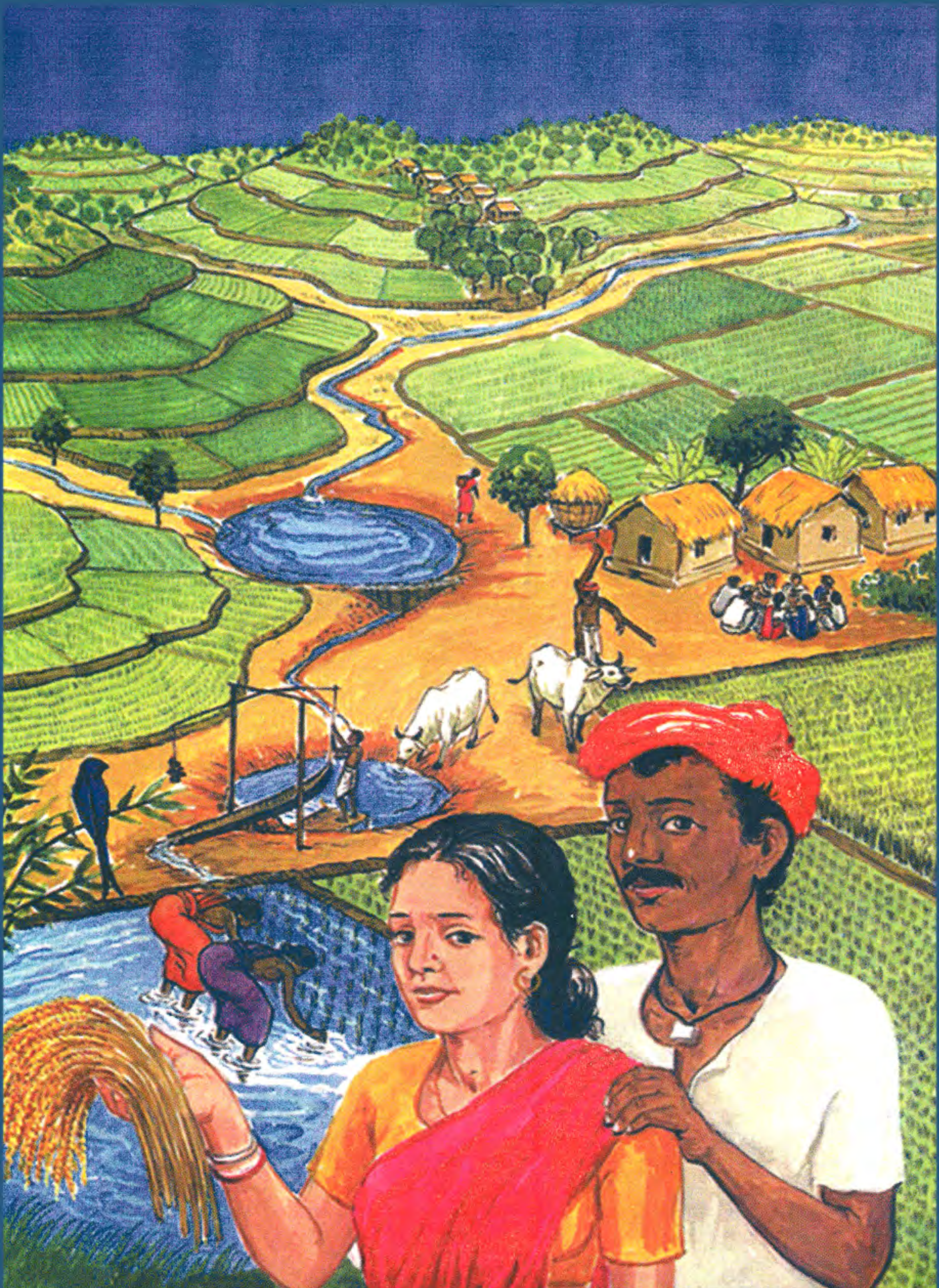
RAINFED RICE

A Sourcebook of Best Practices and Strategies in Eastern India



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RAINFED RICE

A SOURCEBOOK OF BEST PRACTICES AND STRATEGIES IN EASTERN INDIA

IRRI IFAD ICAR IIRR

April 2000

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundation with the help and approval of the Government of the Philippines. Today, IRRI is one of the 16 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP). Its membership comprises donor countries, international and regional organizations, and private foundations.

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International Rice Research Institute
Los Baños, Philippines
Mailing address: MCPO Box 3127, 1271 Makati City, Philippines
Phone: (63-2) 845-0563; 844-3351 to 53
Fax: (63-2) 891-1292, 845-0606
Email: IRRI@CGIAR.ORG
Telex: (ITT) 40890 Rice PM; (CWI) 14519 IRILBPS
Cable: RICEFOUND MANILA
URI: http://www/cgiar.org/irri
Riceweb: http://www.riceweb.org
Riceworld: http://www.riceworld.org
Courier address: Suite 1009, Pacific Bank Building
6776 Ayala Avenue, Makati City, Philippines
Phone (63-2) 891-1236; 891-1174; 891-1256; 891-1303

Suggested citation:
Singh, V.P. and R.K. Singh, editors. 2000. **Rainfed Rice: A Sourcebook of Best Practices and Strategies in Eastern India.** International Rice Research Institute. 292 p.

