled with natural resource management practices (mainly soil and water conservation) can help realize the potential of these technologies. The grains of these crops are in great demand. The demand for moth bean comes mainly from bakeries, while cluster bean is used as a raw material in a number of industries. The export demand for cluster bean is also increasing. Thus, developing suitable production technologies for these crops would help bring prosperity to agriculturists of the arid region.

References

Bisaliah, S. 1997. Decomposition analysis of output change under new production technology in wheat farming — some implications to returns on research investment. *Indian Journal of Agricultural Economics* 32(3):193-201.

Hussain, R.Z. and **Young, R.A.** 1985. *Salinity damage of irrigated crops—Economic measurements from a farm survey in Pakistan*. Working paper 85-4. Fort Collins, Colorado, USA: Department of Agriculture and Natural Resource Economics, Colorado State University.

Joshi, P.K. and **Jha, D.** 1992. An economic enquiry into the impact of soil salinity and waterlogging. *Indian Journal of Agricultural Economics* 47(2):195-204.

Thakur, J. and **Kumar, P.** 1984. A comparative study of economic efficiency of different irrigation systems in western U.P. *Indian Journal of Agricultural Economics* 39(3):521-527.

24

Economic Evaluation of Integrated Pest Management in Cotton

P S Birthal,[1] O P Sharma[2] and S Kumar[1]

Introduction

Together with high-yielding crop varieties and fertilizers, pesticides have helped Indian farmers achieve substantial increases in agricultural productivity. However, in recent years, the use of pesticides has come under severe criticism because of their technological failure in terms of pest resistance, resurgence and secondary outbreak of diseases and the hazards they pose to both ecology and human health. On the farm economy, this has led to an escalation in cost of production, greater crop losses and fall in farm profitability (Rola and Pingali 1993; Dhaliwal and Arora 1993; Kishor 1997). These concerns have given rise to a demand to curtail pesticide use in agriculture.

Insects, weeds and diseases inflict considerable damage on crops. Globally, about 40% of output is lost due to pests before harvest; post-harvest losses account for another 10-20% (Oerke et al. 1995). Had pests not been controlled, the losses could have risen to about 70%. In India, output losses due to insect pests are estimated at 50% in cotton, 35% in rapeseed-mustard, 30% in pulses, 25% in rice, 20% in sugarcane and 5% in wheat (Dhaliwal and Arora 1993). Thus, there are apprehensions that reducing pesticide use without effective

---

Birthal, P.S., Sharma, O.P. and **Kumar, S.** 2005**.** Economic evaluation of integrated pest management in cotton. Pages 261-279 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] National Centre for Agricultural Economics and Policy Research, Library Avenue, Pusa, New Delhi 110 012, India.

[2] National Centre for Integrated Pest Management, New Delhi 110 012, India.

technological alternatives may lead to a decline in crop yields and food and fiber supplies, and increase output prices.

In order to address these concerns, the focus of plant protection research is gradually shifting towards the development of environmentally safe and economically feasible alternatives to chemical pesticides using biotechnological approaches. Several living microorganisms (parasites, parasitoids, fungi, viruses, etc.) and herbs (neem, turmeric and mahogany) have been identified for their pesticidal properties. Some of the products of biotechnological research that are commercially available include *Trichogramma* spp., Nuclear Polyhedrosis Virus, *Bacillus thuringiensis,* and neem-based pesticides. In India, the efficacy of these products has been proven under controlled experimental conditions. Though their success in farmers' fields has been limited (Unni 1996; NCIPM 1998), they are reported effective when used in an Integrated Pest Management (IPM) mode, i.e., in conjunction with physical, cultural and chemical methods of pest control (Jayraj 1989; Ram and Gupta 1990; Srinivas and Krishnamoorthy 1991; Kumar 1992; Kishor 1997; NCIPM 1998).

Currently, the production of bio-agents and bio-pesticides for use in IPM is limited. So is their adoption. Individual estimates reveal their application to be hardly 1-2 % of cropped area (Jayraj 1989). Therefore, not much attention has been paid to either economic evaluation or constraints to adoption of IPM. Studies are few and often based on limited information (Unni 1996; Chowdry and Seetharaman 1997; Kishor 1997). This paper therefore attempts to evaluate the economic feasibility of IPM in cotton under field conditions and its farm-level impacts.

Background and Data

Need for IPM in Cotton

The need for IPM in India appears to have arisen largely out of economic concerns, as pesticide use is only about 300 grams ha^{-1} of total cropped area. However, pesticide use is highly uneven across crops; cotton alone accounts for about half the pesticide used in agriculture, though its share in gross cropped area has rarely exceeded 5% (Chand and Birthal 1997). Consumption of technical grade pesticide in cotton is estimated to be around 3.5 kg ha^{-1}. Despite this, about half the cotton output is lost to insect pests (CICR 1988; 1994). The loss has increased from about 20% in the early 1960s (Dhaliwal and Arora 1993) because a number of cotton insects such as *Helicoverpa armigera* and white fly have developed resistance to almost all the insecticides used to control them. However, it is claimed that IPM practices provide effective protection against such insect pests.

Development and Validation of IPM Module

Using research findings from India, an IPM module for rainfed cotton was developed jointly by the National Centre for Integrated Pest Management (NCIPM), New Delhi (an offshoot of ICAR), and the Cotton Research Station (CRS) of the Marathwada Agricultural University, Parbhani, Nanded[3] . Details of the pest control techniques used and the rationale thereof are given in Table 1.

The module was validated at CRS and on a progressive farmer's field in Barad village in Nanded district during two successive crop seasons, 1996-97 and 1997-98. During both years, the IPM strategy proved more effective than chemical control strategy. Encouraged by this result, researchers planned to implement the IPM module over a larger area in the ensuing cotton season, for which village Ashta in Nanded district was identified.

Program Implementation

Since pests have the characteristics of a common property resource and leave no field unaffected (Regev et al. 1976), the problem needs to be tackled at the community level. This is particularly so in the case of IPM as it involves the use of bio-agents and bio-pesticides. The exclusive use of chemical pesticides on farms in the vicinity of IPM farms has adverse affects on the activities of bio-agents and bio-pesticides, and therefore on the effectiveness of IPM itself.

Since IPM is akin to a new technology, it was feared that some farmers would not adopt it because of risk aversion. Therefore, farmers' meetings were called where they were apprised of the characteristics and benefits of IPM. They were guaranteed regular monitoring of pests and the free supply of two critical inputs, *Trichogramma* and HaNPV. Further, crop failure in the preceding

[3] Maharashtra was deliberately chosen to validate and implement this module because the state accounts for the country's maximum share (34 %) in total cotton area; about 96% of the cotton area is rainfed; and cotton productivity in the state is amongst the lowest (141 kg lint ha^{-1}) in the country.

Table 1. The structure of the IPM module validated on an experimental farm and a farmer's field in Barad village, Nanded district, Maharashtra.

Measures	Practices suggested	Rationale
1. Indirect measures		
Field sanitation	Removal, collection and destruction of stacks and fallen bolls of the previous crop before sowing	To prevent the carrying over of hibernating insect pests (bollworms and bacterial diseases) to the ensuing crop
Soil solarization	Soil inversion by mould board plough	To expose and kill harmful insect pests (eggs, larvae, etc.) and micro-seclerotia of wilt disease hibernating in the upper layer of the soil
Seed	Use of certified and acid-delinted seeds @ 2-3 kg ha^{-1} and seed dressing with Imidacloprid @ 7 grams a.i. kg^{-1} seed	Seed treatment for prophylactic control of sucking pests
Variety	NHH 44 or Renuka	To maintain uniform crop architecture and ensure uniform control actions
Synchronous sowing	Synchronous sowing, preferably drying and sowing before the onset of monsoon	To ensure uniformity in application of pest control measures at different stages of crop growth
Spacing	90×60 cm for NHH 44 60×30 cm for Renuka	Appropriate spacing ensures an unfavorable microclimate for pest multiplication
Fertilization	Application of nitrogen as a basal dose @ 42 kg ha^{-1}	Steady and sturdy plant growth. Appropriate quantity of nitrogen creates an unfavorable microclimate for pest multiplication (sucking pests).

Contd.

Table 1 — Contd

Intercrop	One row of *Setaria* after every 10 rows of cotton	Attracts predatory birds that feed on insect larvae
Border crop	One row of maize intercepted with cowpea around the cotton field	To induce multiplication of natural enemies such as coccinellids and chrysopid
2. Direct measures		
Pheromone trap	One pheromone trap for every 20 ha	To monitor pest population
Physical and cultural controls	Hand picking of *Helicoverpa* larvae	Reduces pest density
	Manual weed control	Reduces pest multiplication sites
Biological control	*Trichogramma chilonis* released four times @ 1.5 lakh ha^{-1} at weekly intervals or as determined by moth captures	*T. chilonis* ensures the destruction of microscopic eggs
	Spraying of Helicoverpa Nuclear Polyhedrosis Virus (HaNPV) @ 250 Larva Equivalent (LE) ha^{-1} 1-2 times 40 and 65 days after sowing or as determined by moth captures	HaNPV at 3 star larvae ensures destruction of pest through their lytic effect and natural spread
	Spraying 5% Neem Seed Kernel Extract (NSKE) 75, 85, 110 and 120 days after sowing	NSKE acts as pest anti-feedant and repellant
Chemical control	Application of pesticides	In the case of high pest infestation

year acted as a catalyst in convincing farmers to try out IPM practices. The farmers' response was overwhelming, and even those who resisted later agreed to try it. Thus the program could be implemented over the entire cotton area (127 ha) in the village, comprising 76 farmers.

Since IPM is a knowledge-intensive technology, it requires farmers to have sufficient knowledge of pest ecology, pest-predator relationships and pest control practices. Thus, in order to make farmers self-reliant in pest control methodology, farmers' field schools were organized on a regular basis.

Data

Sampling and Farm Characteristics

A sample of 40 households was randomly drawn from Ashta village to collect information on cotton cultivation practices with emphasis on plant protection. In order to compare the technical and economic parameters of IPM, a random sample of 40 cotton-growing farmers was drawn from Murli, an adjoining village, where chemical pest control was the dominant approach to pest management.

The average size of landholdings of sample farmers in Ashta was 4.0 ha with 24% of the area having access to irrigation. In Murli, the average size of a holding was 2.3 ha and only 13% of the area had access to irrigation. Tubewells were the main source of irrigation in both the villages and cotton was the principal rainy-season crop, grown entirely under rainfed conditions. It accounted for 62% of the gross cropped area in Ashta and 50% in Murli. Sorghum, black gram, pigeonpea and green gram were the other important rainy-season crops. Wheat and chickpea were the main postrainy-season crops, but these were grown over a limited area because of land constraints imposed by the longer duration of cotton and the lack of irrigation facilities. Hereafter, Ashta will be referred to as the IPM village and Murli as the non-IPM village.

Analytical Approach

Partial budgets were prepared to assess the economic feasibility of IPM. Only variable inputs were taken into consideration. Input prices were taken as reported by the farmers and rectified for anomalies, if any, by cross checking with local markets. *Trichogramma* and NPV supplied by the implementing agencies were reckoned at the prices charged by some of the producers of these inputs. Cotton output was valued at the price paid to farmers under the State's Cotton Monopoly Procurement Scheme.

The difference in crop yields between IPM and non-IPM villages could be due to the different pest control methods used as well as input levels. Thus, IPM's contribution to the difference in output was quantified using the decomposition technique (Bisaliah 1977).

Economic Feasibility and Impacts

On-farm Adoption of IPM Practices

IPM is a flexible approach which emphasises the need-based application of pest control inputs, depending on the level of infestation or action threshold. Therefore, the types of inputs used and their intensity on farmers' fields need not necessarily replicate those given in Table 1. Moreover, deviations may be due to heterogeneity in farmers' resource endowments.