ISBN 81-86789-02-2

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Foreword

Rainfed rice farming in Eastern India has been recognized among the major food production systems in India. This region has been making a significant contribution to the rice supply of the country. Consistently, during the last five years, the annual growth-rate in rice productivity of this region has been more than 2%. An average yield increase of about 0.38 tonnes per ha in a rainfed rice area of about 21 million ha, has provided about 8 million tonnes more rice.

Such a contribution has been possible through the concerted and collaborative research efforts of rice scientists from the International Rice Research Institute, (the Philippines) of the CGIAR, the Indian Council of Agricultural Research, State Agricultural Universities in the different states of Eastern India, Non-Government Organizations of the region and farmers' groups. These teams have identified, developed and perfected the site specific appropriate rainfed rice farming technologies which are productive as well as profitable, and are being adopted by the farming community.

Scientists have compiled this knowledge in the present book "Rainfed Rice: A Sourcebook of Best Practices and Strategies in Eastern India". Written in a simple language and presented in an easily understandable format, this is a valuable publication, which contains relevant technical and useful information about rice farming in rainfed situations. This is a unique publication and is probably first of its kind. I am confident that this will be a highly useful source book for researchers, extension workers and farmers not only in India but also in similar ecologies elsewhere. I congratulate all the contributors to this book, and the editorial and production staff, particularly Dr. V.P. Singh and Dr. R.K. Singh, senior scientists and technical editors from the International Rice Research Institute, for having done such an outstanding job.

R.S.Paroda
Secretary, Department of Agricultural Research and Education
Director-General, Indian Council of Agricultural Research
Ministry of Agriculture
New Delhi 110 001, India

Foreword

About 45% of the world's rice area is currently rainfed and about 25% of global rice production depends on rainfed areas. The major constraints to higher rice productivity in rainfed areas are drought, submergence and flash flooding, farmers' low resource base and the unavailability of appropriate technologies. The expected future demand for rice from increased population can no longer be met only by higher yields from irrigated areas. More efforts are needed to enhance the contribution of rainfed rice areas to overall rice production by identifying, validating, delivering and applying situation-specific, appropriate technologies.

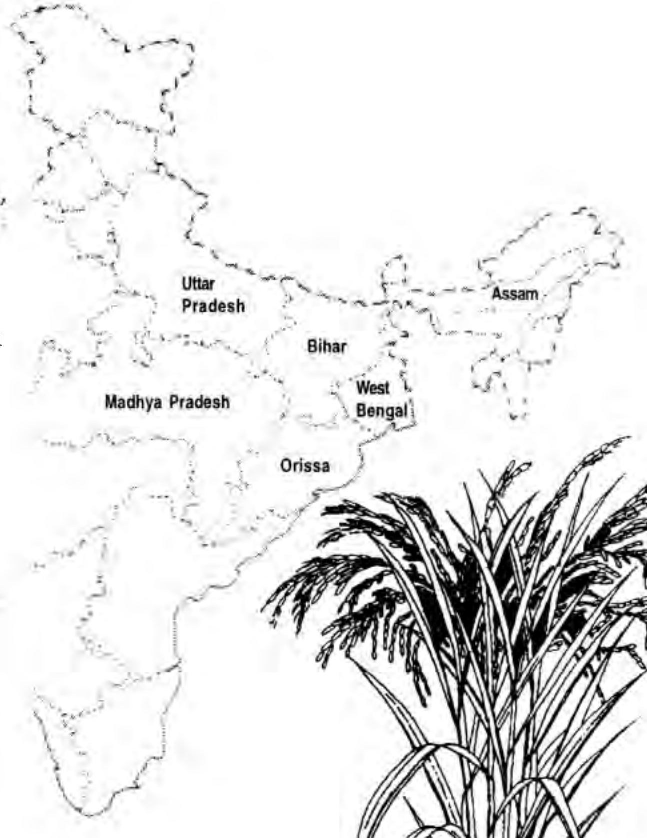
Rainfed rice farming technologies developed through the collaborative efforts of rice scientists from the Indian Council of Agricultural Research, state agricultural universities in different states of eastern India, NGOs in the region, groups of farmers and the International Rice Research Institute have started making a significant contribution to rainfed rice production in India. In the past five years, the annual growth rate in rice productivity in Eastern India has surpassed 2%.

These technologies have been synthesized in this book, which contains 50 topics on different aspects of rainfed rice farming. The publication features some exemplary practices drawn from on-farm research and emphasizes the experiences of scientists along with farmers' traditional knowledge for the improvement of rainfed rice farming. The material is presented in an easily understandable form, This unique and valuable contribution to rainfed rice science is probably the first of its kind. We hope that this will be a highly useful resource, not only in India but also in similar ecologies around the world.