Based on the level of pest infestation, two releases of *Trichogramma*, one spray of HaNPV, and three sprays of Neem Seed Kernel Extract were recommended for application on farmers' fields. There was a slight variation in the number of applications recommended. *Trichogramma* was released twice on 98% of the farms and NPV was sprayed once on 90% of the farms and twice on the rest. Only one farmer did not use *Trichogramma*. NSKE was used thrice on a majority of the farms (78%), twice on 20% of them, and four times on 2% of them. Use of chemical pesticides was restricted to seed treatment, which was religiously followed by all the farmers.

One farmer did not follow the suggested intercropping with *Setaria* and border cropping with maize and cowpea, perhaps due to the higher opportunity cost of diverting land to these crops. Dry seeding, which was recommended to ensure synchronicity in sowing and consequently in pest control operations, was not followed at all. Dry sowing was not followed because of the uncertainty in the arrival of the monsoon; the failure of which could result in seed and labor wastage. Sowing, however, was completed within a week of the onset of the monsoon. All the sample farmers planted hybrid NHH 44, but the seed rate varied from farm to farm. Similarly, farmers applied nitrogen as a single basal dose, with variations in application across farms. The means and standard deviations of costs of variable inputs per hectare presented in Table 2 confirm these variations.

Technical Potential of IPM

The technical potential of IPM can be measured in terms of reduction in pesticide use, efficacy of pest suppression and conservation of natural enemies of insect pests. The cumulative effect of these is reflected in the additional yield of IPM farms over non-IPM farms. The mean values of these parameters are presented in Table 2.

Table 2. Pesticide use, yield and incidence of pests and their natural enemies under IPM and non-IPM situations.

Items	Non-IPM	IPM
Pesticide use (a.i. kg ha^{-1})	3.16	0.014
Crop yield (kg ha^{-1})	880	1090
Pest infestation (numbers per three leaves)[1]		
Sucking pests		
Jassids (*Amrasca bigutulla bigutulla*)	3.5	2.1
Aphids (*Aphis gossypii*)	21.6	6.8
Thrips (*Thrips tabaci*)	1.0	0.9
White fly (*Bemesia tabaci*)	0.1	0.1
Bollworms		
American bollworm (*H. armigera*)	0.23	0.13
Spotted bollworm (*Earias insulana*)	0.14	0.09
Pink bollworm (*Pectinophora gossypiella*)	0.30	0.17
Natural enemies (numbers per three leaves)[1]		
Coccinellid grubs	0.1	0.3
Coccinellid adults	0.7	2.7
Chrysopa eggs	0.2	0.5
Chrysopa adults	0.0	0.1

[1]Observations are from 10 plots each from IPM and non-IPM villages.

Fall in Pesticide Use

IPM could reduce pesticide use substantially. No direct application of pesticides was needed for either insect, disease or weed control. They were used only for seed treatment. Mean pesticide usage was 14 grams active ingredient ha^{-1}. In a non-IPM situation, the number of pesticide applications ranged between 3 and 14, with a mean of eight applications per farm. Mean pesticide use was estimated at 3.2 kg active ingredient ha^{-1} with a range of 1.6 to 5.6 kg. Insecticides were frequently used and accounted for 83% of the total pesticides. Fungicides accounted for 11% and weedicides 6% of the total pesticides. Weedicides were used by 30% of the farmers. About half the number of farmers applied fungicides to control diseases.

Pest Control Efficacy and Conservation of Natural Enemies of Pests

A reduction in pesticide use can be accompanied by greater yield losses if alternative pest control techniques are ineffective. A comparison of pest infestation levels on IPM and non-IPM farms showed that IPM provided better control of all major loss-causing insects. The IPM practices were more efficient at killing pests compared to non-IPM practices. The incidence of sucking pests such as jassids (*Amrasca bigutulla bigutulla*), aphids (*Aphis gossypii*, and thrips (*Thrips tabaci*) was much less on IPM farms. Chemical seed treatment helped reduce their incidence in the initial stage of crop growth. Thereafter, maize and cowpea on plot borders acted as catalysts in the multiplication of coccinellids and crysopids, which regulate the activities of sucking pests. *Helicoverpa* infestation on IPM farms was also substantially less. Similar observations were recorded for *Pectinophora gossypiella* and *Earias insulana*. Use of bio-pesticides and bio-agents provided effective control of bollworm complex. Intercropping of *Setaria* is also expected to have contributed to effective control of bollworm complex by attracting birds like the mynas, finches and backjays that are predators of bollworm larvae.

Yield on IPM farms was 1090 kg ha^{-1}, about 24% more than on non-IPM farms[4] (Table 2). This gives credence to the scientific claims that IPM is a technically superior method of pest control which is in tune with the objectives of productive agriculture, conservation of the ecology and human health safety.

Economics of IPM and its Impact

Farmers need not adopt a technically feasible alternative if it is not in tune with their objective of profit maximization. The cost of applying the new technology,

[4] Yield included cotton-equivalent yields of intercrops. On IPM farms, *Setaria* was intercropped with cotton and it yielded 43 kg cotton equivalent output ha^{-1}. On non-IPM farms, pigeonpea was grown as an intercrop. Its cotton equivalent yield was 90 kg ha^{-1}. Cotton equivalent yield was obtained by dividing the value of the output of the intercrop by the price of cotton.

crop productivity, and output price have a bearing on profitability. There was no difference in cotton price received by IPM and non-IPM farmers. Thus, given the output price, productivity and cost of technology are the main determinants of profitability.

Cost of Cultivation

The average cost of variable inputs on IPM farms was estimated to be Rs 8067 ha^{-1} which is marginally higher compared to non-IPM farms[5] (Table 3). However, input-specific costs differed between IPM and non-IPM situations. Expenditure on plant protection inputs was 13% less on IPM farms than on non-IPM farms. Thus, expenditure on pesticides could be reduced substantially.

The free supply of HaNPV and *Trichogramma* was expected to relax some budgetary constraints so that the ensuing savings could be reallocated to other farm inputs such as seed and fertilizer. The per hectare cost of variable inputs (Table 3) show that IPM farmers spent about 14% more on fertilizers and 10% more on farmyard manure than non-IPM farmers. Expenditure on human labor on IPM farms was higher by 15% and statistically significant. Expenditure on seeds and draught power was, however, significantly less on IPM farms. However, the marginal difference in average cost of cultivation between the two situations implies that in general IPM requires no additional financial resources.

Value of Output

The mean value of output on IPM farms was Rs 21,793 ha^{-1}, about 24% higher than on non-IPM farms and was statistically significant (Table 3). The value of output included the value of the output of cotton as well as that of the intercrop. Though *Setaria* was grown as an intercrop to attract predatory birds on IPM farms, its contribution to the gross value of the output was about 4%. On the other hand, intercropping of pigeonpea was common on non-IPM farms, and its contribution to the gross value of the output was estimated at 10%.

Net Returns

IPM generated net returns worth Rs 13,726 ha^{-1} (Table 3), which is about one and a half times more than the cost of cultivation. A comparison of net

[5] Cost of cultivation includes the costs of the main crop and intercrop.

returns with and without IPM provides an estimate of the economic potential of IPM. Net returns ha^{-1} on IPM farms were 43% higher than on non-IPM farms. This difference is statistically significant.

Table 3. Cost and returns (Rs ha^{-1}) under IPM and non-IPM situations.

Item	Non-IPM	IPM	Change over non-IPM (%)	t-statistics
Cost				
Pest control inputs				
Pesticides	2,350.0 (860.8)	492.5 (43.6)	-79.04	13.62*
HaNPV	-	403.5 (63.3)		
Trichogramma	-	580.7 (164.1)		
Nimboli	-	587.3 (94.1)		
Intercrop seed	58.0 (32.0)	32.8 (16.6)	-44.14	4.36**
Total	2,408.0 (849.0)	2,096.8 (306.7)	-12.92	2.18*
Manure and fertilizers				
Farmyard manure	342.4 (502.5)	377.8 (395.9)	+10.34	0.36
NPK	940.3 (300.8)	1,076.2 (324.1)	+14.44	1.94*
Seed	797.1 (396.3)	565.6 (136.4)	-29.04	3.50**
Bullock labor	350.0 (98.9)	288.4 (71.2)	-17.60	3.22**
Human labor	3,185.3 (589.5)	3,662.0 (769.8)	+14.96	3.10**
Total variable cost	8,023.2(1886.3)	8,066.7(1371.0)	+0.54	0.12
Returns				
Gross returns	17,600.8(3272.1)	21,792.8(4782.1)	+23.92	4.57**
Net returns	9,577.6(3735.1)	13,726.1(4821.3)	+43.31	3.84**

Figures in parentheses are standard deviations.
* = significant at 5 % level; ** = significant at 1% level.

Cost Effectiveness

The cost per unit of output under different technological options is an indicator of their economic efficiency. Table 4 presents the cost of cotton production ha^{-1} with and without following IPM practices. With IPM, the cost of production was Rs 7.40 kg^{-1}, about 19% less than on non-IPM farms. On IPM farms, the cost of plant protection ha^{-1} of output (including the cost of inputs, their application and labor incurred in hand-picking insect larvae) was 21% less than on non-IPM farms. The cost of plant protection inputs alone was less by about 30%. These differences are statistically significant. Thus, IPM emerges as a cost-reducing strategy with economic potential to substitute chemical-based pest control.

Table 4. Cost of production (Rs kg^{-1}) under IPM and non-IPM situations.

Inputs	Non-IPM situation	IPM situation	Change over non-IPM situation (%)	t-statistics
Total variable cost	9.1169	7.4026	-18.80	2.79**
	(2.5465[1])	(2.9479)		
Cost of plant protection inputs	2.7363	1.9237	-29.70	3.92**
	(1.1261)	(.6917)		
Total cost of plant protection	4.4618	3.5194	-21.12	2.90**
	(1.5423)	(1.3544)		

[1] Figures in parentheses are standard deviations.

** = significant at 1% level.

IPM's Contribution to Additional Returns

There were substantial yields or return gains on adopting IPM practices, though not all could be attributed to IPM alone. The intensity of some of the inputs on IPM farms was higher than on non-IPM farms, which could have partially contributed to the additional returns. The shares of IPM and inputs in additional returns are given in Table 5.

IPM's contribution to enhanced gains was 56%. This vindicates earlier observations that IPM has the economic potential to substitute chemical methods of pest control. Changes in input costs accounted for the rest of the difference in gross returns. Human labor appeared to be the most important input, accounting for more than two-thirds of the difference in gross returns between IPM and non-IPM farms. This was expected because of the additional labor needed to harvest the additional output on IPM farms. The share of the other inputs in additional returns was not significant.

Table 5. Decomposition of gains in gross returns ha^{-1} due to IPM and inputs.

Sources of difference	Absolute contribution	Contribution (%)
Difference in gross returns	0.2062	100.00
Difference in gross returns due to IPM	0.1147	55.65
Difference in gross returns due to inputs	0.0915	44.35
Seeds	-0.0578	-28.04
Manures and fertilizers	0.0026	1.26
Plant protection inputs	-0.0041	-1.97
Human labor	0.1379	66.93
Bullock labor	0.0127	6.17

Impact on Labor Use

In view of the higher expenditure on human labor on IPM farms and its substantial contribution to additional returns, IPM's impact on labor use needs to be examined. The higher cost of human labor could have been due to differences in labor intensity, composition of labor used and differential wage rates for male and female workers as well as the difference in wage rates between IPM and non-IPM villages. No difference in wage rate for male (Rs 40) and female workers (Rs 25) was observed across villages. Given the wage rate, the higher expenses could be attributed to differences in labor intensity and its composition. Estimates of sexwise and activitywise labor use ha^{-1} on IPM and non-IPM farms (Table 6) enable us to discern the impact of IPM on labor use and gender equity.