Ronald P. Cantrell
Director General
International Rice Research Institute

Introduction

The six states in eastern India (Assam, Bihar, Orissa, West Bengal, Madhya Pradesh, and Uttar Pradesh) account for about 63.3% of the total rice cropped area in the country (26.8 million ha out of 42.3 million ha total) but produce only 48% of the total rice. Average rice yields of eastern India are lower than the national average with the exception of West Bengal, where productivity equals or exceeds the national average.



About 80% of the rice area of eastern India is rainfed and exposed to abiotic stresses such as drought, low soil fertility, flood and stagnant water. Some of the poorest rice farmers live in this region. Yet, future increases in rice productivity (to meet projected needs) will likely have to come from eastern India. It is within this context that the IFAD-Aided Project on Collaborative Research and Development of Sustainable Rice Farming Systems in South Asia was set up. It was supported by the Indian Council of Agricultural Research (ICAR), International Fund for Agricultural Development (IFAD) and the International Rice Research Institute (IRRI). The project was implemented by different participating institutions in the region including ICAR institutions, state agricultural universities and state departments of agriculture and non-governmental organisations.

IFAD funded the project in two phases: the first phase in 1987-92 and the second phase on 1994-99. All the activities between the first and second phase were supported by a bridging grant from IRRI. The project followed a systems approach to research and training.

The principal objective of the project was to develop ecologically sustainable and economically viable rice and rice-related systems production technologies through research and technology verification in farmers' fields to increase the income and improve the socio-economic conditions and quality of life of rice farm families in the rainfed ecosystems.

The project developed a cadre of scientists trained on methods for ecosystems and farming systems analysis and on-farm farmer participatory research (OFR). It addressed farmers' needs, technology development and synthesis; and sustainability issues. Methodologies were refined and adapted to enhance farmers' participation in OFR by incorporating the considerations of gender, farm and household size, resource base (labour, cash and material availability and use) and the value of enterprises in terms of food, fodder, fuel and cash. Agroecological analysis to characterise biophysical and socio-economic environmental factors was conducted at the micro level in all project sites (about 90 villages or village clusters). Based on the characterisation and delineation and crop production technology requirements, promising technologies including rice genotypes have been identified. Improved crop management practices and new varieties of crops are continuously being tested and jointly selected by researchers and farmers for specific situations throughout the eastern region; crops include rice, wheat, gram, mustard, lentil, pea, jute, sesame, lathyrus and fish. Economically profitable farming systems have been identified for all the test sites. In the drought-prone rainfed lowlands, efforts are being made to extrapolate rainwater management technologies for stabilising yields and increasing cropping intensity and resource productivity.

This publication features some of the exemplary practices drawn from on-farm research undertaken as part of this project. A workshop was organised by IRRI with the assistance of the International Institute of Rural Reconstruction (IIRR). The workshop, which was held at the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun, India, 5-18 April 1999, brought all the participating scientists together primarily for the purpose of documenting the best practices and strategies. Artists, editors and desktop publishing staff provided support during the workshop. Papers were intensively reviewed and critiqued by participants representing a wide range of disciplines. Often, scientific assumptions were challenged. The practical relevance of the topics was continuously emphasized. Papers were revised and small teams were set up to further deliberate and improve the papers. At the end of two weeks, a near final draft was prepared for review and finalisation. The result is this publication, a user-friendly compilation of findings and practices of relevance to governments, NGOs, universities, district administrators, authors and researchers within the region and in other countries with similar ecologies.

Overview of Rainfed Rice Issues

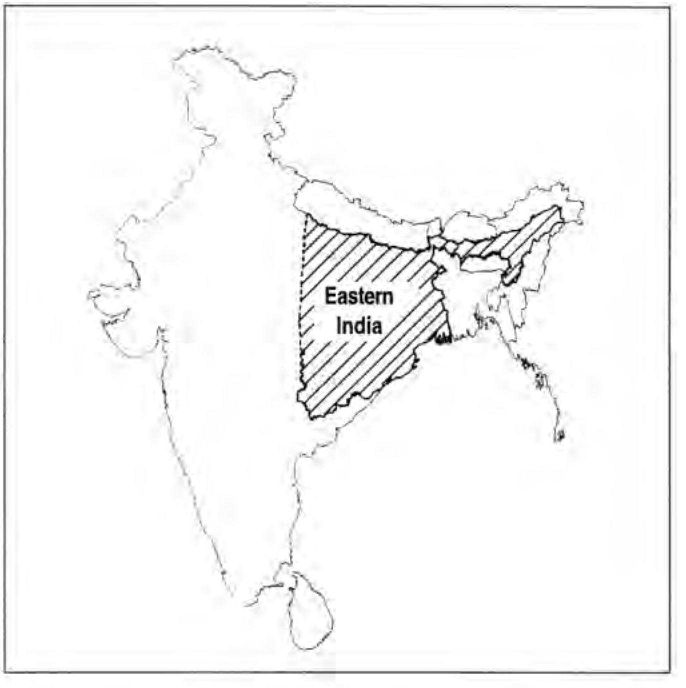
Overview of Rainfed Rice in Eastern India: Area, Production and Yield

India produces nearly one-fourth (22%) of the rice in the world, next only to China. The domestic supply is about 87 million tons per year, which includes over 80 million tons of rice produced on about 43 million ha. The surplus is about 2 million tons; therefore, today there is no need to import rice, as in the past.