Mean labor use on IPM farms was 133 mandays, about 25% higher than on non-IPM farms. There were two major sources of difference in labor intensity. Firstly, IPM itself is a labor-intensive method as hand picking of insect larvae is a widely followed practice. Labor use in collecting insect larvae was estimated to be 12.4 womandays ha^{-1} on IPM farms and 0.3 womandays ha^{-1} on non-IPM farms. There was 24% higher labor used in manual weeding on IPM farms than on non-IPM farms. Intensity of labor use in other activities such as application of pesticides/bio-pesticides did not differ much between IPM and non-IPM farms. Secondly, about 36% more labor input was used for picking the additional yield on IPM farms. The difference in labor used in other activities between IPM and non-IPM farms was marginal.

Table 6. Activitywise use of male and female labor in cotton production under IPM and non-IPM situations (person day ha^{-1}).

Crop activity	Non-IPM situation		IPM situation	
	Male	Female	Male	Female
Field preparation	5.82	9.20	4.83	8.79
Planting	1.56	5.70	2.16	6.21
Manuring	0.81	2.08	0.31	1.46
Fertilizer application	1.04	3.48	1.46	3.54
Pesticide spraying	15.67	0.10	0.18	-
NPV spraying	-	-	2.45	-
Trichogramma release	-	-	4.23	-
Spraying of NSKE	-	-	6.55	0.13
Mechanical collection of larvae	-	0.33	-	12.43
Weeding	-	22.23	-	27.45
Intercropping (harvesting)	-	6.66	-	8.08
Picking	-	31.44	-	42.90
Total	24.90	81.22	22.19	110.91

Female labor use overwhelmingly outweighed male labor use under both IPM and non-IPM situations. The contribution of females to total labor use (persons day^{-1}) was 77% on non-IPM farms and 81% on IPM farms. Thus, it was found that the composition of labor used did not contribute much to the observed difference in human labor costs.

There was a distinct gender-based division of labor for different cropping activities. Manual collection of insect larvae, weeding and harvesting were carried out solely by females. Their share in labor used in field preparation, planting, manuring and application of fertilizers was higher than that of males. Spraying of pesticides and bio-pesticides and the release of bio-agents were entirely in the domain of males.

These findings indicate that switching over to IPM might demand additional labor, subject to the nature of IPM practices and its yield-saving potential. Activities such as hand-picking of insect larvae, manual weeding and harvesting (if the yield-saving potential of IPM is more) would render IPM into a labor-intensive technique, with implications on its adoption and the labor market. Adoption of IPM may generate opportunities both on and off the farm. The off-farm employment opportunities would be in the areas of production and marketing of new pest control products.

Adoption of IPM practices is likely to be influenced by labor market conditions. In labor-surplus, low-wage areas, IPM adoption is expected to be higher, while in labor-scarce, high-wage areas, it may not be a preferred option. This would depend on the additional costs due to and returns from IPM.

Conclusions

Integrated pest management appears to be an effective alternative to chemical pest control. The IPM package implemented on farmers' fields was bio-intensive, with bio-control agents and cultural control being the major components. This could almost completely reduce pesticide use without any adverse effect on crop yield. IPM's pest-killing efficiency was higher; so was its potential to conserve natural enemies of insect pests. Per hectare crop yield was 24% higher and unit cost of production was 19% less on IPM farms.

Gross returns from IPM farms were 24% higher compared to non-IPM farms, to which IPM contributed about 56%. Inputs like fertilizers, draught power and seed did not contribute significantly to the observed difference whereas human labor's contribution was substantial. As such, intensity of human labor use was greater on IPM farms on account of activities such as hand-picking of insect larvae, manual weeding and harvesting of additional output.

Prospects of IPM

Though IPM as a concept has since long been in existence in the form of cultural, physical and natural interventions, it is only in recent years that it has been revitalized in response to the increasing technological failure of chemical pest control technology and its negative impact on the environment and human health. One of the important features of the emerging concept is the use of laboratory- or commercially-produced bio-agents and bio-pesticides rather than relying on the natural control of pests by their enemies.

The findings of this study have some important implications for plant protection strategies, especially the use of bio-agents and bio-pesticides in India, where IPM is still in a nascent stage. IPM is akin to a new technology; therefore its widespread adoption is likely to be constrained by a number of socioeconomic and policy-related factors. Farmers are risk averse and have since long been using chemical pesticides to limit crop loss. A switchover to IPM may require considerable effort and resources. The first step, therefore, would be to demonstrate IPM's economic benefits to farmers through on-farm participatory research and demonstrations, and widely publicize the higher benefit-cost ratios obtained elsewhere since farmers are more impressed by economic benefits rather than environmental and health benefits[6] .

Since IPM is a knowledge-intensive process, it requires extension workers and farmers with sufficient knowledge of insect pests and their life-cycles, pest-predator relationships, timings and methods of application of bio-agents and bio-pesticides, pest-suppressing cultural practices, etc. A lack of understanding at any level would render any IPM program unsuccessful. So the pivotal objective of any IPM program should be the empowerment of extension workers and farmers in the use of tools and methods of IPM. In this context, central and state governments have adopted a three-tier approach encompassing master trainers, agricultural extension officers and farmers through the establishment of Farmers' Field Schools. Since 1994-95, about 1000 master trainers, 27,000 agricultural extension officers and 1.9 lakh farmers have been trained through more than 6000 Farmers' Field Schools. These efforts are, however, insignificant considering the dimensions of the cropped area in the country.

Another related issue is community participation in pest management, especially in IPM that involves the use of bio-agents and bio-pesticides. The use of chemical pesticides in the vicinity of IPM farms adversely affects the activities of bio-agents and bio-pesticides. Community action is important in internalizing such negative externalities and in economizing on information and pest control costs (Rook and Carlson 1985). Involvement of local institutions such as panchayats and NGOs would be helpful.

Once they experience the benefits of IPM, farmers will willingly adopt it provided there is a committed supply of inputs. For instance, the IPM program in Ashta is continuing not because of the free supply of bio-control inputs, but because of their committed supply. The implementing agencies are gradually withdrawing the free supply of bio-control inputs by culling out some of the beneficiaries, though they have arranged to supply these inputs at a cost from a

---

[6] Farmers being profit maximizers, they seek savings in cost and yield advantages rather than environmental benefits while switching over to a new technology. Since there is no premium on output price for low chemical produce in India, the health and environmental benefits of reduced pesticide use are often heavily discounted by farmers.

producer in Nanded town. It may be noted that none of the culled out beneficiaries has discontinued the use of these inputs. Another notable impact of the program has been the village-to-village and farmer-to-farmer spread of IPM practices, revealed by a later survey by the authors in the villages around Ashta. The extent of adoption, however, was found to be limited. These evidences indicate that a committed supply of inputs would be a key factor in switching over to and maintaining the processes of IPM. The production of important bio-control inputs such as *Trichogramma* spp., Nuclear Polyhedrosis Virus and *Crysoperla carnea* is currently limited to 251 public sector and 105 private sector laboratories. There is therefore a need to commercialize the production of bio-control inputs.

Economic incentives such as giving wide publicity to its improved benefit-cost ratio, empowerment of clients through training and a committed supply of IPM inputs can spur widespread adoption. However, disincentives to use chemical pesticides such as the withdrawal of subsidies and the imposition of taxes act as incentives for the adoption of IPM practices. On the other hand, subsidies, tax exemption on bio-control inputs, IPM-linked institutional credit and insurance, awards and recognition to IPM farmers, etc. can have a significant impact on IPM adoption. One of the incentives, hitherto lacking in India, is the premium price paid on pesticide-free or low-pesticide residue products primarily due to the lack of a domestic market for them. Further, lack of standards to distinguish pesticide-free produce from contaminated ones makes consumers diffident about the quality of the produce. Nonetheless, a price premium could be an important factor in increasing the adoption of IPM practices.

India's rich bio-diversity and huge crop production dimensions offer considerable scope for industry to commercialize available technologies developed using flora and fauna. More than 160 natural enemies including pathogens, parasitoids and predators have been studied for their potential pesticidal properties. Some of these like NPV, *Bacillus thuringiensis, Trichoderma, Trichogramma, Tricospilus, Elasmus, Eriborus, Chilocorus, Chrysopa*, *Nephus* and *Scymnus* have proved their efficacy under both experimental and field conditions. Besides, several plants such as neem, Chinaberray, mahogany and turmeric have been reported to have pesticidal properties. Among these, neem is widely available and has a wide range of host pests. To tap this potential, a level playing field has to be created through policy instruments. Regulatory and registration processes must be eased. Regulatory and registration processes for some products like neem pesticides, NPV and *Bacillus thuringiensis* have been evolved keeping in view their pest-killing efficiency and ecological benefits. In addition, cooperation from India's well established pesticide industry is a must. The industry needs to gradually diversify its product portfolio towards ecofriendly bio-pesticides.

Acknowledgement

The authors are thankful to D Jha, P K Joshi, S N Puri and T Haque for their valuable suggestions on this paper.

References

Bisaliah, S. 1977. Decomposition analysis of output change under new production technology in wheat farming: some implications to returns on research investment. *Indian Journal of Agricultural Economics* 32 (2):193-201.

Chand, R. and **Birthal, P.S.** 1997. Pesticide use in Indian agriculture in relation to growth in area and production and technological change. *Indian Journal of Agricultural Economics* 52(3):488-498.

Chowdry, K.R. and **Seetharaman, S.** 1997. Economic evaluation of integrated pest management technology in cotton farming in Guntur district, Andhra Pradesh. *Indian Journal of Agricultural Economics* 52(3):544-545.

CICR (Central Institute of Cotton Research).1988. *Annual Report*. Nagpur, India: Central Institute of Cotton Research.

CICR (Central Institute of Cotton Research).1994. *Annual Report.* Nagpur, India: Central Institute of Cotton Research. .

Dhaliwal, G.S. and **Arora, R.** 1993. Changing status of insect pests and their management strategies. Pages 98-145 *in Changing scenario of Indian agriculture* (Gill, K.S., Dhaliwal, G.S., and Hansara, B.S., eds.). New Delhi, India: Commonwealth Publishers.

Jayraj, S. 1989. Advances in biological means of pest control. Pages 181-187 *in The Hindu Survey of Indian Agriculture.* Chennai, India: Kasturi and Sons Ltd.

Kishor, N.M. 1997. Pesticide externalities in coastal Andhra Pradesh. Pages 589-612 *in Natural resource economics: theory and application in India*

(Kerr, J.M., Marothia, D.K., Singh, K., Ramasamy, C., and Bentley, C.R., eds.). New Delhi, India: Oxford and IBH.

Kumar, N. 1992. Biological pest control becomes established technique in Asia. *Biotechnology and Development Monitor* 13(9) .

NCIPM (National Centre of Integrated Pest Management). 1997. *Annual Report*. New Delhi, India: National Centre of Integrated Pest Management. 80 pp.

NCIPM (National Centre of Integrated Pest Management). 1998. *Annual Report*. New Delhi, India: National Centre of Integrated Pest Management. 80 pp.

Oerke, E.C., Dehne, H.W., Schohnbeck, F. and **Weber, A.** 1995. Pages 1-22 *in Crop production and crop protection; estimated losses in major food and cash crops*. Elsevier, Amsterdam.

Ram, S. and **Gupta, M.P.** 1990. Integrated pest management in Lucerne (*Mdicago sativa* L.) and its economics in India. *Tropical Pest Management* 36: 258-262.

Regev, U., Gutierrez, A.P. and **Feder, G.** 1976. Pests as a common property resource: a case study of alfalfa weevil control. *American Journal of Agricultural Economics* 58(2):186-197.

Rola, A.C. and **Pingali, P.L.** 1993. *Pesticides, rice productivity, and farmers' health — an economic assessment*. The Philippines, Manila: International Rice Research Institute; and Washington, USA: World Resources Institute. 100 pp.

Rook, S.P. and **Carlson, G.A.** 1985. Participation in pest management groups. *American Journal of Agricultural Economics* 67(3):563-566.

Srinivas, K.R. and **Krishnamoorthy, P.N.** 1991. Indian mustard as a trap crop for management of major lepidopterous pests on cabbage. *Tropical Pest Management* 37:26-32.

Unni, K.K. 1996. Role of agrochemical industry in the Ninth Five Year Plan. Paper presented at the *National Seminar on Agricultural Development Perspective for the Ninth Five Year Plan*, Indian Institute of Management, Ahmedabad, India.

25

Impact Assessment of Improved Management Practices for *Phytophthora* Foot Rot Disease in Black Pepper

M S Madan,[1] Y R Sarma,[1] K V Peter,[2] K Sivaraman,[3] S Varma,[2] V Srinivasan[1] and P Singh[4]

Introduction

India is one of the important producers of black pepper, accounting for about 50% of the global area under its cultivation. However, its productivity is low (294 kg ha^{-1}) compared to Thailand (3594 kg ha^{-1}), Malaysia (1888 kg ha^{-1}), Vietnam (1100 kg ha^{-1}), and Brazil (883 kg ha^{-1}). Black pepper cultivation in India is concentrated in the southern states of Kerala and Karnataka.

Disease is the main yield-limiting factor in black pepper. Among the various diseases, *Phytophthora* foot rot inflicts large-scale deaths in black pepper vines, causing an estimated annual loss of around 2000 t valued at Rs 320 million. Realizing the gravity of the situation, the Indian Institute of Spices Research and the State Agricultural Universities in Kerala and Karnataka jointly developed a technology package for the management of the disease. The technology was demonstrated on farmers' fields in Kerala during 1994-98 through the Integrated

Madan, M.S., Sarma, Y.R., Peter, K.V., Sivaraman, K., Varma, S., Srinivasan, V. and **Singh, P.** 2005. Impact assessment of improved management practices for *Phytophthora* foot rot disease in black pepper. Pages 281-292 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

[1] Indian Institute of Spices Research, Calicut 673 012, Kerala, India.

[2] Kerala Agricultural University,Thrissur, Kerala, India.

[3] Indian Institute of Sugarcane Breeding, Coimbatore, Tamil Nadu, India.

[4] Government of India, Krishi Bhavan, New Delhi 110 001, India.

Program for Development of Spices, a Central Government-sponsored scheme. Subsequently in 1999, a survey was carried out to assess its impact and the constraints to its adoption.

The Technology Package

The recommended package consisted of improved cultural practices and chemical control measures.

Phytosanitary Measures

These consisted of:

- Uprooting of infected and dead vines, and burning them to check the population buildup of pathogens, and drenching the spot with 5 liters of copper oxychloride (0.2%)
- Replanting disease-free rooted cuttings in pits a year after the dead vines have been removed
- Burning dry trash in pits and drenching them with 0.2% copper oxychloride, 15 days before planting
- Providing good drainage where the plantation is prone to water stagnation
- Maintaining a legume or grass cover during the rainy season to reduce soil splash and consequent foliar infection
- Lopping-off branches of live standards during May to ensure better light penetration and to reduce humidity build-up
- Practising minimum tillage to avoid root injury
- Avoiding frequent movement of personnel from diseased gardens to healthy ones.

Chemical Control Measures

- Spraying aerial parts of the plant with 1% Bordeaux mixture @ 2 liters vine^{-1} round^{-1}
- Drenching the basin of the vine with 3-5 liters of (0.2%) or 1% Bordeaux mixture round^{-1}

Table 1. The time schedule for the application of chemical pesticides on black pepper.

Time	Operation
Mar-Apr	Cultural operations and phytosanitary measures
Second fortnight of May to first week of Jun	First round (pre-monsoon) of chemical control measures
Aug-Sept	Second round (pre-monsoon) of chemical control measures
Oct	Third round of soil drenching if the northeast monsoon is prolonged

Application Time Schedule

To ensure effective disease control, chemical pesticides have to be applied as per the schedule given in Table 1.

History of Technology Development

Research to tackle this problem was taken up through projects of the Indian Institute of Spices Research. The etiological and epidemiological investigations led to the identification of cultural practices that result in reduced disease spread. The causal organism was identified as *Phytophthora capsici*. Factors conducive to disease development were identified, among which temperature and rainfall were found to have a positive correlation with disease incidence. *Phytophthora* being a wet-weather pathogen, the continuous wet period from June to August in the pepper belt is highly congenial for its emergence and spread. Since the disease is soilborne, the poor phytosanitation in pepper gardens makes disease management difficult. The contact copper fungicides are prone to leaching during heavy monsoons. Given these circumstances, research efforts evolved a package to suppress *Phytophthora* foot rot disease. Details of the area over which the technology was applied and farmers covered are given in Table 2. About 58% of the pepper growers and 50% of the area could be brought under the scheme.

Methodology

Data on size, distribution, cropping pattern, use of human labor and material inputs with emphasis on plant protection were collected from farmers. The inputs and outputs were valued at 1998-99 prices.

Table 2. District-wise area under black pepper which was covered by the program (1997-98)[1].

District	Total area (ha)	Area brought under the program (ha)	Number of growers who benefitted
Idukki	68,400	32,000	74,800
Wayanad	42,139	28,000	49,785
Calicut	15,962	9000	26,362
Kannur	14,815	14,650	73,250
Kasaragod	4251	4000	11,150
Kerala	81,550	87,650	235,347

[1]A total of 135,829 (57.71%) farmers were trained.
Source : Department of Agriculture, Government of Kerala.

The physical and financial aspects of the scheme were evaluated in terms of the following factors:

- timing of the disbursement of inputs in relation to needs
- effective distribution of material from the development agency to farmers
- consistency between the training provided and chemicals supplied for application.

Sampling Procedure

A field survey was carried out in Idukki, Wayanad, Calicut, Kannur, and Kasaragod districts of Kerala during Feb-May 1999. A sample of 134 farmers was selected in consultation with local government agencies using a stratified random sampling technique. Other participants in the pepper production system such as traders and development workers were also contacted to elicit their opinions on the project and its impact on disease management.

Analytical Techniques

Simple statistical techniques were used to study farmers' level of knowledge of suggested control practices, and their adoption. A teacher-prepared knowledge test as suggested by Anastasi (1961) was constructed using seven chemical control practices and nine cultural practices as recommended in the package.

Responses were sought on a list of knowledge items relating to the two practices, with the correct response obtaining a score of 1 and an incorrect one getting a score of 0. The raw knowledge score of each individual was converted into a knowledge index using the following formula:

$$\text{Knowledge index} = \frac{\text{Number of correct responses}}{\text{Total number of knowledge items}} \times 100$$

The respondents were grouped into high, medium and low categories by taking the mean and standard deviations as a measure of control.

The adoption quotient as suggested by Sengupta (1967) was calculated as follows:

$$\text{Adoption quotient} = \frac{\text{Adoption score of the respondent}}{\text{Maximum adoption score one could get}} \times 100$$

A score of 3 was given for very high level of adoption, 2 for medium and 1 for low level of adoption. Since all the respondents had adopted the practices, there was no 0 score for nonadoption.

Adoption of Improved Technology

Extent of Adoption of Cultural Practices

Maintaining plant hygiene, disease-free nursery stock and better drainage in the garden are instrumental in reducing disease incidence. Pruning runner shoots and maintaining grass cover too reduce disease incidence and its spread. Application of fertilizer and proper postharvest management play a key role in improving productivity. Fields of sample farmers were visited to examine the prevailing phytosanitary conditions. Farmers were questioned on their awareness about and adoption of various phytosanitary measures and cultural practices. Soil samples were collected to ascertain the application of copper oxychloride. Answers were sought on the adoption and nonadoption of certain practices. Based on this information, awareness and adoption quotients were worked out. About 97% of the farmers in the region were aware of the program and its components (Table 3). About 81% of the respondents expressed their satisfaction with it. These figures confirm the overwhelming success of the technology.

Table 3. Awareness and adoption of cultural control measures to manage *Phytophthora* foot rot in black pepper.

	Adoption level (%)					
Particulars	**Calicut**	**Kannur**	**Kasaragod**	**Wayanad**	**Idukki**	**All districts**
Awareness about the program	98.0	94.0	96.0	98.0	99.0	97.0
Opinion about its usefulness and effectiveness	77.5	79.7	83.0	82.0	85.0	81.4

Cultural practices such as application of manure and fertilizer were not on the lines of the recommended agronomic practices and as per time schedule. Weeding and irrigation were not practised in most of the gardens. Farmers with many plantation crops in their fields gave secondary importance to black pepper. In all, more than 50% of the pepper gardens were maintained. However, the recent spurt in pepper prices has drawn farmers' attention to the crop. Farmers with better contact with agricultural extension officers maintained their gardens based on the recommended package of practices.

Fertilizer Application

Among the farmers surveyed, barely 32% applied chemical fertilizers. Of the remaining 68%, about 60% had discontinued their application 3-4 years ago, while the rest reported never having applied chemical fertilizer to pepper vines.

Application of Organic Manure

This is a common practice followed by more than 70% of the farmers. On an average, farmers applied nearly 4 kg of organic manure per vine. The quantity applied varied from vine to vine in the same field depending on its age. Due to the uneven terrain, the cost of application was greater than the cost of manure. Farmyard manure, which is mostly brought from neighboring states, costs Rs 7500 per truckload. Bone meal and chicken manure are the other nonchemical fertilizers used by pepper growers. Application of vermicompost (own and purchased) was reported by farmers in Idukki district.

Application of Neem Cake

Application of neem cake @ 1 kg vine^{-1} is one of the essential components of *Phytophthora* foot rot management. Most of the farmers understood the importance of applying neem cake, but the nonavailability of quality material was a major constraint. Barely 20% of the farmers applied the full dose (1 kg vine^{-1}), while another 40% applied 400-500 g vine^{-1}. To ensure desirable oil content (at least 3-4%) and avoid adulterated neem cake, farmers crushed purchased neem seeds before application.

Irrigation is rarely practised in the plains. About 35% of the farmers reported using drip irrigation in the high ranges. In the plains, where black pepper is intercropped with arecanut, irrigation is provided at regular intervals during summer months. Mulching of vines and pruning of standards are fairly well-known practices in Wayanad and Idukki districts.

Phytosanitation

There were nine recommended cultural (phytosanitary) practices to be followed for the successful management of *Phytophthora* foot rot disease. More than 66% of the farmers reportedly followed these practices. However, the adoption level of the package varied across the districts. The maximum adoption was in Kasaragod district (79.74%), where well-maintained fields showed the least effect of *Phytophthora* foot rot disease (Table 4). Idukki and Wayanad too revealed equally good adoption levels. An overall adoption quotient of 94.44% indicated the successful implementation and impact of the technology.

The respondents were grouped into high, medium and low categories by considering mean and standard deviations as a measure of control. Farmers were grouped on the basis of the level of adoption of cultural practices (Table 5).

Chemical Control Measures

Pre- and post-monsoon foliar sprays of chemicals as recommended in the package were given by 46% of the farmers. The rest used sprays at least once in a crop year (Table 6). Application of Bordeaux mixture (1%) as a spray component of the total recommended package was the maximum in Idukki district (62%) and minimum in Kannur district (33%). Almost a similar pattern was observed for drenching too. Hardly 36.6 % farmers drenched the basins of

Table 4. Cultural practices for the management of *Phytophthora* foot rot and their adoption (%).

Cultural practices	Districts					
	Calicut	Kannur	Kasaragod	Wayanad	Idukki	All
Use of disease-free plant material	89.25	73.26	89.21	90.32	83.33	85.07
Avoiding soiled runner shoots as plant material	92.0	82.0	73.34	90.32	83.33	84.19
Avoiding low-lying areas	78.18	91.50	89.00	67.74	91.66	83.62
Collection and burning diseased vines	60.40	52.3	79.42	77.41	83.33	70.57
Shade regulation	47.60	67.80	67.64	74.19	41.66	59.78
Not disturbing the basins (digging)	92.73	94.00	92.37	93.55	91.67	92.86
Basal pruning	40.90	33.00	73.67	70.96	70.83	57.87
Avoiding entry of cattle	76.36	80.60	90.00	80.65	70.83	79.62
Application of neem cake	48.66	37.33	63.00	45.16	41.67	47.16
Mean deviation	69.56	67.97	79.74	76.70	73.15	73.42
S.D.	20.53	22.42	10.87	14.94	19.33	26.52
Variance	421.62	502.86	118.09	223.17	373.74	703.28
Adoption quotient	83.33	88.88	100.00	94.44	88.88	94.44

Table 5. Grouping of farmers based on the level of adoption (%) of cultural practices.