The situation may change in the next five to six years, when the supply and demand will have a negative gap of more than one million tons. Unfortunately, this gap is likely to widen in the distant future.

To bridge this gap, rice production in 2020 will have to be about 134 million tons. But due to high population growth, the food demand challenges ahead are formidable.

This is the present situation where the area for rice production is progressively increasing. From 1970 to 1996, rice production increased from 41 to 80 million tons/year. Productivity increased from 1091 to 1862 kg/ha. In the next 15 years, average productivity will have to reach 2548 kg/ha, an increase of 35% over the present level.



Population growth leads to food shortage

Rice in eastern India

Eastern India includes the states of West Bengal, Orissa, Bihar, Assam, eastern Uttar Pradesh and eastern Madhya Pradesh. It is the most important rice-growing and -consuming area in India. Although 35% of the people live in this region, their demand is about 49% of the rice grown in the country. The annual per capita rice consumption in this region is 133 kg versus 37 kg in the western region, 39 kg in the northern region and 113 kg in the southern region. Eastern India cultivates 51.3% of the area under rice in the whole country and produces 45% of the total production needs.

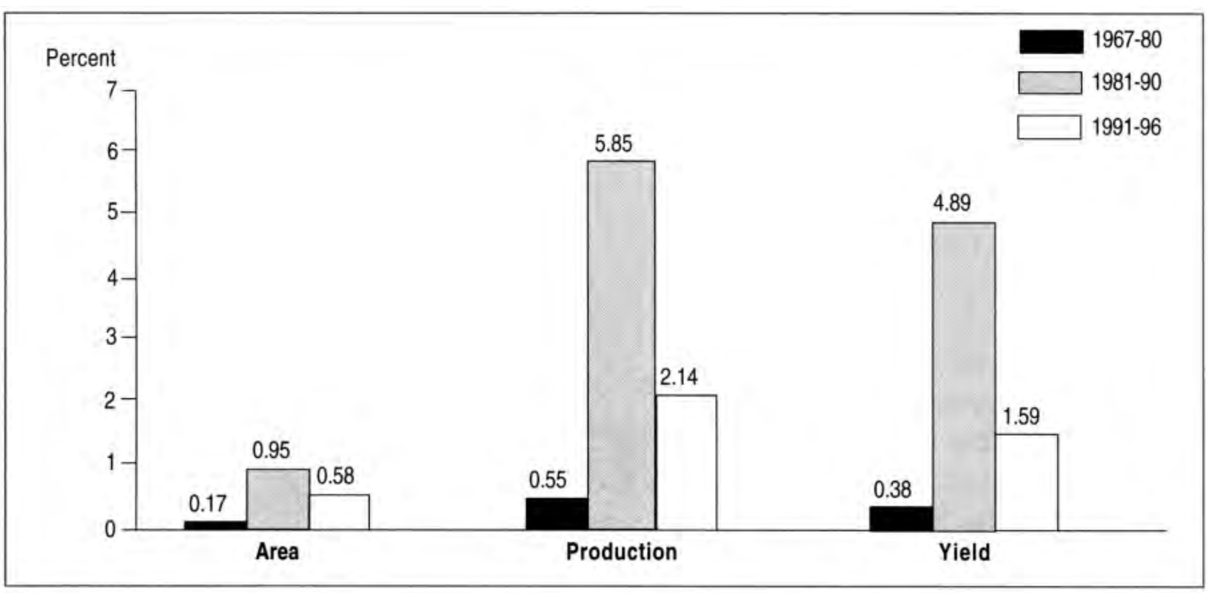
Projected rice demand and targets of rice yield in the eastern region

Year	Demand (m tons)	Yield target (kg/ha)
1996	36.7	1652
2000	41.5	1870
2005	45.3	2038
2010	49.4	2222
2015	53.6	2548

Rice production and productivity in the eastern region

Growth trends in rice production and yield in the eastern region showed significant increases in the 1980s. However, in the 1990s, overall production and productivity have decreased marginally along with area.