Category	Districts					
	Calicut	Kannur	Kasaragod	Wayanad	Idukki	All
High (X± ½ SD)	79.18 and above	79.18 and above	85.18 and above	84.17 and above	82.82 and above	79.52 and above
Medium (X± ½ SD)	59.4 to 79.82	56.8 to 79.2	74.4 to 85.2	69.2 to 84.2	63.5 to 82.8	53.1 to 79.5
Low (X± ½ SD)	59.3 and below	56.8 and below	74.3 and below	64.2 and below	63.5 and below	53.0 and below

the vines twice with copper oxychloride as recommended. Fewer farmers adopted chemical control measures compared to phytosanitary measures, the reason being insufficient and irregular input supply.

The knowledge index for chemical control measures was as high as 97% and the estimated overall adoption quotient 87.5% (Table 6). A detailed analysis of the data reveals that it was mostly large and medium size farmers who adopted the recommended practices religiously (Table 7). This was so because they purchased the same chemicals in bulk to be used for other plantation crops. Besides, they were getting subsidized chemicals for other plantation crops under various developmental schemes.

Constraints to Adoption

Reasons for the nonadoption of the recommended practices were:

- Nonavailability of quality (disease-free) plant material from reliable sources
- Nonavailability of pest- and disease-resistant varieties
- Nonavailability of chemicals on time
- Irregular and insufficient supply to cover the entire area
- Inability to buy the exorbitantly priced chemicals from the local market
- Nonavailability of labor during peak seasons
- High labor cost
- Farmers' reluctance to buy and use
- Only a negligible number of farmers reported the ineffectiveness of the scheme as a reason for nonadoption.

Impact of Improved Technology

Fall in Disease Incidence

A review of literature on the level of disease prevalent in the pepper fields indicated that the number of vines lost due to quick wilt was 25.72% in 1994. This survey showed 3-7% loss.

Pepper growers are now more aware about the disease. Nearly 33% of them were willing to continue the recommended chemical control measures even if the supply of subsidized chemicals was discontinued. Farmers began identifying the infected fields from where they had once sourced their planting

Table 6. Level of adoption of chemical control measures for the management of *Phytophthora* foot rot in black pepper.

	Adoption level (%)					
Measures	**Calicut**	**Kannur**	**Kasaragod**	**Wayanad**	**Idukki**	**All**
Awareness about the program	98.0	94.0	96.0	98.0	99.0	97.0
Farmers were trained in application of technology	63.0	57.8	68.7	83.3	90.7	72.7
Insufficient input (chemicals) supply	68.0	48.0	92.0	94.0	96.0	79.6
Inputs (chemicals) not supplied in time	82.0	62.0	83.0	84.0	92.02	80.6
Spraying on foliage (twice) as recommended	37.0	33.0	43.0	55.0	62.0	46.0
Drenching the basin of the vine with COC (twice) as recommended	33.1	31.7	39.0	37.0	43.0	36.8
Opinion about the scheme's usefulness and effectiveness	77.5	79.7	83.0	82.0	85.0	81.4
Mean deviation	65.5	58.0	72.1	83.3	81.1	70.6
S.D.	23.62	23.09	22.94	13.82	20.76	21.44
Variance	557.83	533.27	526.47	191.22	430.84	459.67
Adoption quotient	87.50	81.25	87.50	81.25	87.50	87.50

material. Now, only properly guided and protected runner shoots from healthy vines are being used as plant material. As a result, the number of vines per unit area has risen; while it was only 252 acre^{-1} in 1992, the present survey revealed an average of 479 stands acre^{-1} .

Impact on Area and Productivity

The area under the crop showed a marked increase in Wayanad (6.54%) and Idukki (3.37%) districts over the base year (1994). However, the overall growth rate in area was negative (-0.78%) (Table 8).

Table 7. Grouping of farmers based on the level of adoption (%) of chemical control measures.

Category	Districts					
	Calicut	Kannur	Kasaragod	Wayanad	Idukki	All
High (X± ½ SD)	$\geq$ 77.3	$\geq$ 69.6	$\geq$ 83.6	$\geq$ 90.2	$\geq$ 91.5	$\geq$ 81.3
Medium (X± ½ SD)	53.7 to 77.3	46.5 to 69.6	60.6 to 83.6	76.4 to 90.2	70.7 to 91.5	59.8 to 81.3
Low (X± ½ SD)	$\leq$ 53.7	$\leq$ 46.5	$\leq$ 60.6	$\leq$ 76.4	$\leq$ 70.7	$\leq$ 59.8

Macro-level Impact

In the country as a whole, the impact was observed in terms of changes in area, production and productivity. Area declined by about 5%, but yield hectare^{-1} increased by about 18% (Table 9).

Table 8. Growth in black pepper area in Kerala.

District	Annual growth (%)
Wayanad	6.54
Idukki	3.37
Calicut	-3.10
Kannur	-3.99
Kasaragod	-5.11
Overall	-0.78

Table 9. Changes in area, production and yield of black pepper, 1993-94 to 1997-98

Area	1993-94	1997-98	Change (%)
Area (ha)	190990	181550	-4.94
Production (t)	51110	57270	12.05
Productivity (kg ha^{-1})	268	315	17.70
Increase in productivity (kg ha^{-1})	47.45	-	

Table 10. The economics of adopting chemical control measures for *Phytophthora* foot rot management in black pepper.

Item	Amount (Rs ha^{-1} $year^{-1}$)
Cost of technology (including application cost)	3233
Gross returns	7592
Net benefit	4359
Benefit cost ratio	2.3

Farm-level Impact

The economic impact of the technology at the farm level was computed by comparing the monetary value of the package per unit area along with application cost (cost of the technology) with output value. A benefit-cost ratio of 2.3 indicated the financial feasibility of the technology (Table 10).

Conclusions

Pepper-growers showed a high level of knowledge about various phytosanitary, cultural and chemical measures for the management of *Phytophthora* foot rot disease. However, irregular supply of inputs was the major constraint to the adoption of chemical control measures. Farmers were convinced about the benefits of the recommended practices and were willing to continue their use.

Reference

Anastasi, A.T. 1961. *Psychological testing*. New York, USA: Macmillan and Co.

ABSTRACTS

Determinants of Scientific Productivity

Premlata Singh
Indian Agricultural Research Institute, New Delhi 110012, India

Scientific productivity, perceived as reflecting resource-use efficiency, effectiveness and the achievement of organizational goals, has become a multi-dimensional phenomenon. Analyzing scientific productivity assumes importance in view of the static or declining government and donor support for agricultural research in many developing countries during the past decade. Under these circumstances, many organizations may opt to freeze or reduce staff and concentrate on improving the quality of scientists and their research programs.

This paper raises complex questions pertaining to scientific productivity. What are the criteria for evaluating it? How does one foster high quality research? Can we foresee the qualities and conditions that will have greater social impact? Answers to these questions have theoretical and practical implications. Studies indicate that mainly judges' ratings, publications and patents have been used to measure scientific productivity. Studies indicate that scientific productivity is governed by institutional as well as personal factors. The main institutional factors include motivation by peers, autonomy, research facilities and interpersonal communication. The management should facilitate and not control. The dominant personal attribute is professional qualification and the age of its attainment. Professional commitment too has a bearing on scientific productivity. Academic qualifications and the mother's profession were found to be positively associated with the productivity of women scientists. Finally, the paper raises issues on ways to improve scientific productivity in the Indian agricultural research system.

Impact of Agricultural Research on Poverty Alleviation in India

P K Joshi, Suresh Pal and N P Singh
National Centre for Agricultural Economics and Policy Research, New Delhi 110012, India

Investment in agricultural research has significantly enhanced agricultural and livestock production in India. However, how such research has contributed to the country's poverty alleviation program has not yet been analyzed. Available estimates suggest that though the number of people below the poverty line has remained around 320 million, the poverty ratio declined from 55% in 1973-74 to 36% in 1993-94. Estimates further suggest a wide spatial variation in declining poverty in different agroecoregions.

This study attempts to assess the role of agricultural research in poverty alleviation in different agro-ecoregions. Its specific objectives were to: (i) develop a framework to assess the impact of research investment on various indicators of poverty; (ii) examine the role of specific research outputs in terms of indicators of poverty, and (iii) develop a procedure to screen agricultural research in order to enhance its prospects for a positive impact on the poor.

The study delineated five agro-ecoregions — arid, coastal, hill and mountain, irrigated and rainfed — and developed few indicators of poverty to relate with investment on agricultural research. A positive association was observed between research outputs and poverty alleviation. The harsh and fragile environment (rainfed and hill and mountain) yielded few acceptable research outputs while the better-endowed region (irrigated) produced a large number of successful technologies, which significantly contributed to enhancing the food security of that region as well as that of the fragile environments. Based on results from the various agro-ecoregions, the study proposed methods to screen agricultural research to enhance the livelihood of people depending on both fragile and better-endowed agro-ecoregions.

Wheat Research: An Assessment of Gains in Uttar Pradesh

R K Singh, G N Singh and Ziauddin Ahmed
CSA University of Agriculture and Technology, Kanpur, India

The introduction of genes (Rht) for reduced height into local wheat varieties dominated wheat production after 1966-67. These showed very significant achievements. The two genes (Rht_1 and Rht_2) were the sources in all semi-dwarf varieties grown commercially in the entire Indo-Gangetic irrigated region. About 98% of the area grown to wheat in this area is now covered by such varieties. This study examines diversity in wheat across different production zones by extrapolating available information. Large-scale adoption of dwarf and semi-dwarf wheat varieties was witnessed. Crop yields increased from a near-static level (1950-51 to 1966-67) to about 48 kg ha^{-1} per year (1966-67 to 1997-98).

Impact of Winter Maize Production Technology on the Farm Economy: A Case in Flood-prone Farms of Bihar

C P Yadav, Janmejaya Kumar and Namrata Kumari
Rajendra Agricultural University, Pusa, Samastipur, Bihar, India

Flood-prone farms in Bihar face food insecurity due to recurring floods. Standing rainy-season crops get damaged and a delay ensues in sowing postrainy-season crops, adversely affecting agricultural production. However, adopting HYVs and winter maize production technologies have opened up avenues for enhanced incomes. This study was undertaken during the 1995-96 crop year to assess the impact of agricultural research on the farm economies of 40 farmers (15 small and 25 marginal) of Dinmo Panchayat in Darbhanga district of Bihar. The region faces recurring floods.

Results indicated that almost all farm families adopted winter maize in their cropping pattern in the postrainy season. Its share in the cropping pattern varied from 20 to 38% in the study area and was proportional to the size of the farms as maize is grown both as a subsistence and a commercial crop. The crop responded to yield-augmenting inputs such as irrigation and fertilizer. Adopting the winter maize production technology led to a nearly fourfold increase in yield compared to rainy-season maize. The cost of production fell by only 50%, and in some cases 70%. Gross and net incomes also increased significantly on the farms. Women folk of the farm families were more empowered — they had more fuel in the form of stubble from maize stalk and maize stone. Fodder and feed needs of the farm animals too were met by the adoption of maize, leading to more milk production from milch animals. However, farmers were constrained in bringing more areas under winter maize by improper procurement in the area, unassured and high cost of irrigation and the lack of suitable land to sow the crop. Farmers were forced to grow fewer crops due to the greater duration of the maize crop in the fields, thereby not allowing them of upgrade their farms.

Economic Appraisal of Pulses Production Technologies: Constraints and Prospects

I P S Yadav, Masood Ali and A Srivastava
Indian Institute of Pulses Research, Kanpur, India

India saw a growth in pulse production (by 2 million tons) and yield (by 870 kg ha^{-1}) in 1996-97. However, area declined by 80,000 ha. Chickpea fared better, contributing 36% of the total production. A need was then felt to increase productivity from 623 kg ha^{-1} to 700 kg ha^{-1} by popularizing new varieties and production technologies, providing seed of improved varieties, critical inputs, sulfur, irrigation and adopting Integrated Pest Management strategies. The major research constraints limiting pulse production were the lack of genotypes with high harvest index, low productivity, poor management, lack of genetic resistance to diseases and pest, nonavailability of quality seed, high yield risk, thin markets, and so on. Increases in production would come from the existing area under pulses by adopting dry farming practices as more than 90% of the area is rainfed.

It was felt that the targeted additional production could be achieved by introducing short-duration pigeonpea in irrigated areas; expanding mung bean and urd bean cultivation during spring/summer; substituting low-yielding upland crops with pulses; intercropping pigeonpea with soybean, cotton and groundnut, mung bean/urd bean in the coastal peninsula and spring-planted sugarcane in the eastern zone; introducing French beans and pigeonpea in the postrainy season in Uttar Pradesh, Bihar, Orissa, West Bengal and Maharashtra; introducing pulse crops in high intensive crop rotations; treating seed with fungicides and culture; adopting soil moisture conservation technologies; exploiting the potential of pulse crops to trap atmospheric nitrogen through biological nitrogen fixation; providing early credit facilities to marginal/small farmers; popularizing small *dal* mills and establishing pulse-based food product industries; creating storage and marketing facilities, etc.

Results of demonstrations on farmers' fields in Kanpur Dehat showed that the adoption of improved technologies led to yield increase of 53.14% in early pigeonpea (UPAS-120), 54.40% in fieldpea (HFP-4), 34.89% in spring/summer mung bean (PDM-54 and PDM-11), and 38.84% in urd bean (PU-19) as compared to the local technology.

Impact of the AICRP on Improvement of Pulses on Pigeonpea Production in the Northeast Plain Zone

S K Singh, A K Singh and N B Singh
Indian Institute of Pulses Research, Kanpur, India

While pigeonpea production in India increased from 1.77 million tons in 1950-51 to 2.58 million tons in 1996-97, productivity per unit area has almost remained static (around 750 kg ha^{-1}) during the last 50 years, caused mainly by the nonavailability of improved varieties, susceptibility of cultivars to various biotic and abiotic stresses, lack of appropriate production technology, etc.

The All India Coordinated Research Project on Improvement of Pulses initiated research to improve the production potential of pigeonpea in the country. Sources of resistance to biotic and abiotic stresses were identified, improved varieties with better yields were released (Bahar, Narendera arhar-1, Pusa-9 and Amar) and suitable production technologies were developed. Impact was assessed by estimating the adoption of varieties and technologies developed under the Project in select districts of eastern Uttar Pradesh and some neighboring districts of Bihar during 1994-95. Farmers' perceptions on the improved technologies were sought in select villages.

Preliminary results showed that despite a 20-25% increase in yield with improved seed, only 40% of the area was covered by the varieties developed by the All India Coordinated Projects. The remaining area was still under traditional varieties. This was more so in the case of farmers with small landholdings. The major constraints to the adoption of improved technologies included lack of information about them; nonavailability of quality seed of improved varieties, noninvolvement of farmers in the development of technology, lack of feedback from farmers and other agencies; use of inappropriate methodology for information dissemination; and inadequate coordination between agencies involved in research, extension and on-farm cultivation.

Returns to Investment in Groundnut Research in Gujarat Agricultural University

R L Shiyani

Gujarat Agricultural University, Junagadh Campus, Junagadh, India

Groundnut plays a pivotal role in the agricultural and industrial economy of Gujarat state. This study was undertaken to examine the returns to investment on groundnut research in Gujarat Agricultural University. A survey was conducted to collect primary data for the rainy season of 1997 from 96 groundnut growers (48 farmers growing GAUG-10 and the other 48 growing GG-20 varieties) of Junagadh and Rajkot districts. Secondary data on area, production, yield, farm harvest prices and research expenditure on groundnut were also collected and compiled from published sources.

The study revealed that among the different traits of GG-20, the first rank was assigned to better yield, followed by its potential to fetch higher prices, more shelling percentage, early maturity, high oil content, etc. Aphid, *Heliothis*, jassid, *Spodoptera* and leafminer in this order were the major problems faced by the groundnut growers. Leaf spot and rust were found more chronic in GAUG-10, whereas GG-20 was more adversely affected by stem rot. Relatively higher returns were realized from GG-20 compared to GAUG-10. Though there was a decline in the compound growth rate of groundnut yield during the post-establishment period of GAU, the growth rate of the area under it improved. The annual compound growth rate of total expenditure on groundnut research in all GAU's research centers was higher than the growth rate of the gross value of groundnut production in the state, suggesting optimum allocation of funds/ resources. A multidisciplinary approach to groundnut research will help find answers to the various biotic constraints to groundnut production in the region.

Impact of Cotton Production Technology: A Case Study

K Ramamoorthy, M S Kairon, K Natarajan and R Venkataswamy
Central Institute for Cotton Research, Regional Station, Coimbatore, India

Cotton being a chemical-intensive crop, it is called a pollutant crop. Nearly 55% of agricultural pesticides are applied on this crop, which occupies only 5% of the cropped area. In order to avoid indiscriminate use of pesticides, an Integrated Pest Management project was introduced in 1975. However, it had no significant influence on production due to the neglect of the socioeconomic infrastructure.

The basic constraints to the transfer of IPM technologies were a defective pesticide delivery system and neglected soil health. Balanced soil nutrition is a prerequisite for IPM's success. Therefore, a case study was conducted at the Institute Village Linkage Program (IVLP) in order to compare the economics between Integrated Crop Management (ICM), Integrated Nutrition Management (INM) and IPM practices. The study revealed that those who adopted ICM made a net profit of Rs 1.20 for every rupee invested on TCHB-213 hybrid cotton, while IPM and INM farmers of TCHB-213 made lower profits. Similar was the case of Suvin cotton; ICM adopters made a net profit of Rs 0.64 per rupee invested, whereas INM and IPM adopters made less profits. Precision prescription and the application of cotton production technologies can revive the golden era of cotton for Indian farmers.

Socioeconomic Aspects of Perennial Crop-based Farming System

C V Sairam, D V S Reddy, C Thunban, Bindu Chandran, S R Prabhu and A S Sukumaran
Central Plantation Crops Research Institute, Kasaragod, India

Perennial crops have a life span of more than four decades. They are cultivated with wider spacing; hence monocropping leads to the inefficient use of farm resources. To increase resource-use efficiency, strenuous research efforts have been made since the 1970s. Many Perennial Crop-based Farming System (PCBFS) Models were developed under experimental conditions. A study of farmers cultivating coconut and arecanut was undertaken to examine the benefits of PCBFS models. All the 60 beneficiaries under the Institute Village Linkage Program in Kasaragod district were interviewed and monitored on various aspects during 1997-98 and 1998-99.

Though the primary objective of the technology was effective utilization of land by small and marginal farmers, economies of scale were often not favorable. In general, the models were found more suitable for medium and large farmers since the economies of scale and the capital intensive nature of these technologies favored them. Their impact was far from satisfactory in the study area. Structural factors like high plant density, underplanting of the main crop and the lack of irrigation facilities constrained adoption. Socioeconomic factors like the nonavailability of skilled labor and capital were the major constraints.

Experiments on Farming Systems Research should be taken up with active farmer participation after ascertaining the constraints in the area.

Impact Assessment of Watershed Development Technology in the Tribal Districts of Gujarat

V C Pande, R S Kurothe, H B Singh and V Kumar
Central Soil and Water Conservation Research and Training Institute, Regional Centre, Vasad, Gujarat, India

Two agriculturally backward and highly degraded watersheds (Navamota measuring about 570 ha in Sabarkantha district and Rebari measuring about 313 ha in Panchmahals district in Gujarat) were selected for development. Integrated Watershed Development Plans encompassing soil and water conservation, improved crop production on arable land, forestry and grassland development on non-arable land were prepared by Vasad Center after a comprehensive survey. The Gujarat Government executed the work in the watershed from 1985 to 1990.

A study was conducted in 1993-94 on 60% of the beneficiaries in Navamota and 30% in Rebari, to assess the impact of the technology. Medium to high adoption of various technology components was observed; the most favored being contour farming, intercropping, contour bunding, marginal bunding and agroforestry. This led to increases in cropping intensity (18 to 33%) and greater area under pulses and marginally under oilseeds; greater crop productivity (42 to 195%) increasing net returns by 2.3 to 2.4 times; enhanced farm investment by 2 to 5 times and more returns and investment with a fairer distribution across the watersheds in the post-project phase compared to the pre-project phase.

However, the high capital cost and community-specific nature of some of the components of the technology constrained their adoption. Lack of compensation for land lost/submerged under/behind water conservation structures resulted in great resistance to such components.

Intangibles constituted a substantial part of the benefits. Methodologies need to be standardized to quantify the overall benefits of watershed programs.

Impact of Watershed Development Program in Bareilly District of Uttar Pradesh

Nalini Ranjan Kumar[1] and Parmatma Singh[2]
[1]Central Potato Research Station, Modipuram, Meerut, India
[2]Indian Agricultural Research Institute, New Delhi 110012, India

This study analyzes the impact of the watershed development program in Bareilly district, one of the six drought-prone districts of Uttar Pradesh, selected under ICAR's Model Watershed Development Programme in 1983. Using a two-stage stratified random sampling, 100 farm households from the project area and 100 from the non-project area were selected. Data was collected for 1994-95.

A composite adoption index to measure adoption revealed that farmers adopted about 81% of the major agronomic practices recommended for the watershed. However, most did not adopt soil and water conservation measures. The area under wasteland decreased from 658.4 ha in 1984-85 to 455.8 ha in 1993-94, whereas that under horticulture and forestry increased from 85 ha (1984-85) to 223 ha (1993-94). It was also observed that irrigated area increased by 1063% (from 189 ha in 1984-85 to 2009 ha in 1993-94), and cropping intensity from 86% in 1984-85 to 154% in 1993-94, without lowering the groundwater table. There was substitution of low-value crops with more profitable ones in the project area.

Yields from crop and dairy enterprises were greater in the project area than in the non-project area. Unit cost of production of all the enterprises was 1.5 to 9% lesser in the project area compared to the non-project area. Employment generation was found to be significantly high in the project area (186 mandays ha^{-1}) compared to the non-project area (122 mandays ha^{-1}). The watershed development approach was not adopted fully since farmers lacked knowledge owing to their poor participation in the program and due to the nonavailability of credit on time.

Impact of Research on Alkali Soils for Crop Production

P K Joshi and Arun Kumar
National Centre for Agricultural Economics and Policy Research, New Delhi 110012, India

Alkali soils are considered to be one of the major aboitic constraints. These soils are to a large extent confined to the Indo-Gangetic Plains, and to some extent in the Deccan Plateau. They cover about 2.5 million hectares and possess enormous potential, if reclaimed. The Central Soil Salinity Research Institute was set up by ICAR to address the needs of these degraded soils. Research efforts since the early 1970s were focused on the chemical amelioration of alkali soils for crop production; biological amelioration through salt-tolerant varieties and grasses; and afforestation of alkali soils. The chemical amelioration of alkali soils for rice and wheat production was fairly standardized in the Indo-Gangetic Plains, and was widely adopted by the farmers. This paper reviews various studies conducted to assess the impact of research on alkali soils on crop production in the Indo-Gangetic Plains.

Large-scale adoption of the reclamation technology led to a high benefit-cost ratio (an average ranging from 1.34 to 1.42); generated employment opportunities for landless laborers in the rural areas; significantly contributed to rice and wheat production, when normal soils started showing fatigue in Punjab and Haryana; improved inter-sectoral linkages; contributed to narrowing income disparities in the rural areas; and caused a decline in the gini-concentration ratio. Reclamation of alkali soils facilitated the control of rainwater runoff and contributed to the recharge of groundwater.