Growth in rice area, production and yield in the eastern region

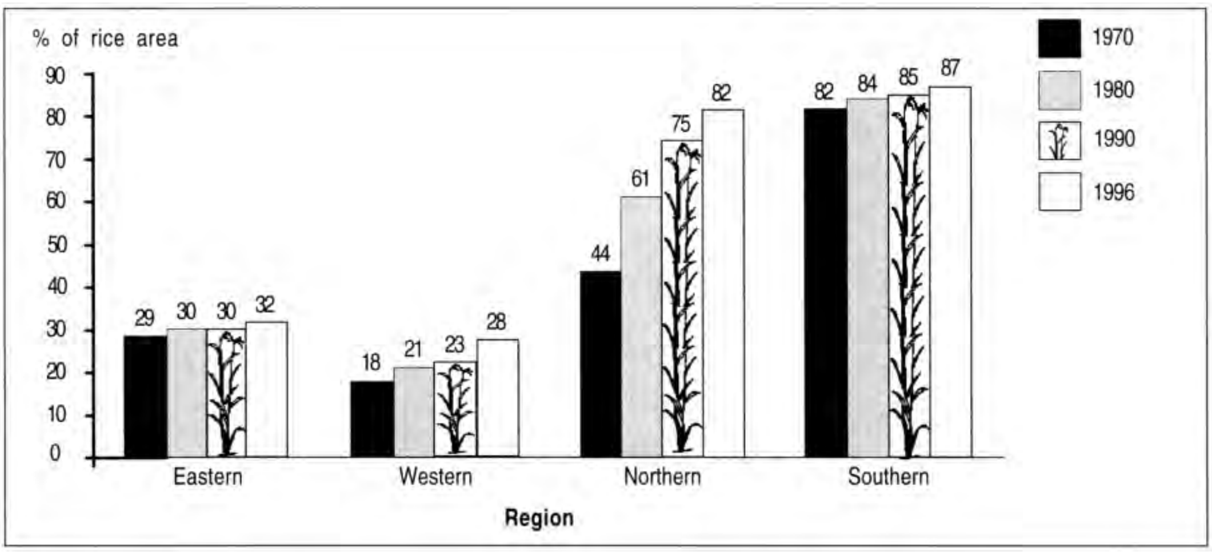


Production factors

Water

Water is the most crucial factor in rice production in the eastern region, where about 70% of the rice area is rainfed. Therefore, to increase rice productivity in this region, crop management under rainfed conditions is crucial. Among the major rice-growing regions, the area under irrigation in the eastern region is the lowest. The following figure compares the irrigated areas.

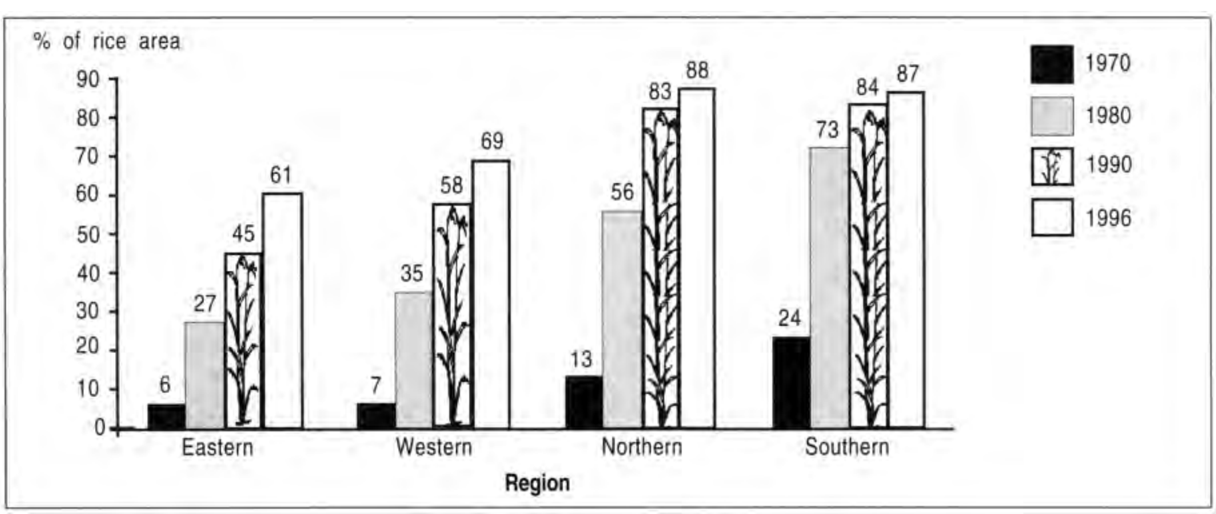
Irrigated area



Use of high-yielding varieties

The use of high-yielding varieties in this region is successful. With only 6% of the area under high-yielding varieties in 1970, now about 60% of the area has been covered with these varieties. In the western, northern and southern regions, coverage is 69%, 88% and 87%, respectively.