Adoption was constrained since resource-poor farmers in the upper and middle Indo-Gangetic Plains lacked enough resources. The government has initiated appropriate programs to tap the potential benefits of this technology.

Adoption of Vertisol Technology in the Indian Semi-Arid Tropics

P K Joshi[1], R L Shiyani[2], M C S Bantilan[3] and G D Nageshwar Rao[3]
[1]National Centre for Agricultural Economics and Policy Research
New Delhi 110012, India
[2]Gujarat Agricultural University, Junagadh Campus, Junagadh, India
[3]International Crops Research Institute for the Semi-Arid Tropics,
Patancheru 502 324, Andhra Pradesh, India

The production potential of an estimated 12 million hectares of rainfed area can be substantially increased by introducing improved crop and resource management practices. Vertisol technology was developed to overcome the existing constraints, increase agricultural production and prevent degradation of soil and water resources. An evaluation of the adoption and impact of management technology for vertisols in the assured rainfall regions in India's semi-arid tropics was undertaken to assess the adoption pattern of different components of the technology, estimate on-farm economics and sustainability benefits as a result of adoption, and determine constraints to adoption. The assessment covered the states of Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh and Karnataka.

An analysis of a sample of 500 farmers revealed that majority of farmers in all the rainfall regimes adopted improved varieties, fertilizer application and placement of seed and fertilizer. In low-rainfall areas, two technology options were additionally popular — summer cultivation and plant protection, and summer cultivation, plant protection and double cropping. In medium-rainfall areas, about half of the farmers opted for summer cultivation, dry seeding, double cropping and plant protection measures along with improved varieties, fertilizer application and placement of seed and fertilizer. In high-rainfall areas, majority of farmers practised summer cultivation, double cropping and plant protection (if required) along with improved varieties, fertilizer application and placement of seed and fertilizer. It was observed that the adoption of different technology components was highest at around 1000 mm rainfall.

The benefits of adopting vertisol technology were listed as easy cultivation, effective pest management, higher production, less labor time and cost, higher income, increased food and fodder security, lower cost of seed and nutrients, better soil and water conservation, prevention of soil erosion and effective use of rainwater. However, the BBF component of the technology was not popular among farmers.

Adoption of Vertisol Technology: A Case Study in Assured Rainfall Region of Gujarat

R L Shiyani[1], P K Joshi[2] and M C S Bantilan[3]
[1]Gujarat Agricultural University, Junagadh Campus, Junagadh
[2]National Centre for Agricultural Economics and Policy Research New Delhi 110012, India
[3]International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324 Andhra Pradesh, India

The vertisols are cultivated within a limited range of moisture regime. They are very hard when dry and extremely sticky when wet. To overcome this problem, a multi-disciplinary team of agricultural and social scientists at ICRISAT suggested a package approach in 1974, which was later known as "Vertisol Technology". The technology was found superior over the traditional practices. This study was an attempt to assess adoption of this technology in the assured rainfall region of Gujarat. Panchmahals district of eastern Gujarat was selected for this study and two talukas, viz. Godhra and Dahod were selected randomly from the district. Three villages from each selected taluka and twenty farmers from each village were randomly selected, which constituted the total sample size of 120 farmers. The relevant data were collected during April-May 1997 by survey method.

The results of the study revealed that more than 60% adoption was noticed for the vertisol components, viz. summer cultivation, double cropping and improved varieties. The adoption of fertilizer application, proper placement of seed, and plant protection measures was found moderate, whereas the proportion of the farmers adopting dry seeding and broad-bed and furrow (BBF) was quite negligible. The lack of awareness about the technology emerged as a common constraint responsible for the non-adoption of various components of the technology. This suggests that concerted efforts by extension workers and other organizations would help in disseminating potential benefits to the tribal farmers. Summer cultivation or dry seeding enjoyed the benefits of better yield, higher net income and reduction in unit cost of production. Price premium was an added advantage to dry seeding due to early harvesting of the crop. Summer cultivation followed by dry seeding was found more profitable than summer cultivation followed by BBF. Relatively higher cost of weeding in case of dry seeding suggested the need for appropriate weed management strategy.

Adoption of Crossbreeding Technology in Different Regions of India

S B Agarwal, C B Singh and S K Jha
National Dairy Research Institute, Karnal, India

This study was undertaken to ascertain the level of knowledge and attitude of dairy farmers towards crossbreeding, their perception of the available facilities, as well as to examine the extent of adoption of crossbreeding technology and improved dairy farming practices. The study was conducted in three select zones of the country, having high, medium and low milk production potential, using a multistage random sampling technique. One state from each zone was selected purposively.

The study revealed that a very low proportion of respondents, both adopters and non-adopters, had higher levels of mass media exposure. Surprisingly, West Bengal had a higher proportion of non-adopters with high levels of mass media exposure as compared to Punjab and Karnataka.

Majority of farmers in all the states had a poor perception of extension services. Most adopters had an average perception of veterinary services, while majority of non-adopters had a poor perception. Development agencies involved in extension and veterinary services need to improve the existing services. In order to increase the probability of adoption of crossbreeding technology, efforts should be made to improve the knowledge and attitude of farmers towards it.

Impact of Improved Dairying Technology on Rural Households in Karnal District (Haryana)

Kulwant Singh
National Dairy Research Institute, Karnal, India

This study was undertaken to ascertain the effect of improved technology on various categories of rural households in Karnal district of Haryana. It showed that milking and herd average had increased by 65% in 1977-78 and by 63% in 1995-96. The overall milk yield per day from crossbred milch cattle was 5.84 liters. Milk yield tended to increase with an increase in landholding size in the case of small farms. Thereafter, it showed a declining trend. This further confirmed the hypothesis that small and marginal farmers and landless cattle owners took better care of their animals compared to medium and large farmers.

Labor input in 1995-96 increased by about 6% in buffaloes, 26% in crossbred cows and 10% in local cattle over 1977-78, showing that milch herds had improved, animal numbers had increased and manpower employment in dairying had increased. Income from milk production was the major source of income on dairy farms. A comparison of net incomes revealed a 525% increase in 1995-96 over 1977-78. The study revealed that improved technology had a positive impact on farmers.

Comparative Performance of Traditional and New Technologies in Dairy Farming in Rural Areas of Haryana

A K Chauhan[1] and T R Kundu[2]
[1]National Dairy Research Institute, Karnal, India
[2]Kurukshetra University, Kurukshetra, India

The Intensive Cattle Development Program in Haryana has since long been providing new dairy farming technology for the genetic improvement of indigenous milch animals. This study attempts to assess the impact of new technology by comparing the economic status of the 'beneficiaries, i.e., households adopting the new technology in terms of crossbred and graded Murrah buffaloes, with that of the 'non-beneficiaries', i.e., households having non-descript cows and buffaloes. Primary data for the year 1995-96 were collected from 300 households (150 beneficiaries and 150 non-beneficiaries) spread over 3 districts of Haryana, namely Kurukshetra, Bhiwani and Sirsa.

The study revealed that the daily average milk yield of crossbred lactating cows (7.00 liters) and graded Murrah buffaloes (7.06 liters) was significantly higher than that of lactating non-descript cows (4.07 liters) and local buffaloes (5.11 liters). As a result of adoption of new technology, milk production in beneficiary households increased, leading to increased employment and income. The average daily labor employment in all the dairy operations taken together was 5.62 manhours for beneficiary households, compared to 4.90 manhours for non-beneficiary households. In addition, more female employment was generated in the beneficiary households. The impact of new technology on income revealed that beneficiary households on an average enjoyed 3.77-times higher levels of annual net income (Rs 7294) than non-beneficiary households (Rs 1931).

Constraints to Adoption of Technologies in Dairy Development

Lotan Singh, J Chattaraj and R K Misra
National Dairy Research Institute, Regional Research Station, Kalyani, India

Eastern India's primitive dairy sector contributes less than 3% milk to the national milk pool despite its impressive cattle population (18%). Buffaloes are almost non-entities with respect to milk production. However, the dairy co-operative movement has brought remarkable changes in total milk output in the region. Member-farmers brought about this change by adopting modern technology.

This study examines 200 households in Nadia district of West Bengal, 203 in Bhojpur district of Bihar and 100 in Puri district of Orissa to identify the factors responsible for the non-adoption of technologies and its impact on total output. The households belonged to two categories of villages. The study revealed that 11% of the sample households from villages that adopted the technologies had adopted crossbreeding (36%) and tick control (33%) compared to 5% in the case of non-adopting villages. Crossbreed production was 61% in villages that adopted the technology compared to 16% in non-adopting villages.

Overall employment generation was 179 MED (Mean equivalent day) in villages that adopted the technology compared to 133 MED in the case of non-adopting villages. However, both the types of sample households faced problems in adoption of technologies. The major constraints to non-adoption were lack of awareness, poor accessibility of technologies, lack of financial resources and lack of suitable apparatus for technology transfer.

Sugarcane Production Technology: Impact Analysis for Productivity Enhancement

Jagdish Lal and R L Yadav
Project Directorate for Cropping Systems Research
Modipuram, Meerut, India

An attempt has been made to analyze the impact of selected aspects of sugarcane production technology on productivity enhancement. Among various planting techniques, spaced transplanting (STP) having a multiplication ratio of 1:35 and a two-thirds saving in seed, proved to be effective in increasing cane yield with normal inputs as compared to conventional planting. The technique could not be widely adopted by farmers because of its high labor and management needs. The ring method of planting produced about 184 t ha^{-1}, almost double that of conventional flat planting. The benefit-cost ratio of this technique was 1.99. The technique is of practical use in sloppy terrain. Companion cropping of potato and mustard in autumn-planted sugarcane and mung bean/urd bean in spring-planted crop were observed to be most remunerative. The benefit-cost ratio was highest with potato (2.109), followed by mustard (1.448), mung bean (1.445) and urd bean (1.417). Companion cropping with potato and mustard was widely accepted by the farmers, adopted under lab-to-land program. The practice improved farmers' income in eastern and western Uttar Pradesh. Trash mulching resulted in a 26% increase in cane yield as compared to mulching without trash.

Research efforts to develop varieties COLK 7901 (early), COLK 8001 and COLK 8102 (mid-late) proved effective in enhancing sugar productivity in the northwest zone. Farmers of Uttar Pradesh and Bihar accepted COLK 8102. Diseases such as red rot, smut, wilt, grassy shoot, ratoon stunting and mosaic brought down cane yield and did not permit good ratooning. Based on the epidemiology of the diseases and probability of secondary infection, a 3-tier seed program was developed to combat many of the maladies. It involved production and distribution of disease-free seed.

Impact of Input Variables on Rice and Wheat Productivity

N D Shukla, A K Shukla and B Gangwar
Project Directorate for Cropping Systems Research
Modipuram, Meerut, India

On-farm experiments were conducted in different agroclimatic regions to study the impact of input variables such as recommended fertilizer (RF), high-yielding varieties (HYV) and improved management practices (IMP) on rice and wheat yield under the All India Coordinated Research Project on Cropping Systems from 1990 to 1995. It was noted that fertilizer played a vital role (30%) in increasing rice and wheat productivity followed by HYV (12%) and IMP (10%). The contributions of IMP and HYV were comparable under rainfed wheat. A quantification of the gap between farmer's and researcher's practices of fertilization revealed a pronounced yield gap of 1458 kg ha^{-1} for rice and 1463 kg ha^{-1} for wheat in the northeastern zone of Uttar Pradesh. This was the highest among all the states/regions. The computation of economic returns per unit of fertilizer used over farmer's practice showed higher returns in the case of rice as compared to wheat.

Impact of Improved Technology on Production, Productivity and Income of Farmers of Haryana

Kulwant Singh
National Dairy Research Institute, Karnal, India

Agriculture in India faces diverse biotic, abiotic and socioeconomic problems. One of the major problems is the skewed distribution of land. About 45% of the total geographical area is under cultivation. The distribution of households possessing land revealed that 75% of the total holdings were cultivating about 26% of the total area, belonging to marginal and small farmers. As compared to this, about 2% of the large farmers had more than 10 ha and cultivated about 23% of the total area.

The transformation of the farm economy from subsistence to commercial type started with the introduction of new technologies after 1966, when farmers adopted improved production technologies to increase production and productivity. Studies reveal that the country has made rapid strides in the use of HYVs of seed, chemical fertilizers, pesticides and weedicides. The use of tractors, modern implements and tube wells has also increased significantly. Field studies reveal that the productivity and production of all the crops doubled during this period.

Alternative Farming System for Sustained Production in the Arid Ecosystem

K Ananthram
National Institute of Animal Nutrition and Physiology, Bangalore, India

The arid areas in India are characterized by a harsh environment, low and erratic rainfall, high wind velocity and higher evapotranspiration due to which the area is prone to soil degradation, and low productivity and its inhabitants to uncertain income. Given such a scenario, crop production as a sole activity is highly risky. Studies have revealed that integration of the tree and/or grass component with annual crops has the potential to reduce such risk. Keeping this in view, experiments were conducted in 1990 at the Central Research Farm, Jodhpur, pertaining to agri-pastoral, silvi-pastoral, agro-forestry, agro-horticulture, farm forestry and arable farming.

Analysis of data (1990-91 to 1993-94) from various components of Integrated Farming Systems (IFS) and Arable Farming System (AFS) revealed that the average returns over variable cost from pure crops ranged between Rs 831 ha^{-1} and Rs 3074 ha^{-1}. In agro-pasture and silvi-pasture, the average returns over variable cost worked out to be Rs 1848 ha^{-1} and Rs 2467 ha^{-1}, respectively. Overall, IFS performed better than AFS in terms of returns. Besides, IFS suited the arid drylands in view of the system's inherent strength to check soil erosion hazards.

Some of the major constraints in IFS were smaller size of holdings, nonavailability of appropriate planting material, long gestation period, high initial investment for establishment and acceptance of the system by farmers. Greater effort is needed to convince the local community about the advantages of IFS through demonstrations and on-farm trials.

Ecofriendly IPM Technology and its Impact on the Cotton-based Farming System of Maharashtra

S N Puri,[1] O P Sharma,[2] K S Murthy,[2] R C Lavekar,[3] A Dhandapani[2] and Sant Kumar[4]

[1]Mahatma Phule Krishi Vidhya Peeth, Rahuri, Maharashtra, India
[2]National Centre for Integrated Pest Management, New Delhi 110012, India
[3]Cotton Research Station, Nanded, Maharashtra, India
[4]National Centre for Agricultural Economics and Policy Research, New Delhi 110012, India

In southern Maharashtra, cotton was adversely affected due to heavy infestation of pests, particularly the bollworm and foliar diseases. Farmers of Ashta, an economically backward village of Nanded District, Maharashtra, had adopted a calendar based on pesticide application to protect and salvage the crop. Despite the heavy use of pesticides, pest problems continued unabated and the year 1997 proved disastrous, leading to increased losses and debts, apart from several environmental hazards.

The Integrated Pest Management (IPM) technology developed by the National Centre for Integrated Pest Management (NCIPM) aimed to solve these problems. It is comprised of exclusive reliance on bioagents, biopesticides and botanical pesticides along with altered crop management practices. Low input costs, higher net returns and management of pests in an ecofriendly manner were the key issues addressed in this study. The target domain was to validate IPM technology on a large scale. The technology was put into practice over 180 ha in Astha in 1998. All the 76 cotton-growing farmers in the village were mobilized to adopt the technology, which they did. All the inputs and technical guidance were made available by NCIPM. The technology reduced the quantity of pesticides used (from 9.3 kg a.i. ha^{-1} to 0.03 kg a.i. ha^{-1}), curtailing overheads on crop protection by 52% over the previous season. Yield gain over the previous season was 3.62-times. Natural fauna was protected and augmented in the natural ecosystem. Predation of bollworm larvae was to the extent of 52%.

Lessons to promote IPM technologies in future include the active participation of the farming community, collective efforts of scientific institutions and developmental agencies and regular farmer's field schools for both men and women farmers.

Impact of IPM Technology in Reducing Pesticide Consumption in Mustard Crop

Saroj Singh, Surender Kumar and Nasim Ahmad
National Centre for Integrated Pest Management, New Delhi 110012, India

To minimize the use of chemical pesticides in mustard crops, an ecofriendly IPM technology was formulated and transferred to farmers' fields for three crop seasons — 1995-96, 1996-97 and 1997-98 — in Bhora Khurd village in Gurgaon district of Haryana. The village is a mustard-growing area. Farmers were regularly exposed to Farmers' Field Schools on IPM, where directions on growing mustard varieties recommended for the area, timely sowing and monitoring of the pest complex and their natural enemies were given.

A team of multidisciplinary scientists monitored the pest complex. It was found that there was almost no attack of insect pests like the painted bug and mustard saw fly on the crop. Most fields escaped mustard aphid attacks. Slight incidence of white rust, *Alternaria* leaf spot and downy mildew was observed, except during 1997-98 when prolonged cloudy conditions and relatively low temperature precipitated severe incidence of white rust. None of the farmers used chemical pesticides on their fields. Farmers obtained good mustard yields during these years, except in 1997-98. Creating awareness about IPM among farmers will help in reducing pesticide-use to a great extent, and consequently ensure an unpolluted environment.

Socioeconomic Evaluation of IPM Module in Basmati Rice-growing Areas of Uttar Pradesh

Vikas Kanwar
National Centre for Integrated Pest Management,
New Delhi 110012, India

Basmati rice is a new crop in western Uttar Pradesh. In the study area, its area went up from a mere 2% in 1995 to 30% in 1998. With an increase in area, insects (leaf folder and stem borer) and diseases (neck blast) too have grown. Integrated Pest Management (IPM) plays an important role in alleviating these problems in order to increase rice production. With this in mind, an IPM module was tested in the Basmati rice-growing areas of Uttar Pradesh in which 50 farmers were interviewed and information collected regarding IPM awareness, the harmful effects of chemical pesticides used and its socioeconomic evaluation.

The IPM package was cost saving and increased rice yields. The benefit-cost ratio was very impressive at 7.41:1 for the IPM package compared to the chemical method of pest control. Despite the benefits, the technology was not widely adopted. Some of the constraints to its large-scale adoption was the lack of trained manpower in the use of bio-pesticides; their slow action, moderate toxicity, specificity and photo-instability; insufficient production of bio-pesticides, fragmentation between research, extension and development agencies, nonavailability of information on the integration of various tools of IPM under farm conditions and lack of information about the availability of IPM inputs.

Development of Improved Equipment for Small Farms

A P Srivastava, J S Panwar and S K Adlakha
Indian Agricultural Research Institute, New Delhi 110012, India

Small farms depend on manual and animal power for most farm operations. The average small farmer's purchasing power is low, requiring efficient, simple and low-cost tools and implements. A number of implements are required for crop production Since these essential farm implements have individual frames, they are beyond the reach of small farmers. To reduce cost, a common frame called the integral toolbar was developed, to which a number of tools, such as the moldboard plough, three types of cultivators, bund former, ridger and a three-row seed-cum-fertilizer drill can be attached and detached as required. A 25% cost reduction can be achieved by using this equipment.

Another implement, the six-row, manual, pre-germinated paddy seeder that facilitates line sowing of metered pre-germinated seeds in puddled soil has been developed. It can cover a hectare a day. During interculture operations, cutting of weeds and detopping are required. The *khurpa*-cum-sickle, a multipurpose tool with serrations along the curved length of the inside edge was developed to facilitate these operations. All the three have been evaluated in farmers' fields and are under commercial production.

Genetic Enhancement of Foodgrain Production in India: Trajectory from Green Revolution to Globalization

P K Joshi, Raka Saxena and Suresh Pal
National Centre for Agricultural Economics and Policy Research, Pusa, New Delhi 110012, India

This paper discusses the trajectory of technology adoption in the country, its determinants, chalking out the path for future growth, drawing its implications on yield levels, stability, area changes, biodiversity and surplus generated. Data on different aspects are collected and analyzed for a period of 33 years (1965-66 to 1997-98).

The Green Revolution technology was initially adopted in the irrigated states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. The adoption varied from 0.05% (Barmer in Rajasthan) to about 100% (districts of Punjab, Haryana, Uttar Pradesh, Tamil Nadu and Maharashtra). The major determinants fell into three categories — agroecological variables (including agroecoregions, production systems, predominance of other major activities, sensitivity to flood and drought, rainfall, mechanization and irrigation); infrastructure (road, markets and electrification); and socioeconomic variables (including rural literacy and relative prices of foodgrains). The agroecoregions were categorized into arid, hill, coastal, irrigated and rainfed. The adoption rate was relatively less in the arid agroecoregions. The gini ratio revealed higher inequality in terms of technology adoption across various agroecoregions. Due to favorable irrigation conditions and the availability of other modern inputs, the irrigated agroecoregions responded the most. All the variables mentioned had a positive impact on technology adoption, except rainfall and predominance of other activities. The future strategy lies in developing specific technologies to address location-specific constraints and help in realizing existing potential.

Economic reforms were launched in India in 1991. The new trade and industrial policy is basically export-oriented and provides concessions and priority to agricultural trade. The export of nearly all foodgrains, except wheat, grew from about 50 to 85% during the period of economic reforms. Very high fluctuations were noticed in wheat exports.

Food Security and Sustainability Issues in the Indo-Gangetic Plain: Threats and Opportunities in the Light of Global Changes

P K Joshi and Laxmi Tewari
National Centre for Agricultural Economics and Policy Research
Pusa, New Delhi, 110012, India

The Indo-Gangetic region in India comprising the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal accounts for 53% of the total area under rice and wheat. A two-third increase in rice and wheat outputs during the last two decades has come from this region, underlining its importance to the country's food security. There are now reports that the system is showing signs of fatigue in terms of production. There is a need to assess issues pertaining to the rice-wheat system in view of the changing technological environment and new economic scenario. This study attempts to measure the temporal and spatial variation in the sustainability status of the Indo-Gangetic Plain of India.

The analysis suggests that large parts of the rice-wheat system are showing clear signs of nonsustainability. It was estimated that about 62% of the rice area and 53% of the wheat area are nonsustainable for rice-wheat production. The nonsustainable subregions are contributing about 55% of both rice and wheat production in the Indo-Gangetic Plain. Increase in production is constrained by the plateauing of rice and wheat yields and the limited scope to expand area. In high productive regions such as Punjab, Haryana and western Uttar Pradesh, overexploitation of groundwater and declining biodiversity are responsible for nonsustainability. Nonetheless, there is great potential to raise yield levels in low-productive regions, where farmers have not fully exploited the technological potential due to inadequate infrastructure investment in irrigation and marketing as well as socioeconomic constraints. Though both regions offer opportunities to increase production and supply, each requires a different technological solution and research strategies to provide the relevant agro-technology.

An Economic Evaluation of Watershed Programs

Y VR Reddy and Mahipal
Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500 059

Dryland agriculture occupies about 60 % of the arable land in India. Even if the irrigation potential if fully exploited ,about 50 % of the arable land would continue to remain as dryland. Dryland farming, therefore, needs improvement through better management of resources especially the land and water to improve living standards of the farmers. This study assessed the impact of watershed programs on cropping pattern, crop yields, labour use and income of the producers at two locations viz. Chevella watershed in Medak district of Andhra Pradesh and Mittemarri watershed in Kolar district of Karnataka. The impact was assessed in comparison of neighboring nonwatershed areas. The area under major crops increased in watershed villages, so was the crop yield. The additional return due to watershed varied from Rs 83 to 560 per ha in Chevella and Rs 801 to 2363 per ha in Mittemarri. Labour use also increased partly due to increase in cropped area and partly due to employment opportunities in watershed works. The nonwatershed villages also benefited from the employment opportunities created in construction and maintenance of watersheds.