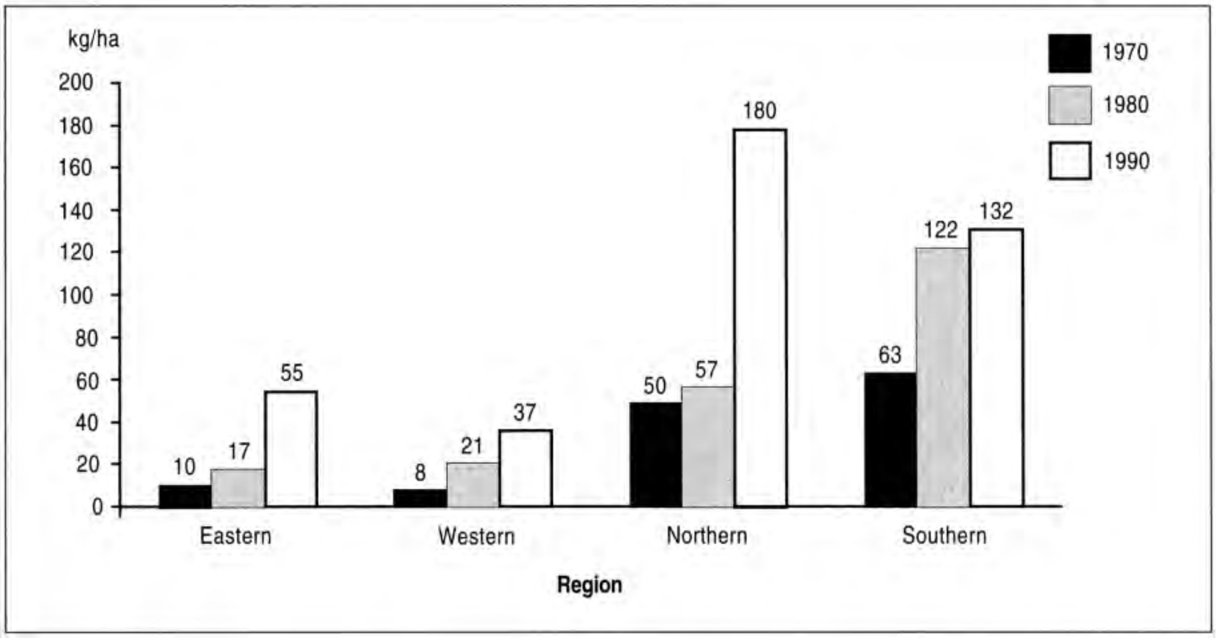
Area planted with high-yielding varieties



Plant nutrients

Consumption of total plant nutrients in the eastern region is much lower than in other regions. An average consumption of 55 kg/ha of plant nutrients is much lower than the 180 kg/ha and 132 kg/ha in the northern and southern regions, respectively.

Fertiliser use (total plant nutrients)



Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Prepared by:
P. Kumar

Rice Area in Different Ecosystems in Eastern India

Eastern India is home to 680 million people who largely depend on rice farming. Mega-level analysis of the four regions of India indicated that rice yields in northern and southern India have increased rapidly in recent years. But yields remained stagnant in eastern India (except in West Bengal, which experienced rapid growth in recent years).

Eastern India, which comprises eastern Uttar Pradesh, eastern Madhya Pradesh and the entire states of Assam, Bihar, West Bengal and Orissa, is the largest rice-growing region in the country and accounts for about 63.3% of India's rice area (26.8 million ha). The average rice yield in five of the six states is 2.7 t/ha. About 78.7% of the rice farming in the region is rainfed. Rainfall is moderate to high and is limited to a short period. This results in drought in the uplands and flooding in the lowlands.

The macro-level analysis of rice-growing ecosystems in eastern India revealed that only 21.3% (5.7 million ha) of the 26.8 million ha rice area is irrigated (Table 1).

About 16% of the area (4.3 million ha) is upland, 48% (12.9 million ha) is rainfed lowland (0-50 cm water depth), and the remaining 14.6%, (3.9 million ha) is deepwater or very deepwater (50 to >100 cm depth). For the rainfed lowland ecosystems, about 82% of the area (10.6 million ha) has shallow water depth (0-30 cm), and 18% (2.3 million ha) has medium water depth (30-50 cm).

Table 1. Rice area (million ha) in different ecosystems in eastern India

State	Irrigated	Upland	Rainfed lowland		Deepwater	Very deepwater	Total
			0-30 cm	30-50 cm	(50-100 cm)	(>100 cm)	
Assam	0.2	0.2	0.9	0.5	0.4	0.1	2.3
Bihar	1.5	0.5	1.7	0.5	0.4	0.7	5.3
Orissa	1.1	0.7	1.7	0.5	0.4	0.1	4.5
Madhya Pradesh	0.6	1.3	2.7	–	–	–	4.6
Uttar Pradesh	1.0	0.7	1.9	0.3	0.2	0.5	4.6
West Bengal	1.3	0.9	1.7	0.5	0.4	0.7	5.5
Total	5.7	4.3	10.6	2.3	1.8	2.1	26.8

Analysis of drought and flooding patterns, water balance, selected land characteristics and length of growing season in the rainfed lowland ecosystem showed that 54.7% (5.8 million ha) is drought-prone, 24.5%. (2.6 million ha) is drought- and submergence-prone, 10.4% (1.1 million ha) is submergence-prone and 10.4% (1.1 million ha) is favourable (Table 2).

The entire area in the medium-depth category of the rainfed lowlands is submergence-prone. There is a wide fluctuation in the extent of the deepwater ecosystem and the medium-deep category of rainfed lowlands, depending on rainfall pattern and amount, and onset and cessation of the monsoon.

Rice yields in all the rainfed ecosystems are low and vary greatly from year to year. Yield in the irrigated area is 3.2 t/ha. The yield range is 0.6-1.5 t/ha in the uplands, 0.9-2.4 t/ha in the rainfed lowlands and 0.9-2.0 t/ha in the deepwater and very deepwater areas. The rainfed lowlands are the first-priority ecosystem in eastern India because of their area, larger dependent population and yield potential.

Table 2. Area (million ha) of the shallow (0-30 cm) sub-ecosystems of rainfed lowland rice in eastern India

State	Drought-prone	Drought- and submergence-prone	Favourable	Submergence-prone	Total
Assam	–	–	0.5	0.4	0.9
Bihar	0.9	0.7	–	–	1.6
Orissa	0.7	0.5	0.3	0.3	1.8
Madhya Pradesh	2.7	–	–	–	2.7
Uttar Pradesh	0.8	1.1	–	–	1.9
West Bengal	0.7	0.3	0.3	0.4	1.7
Total	5.8	2.6	1.1	1.1	10.6

Prepared by:
V. P. Singh and M. Hossain

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Constraints in Rainfed Rice Farming in Eastern India

The rainfed ecosystem is mainly divided into uplands (favourable, unfavourable) and lowlands that can be further sub-divided into favourable (shallow) and unfavourable (semi-deep and deepwater). Unfavourable lowlands are chronically flood-prone (flash flood/stagnant flooding).

Out of 26.8 million ha of rice area under rainfed ecosystems, eastern India occupies 21.1 million ha amounting to 78.7% of its total rice area.

Large heterogeneity exists within each sub-ecosystem in soil type, nutrient availability, water regimes and socio-economic conditions of the farmers.

Constraints in rainfed rice farming

- Biophysical
- Technological
- Socio-economic
- Institutional

Realities in rainfed rice farming

- Population growth at the present rate of 2.1% per annum will continuously require more food. Yield plateauing in irrigated areas has necessitated turning the focus to the rainfed rice ecology.
- Improved rice production and productivity in this region may not only help the resource-poor farmers of the region but also substantially increase the food production of the nation.
- Improved rice production technology, along with a limited number of suitable high-yielding varieties (HYVs) of rice, now available for each of these unfavourable ecologies, needs proper exploitation.
- With national and international collaborative efforts, it has now become possible to develop better location-specific technology and HYVs having regional adaptability at a faster rate through the consortium approach.
- A modest increase by half a ton per hectare in rice yield in the rainfed ecosystem can add about 10 million tons of extra rice from eastern India itself to meet the target of rice production of the country in the next five years.
- Extension agencies have to play a major role to educate the farmers about recent developments.
- Farmers' participation in the process of refinement and acceptance of modern production technology has begun to make an impact and merits wider application of this approach in other research and development programs.

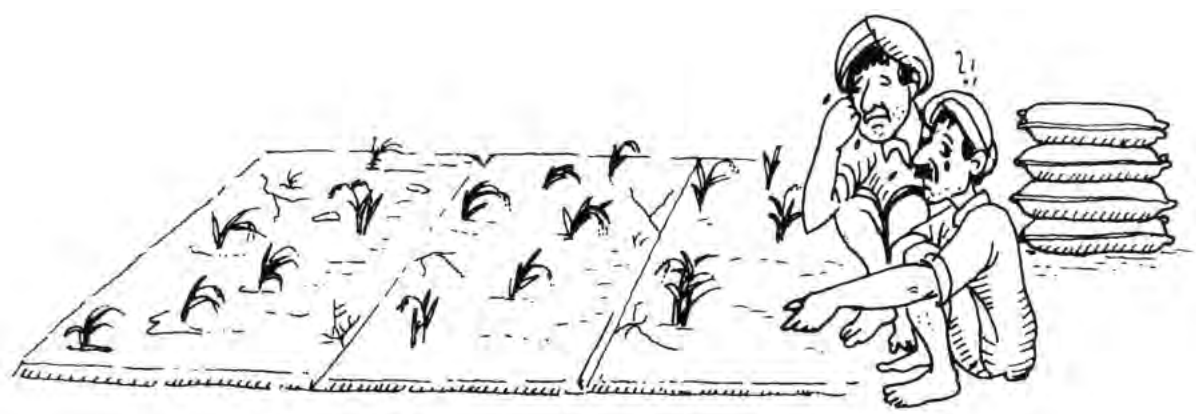
Constraints to rice production

The constraints to rainfed rice farming are many and vary from area to area. Most of the major constraints related to higher rice productivity can be understood under various factors such as:

- Moisture stress due to erratic and often inadequate rainfall, high runoff, poor soils, and lack of facilities for rainwater and soil moisture conservation/life-saving irrigation (upland and drought-prone rainfed lowlands).
- Intermittent moisture stress due to low and erratic rainfall, and poor soils as in Madhya Pradesh, Orissa and some parts of Uttar Pradesh. Flash floods, waterlogging/submergence due to poor drainage, low-lying physiography and high rainfall in submergence-prone lowlands, as in Assam, West Bengal and north Bihar. Accumulation of toxic decomposition products in ill-drained soils and soil reduction, encouraging problems of iron toxicity (in Assam).
- Continuous use of traditional varieties due to the non-availability of improved seeds and farmers' lack of awareness about HYV (uplands, rainfed lowlands and deepwater areas).
- Low soil fertility due to soil erosion leading to losses of soil nutrient and moisture. Low and imbalanced use of fertilisers in the uplands due to non-availability of any suitable method to apply the fertiliser in standing water in rainfed lowlands and semi-deep and deepwater areas.
- Heavy infestation of weeds and insect pests such as blast and brown spot and poor attention for their timely control (uplands and rainfed lowlands).
- Poor crop stand establishment due to broadcast seeding, resulting in uneven germination (uplands and direct-seeded lowlands); delay in monsoon onset, often leading to delayed and prolonged transplanting and sub-optimum plant population (mostly in rainfed lowlands).
- Poor adoption of improved crop production technologies due to technology inappropriateness and economic backwardness of farmers (uplands and lowlands).

Biophysical

Uplands

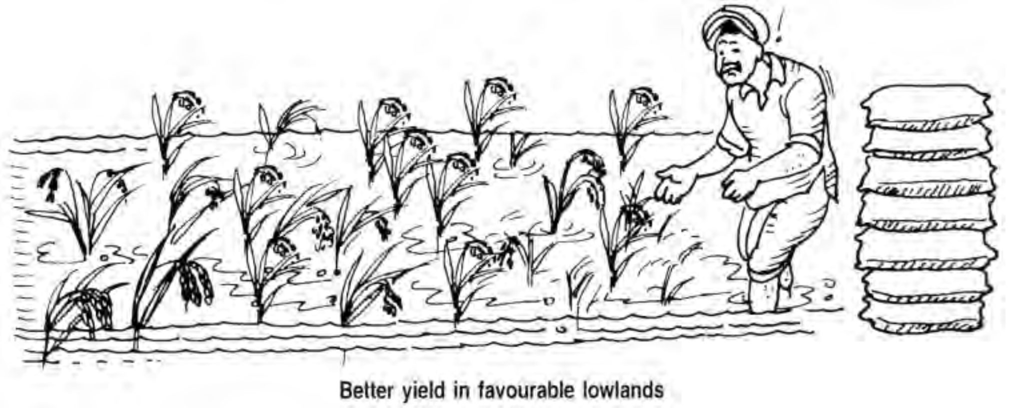


Low yield and sparse growth in rainfed uplands due to moisture stress

Sparse growth and low yield in rainfed uplands due to moisture stress

Constraints	Favourable areas	Unfavourable areas
Moisture stress	Erratic rainfall Light soil texture, flat and bunded	Low and erratic rainfall Light texture of soil, shallow soil depth, unbunded Sloping and undulating topography
Soil acidity	Low pH Leaching loss of nitrogen and potassium	Low pH Leaching loss of nitrogen and potassium
Poor fertility	Low organic matter Deficiency of nitrogen, phosphorus, potassium, calcium and magnesium High phosphorus fixation Aluminium toxicity	Low organic matter Deficiency of nitrogen, phosphorus, potassium, calcium and magnesium High phosphorus fixation Fe deficiency
Weeds	High weed infestation, e.g., *Echinochloa colona, Cyperus rotundus* and *Fimbristylis miliacea*	High weed infestation, e.g., *Echinochloa colona, Cyperus rotundus* and *Fimbristylis miliacea*
Diseases	High infestation of blast, brown spot and root-knot nematode	High infestation of blast, brown spot and root-knot nematode
Insect pests	Gundhibug, termite, armyworms and leafhopper	Gundhibug, termite and leafhopper

Lowlands



Better yield in favourable lowlands

Constraints	Favourable areas	Unfavourable areas
Water regime	–	Periodical drought and/or submergence/ flash flood
Plant population	–	Poor
Fertility	Low/moderate	Low, iron toxicity, zinc deficiency, salinity and sodicity
Diseases	Bacterial leaf blight, sheath rot and sheath blight	Bacterial leaf blight, sheath blight, sheath rot, stem rot, brown spot and blast
Insect pests	Brown planthopper, gall midge, stem borer and white-backed planthopper	Stem borer, caseworm, leaffolder, white-backed planthopper
Weeds	*Echinochloa crus-galli, Cyperus difformis* and *Commelina benghalensis*	*Echinocloa crus-galli, Cyperus difformis* and *Commelina benghalensis*

Deepwater situation

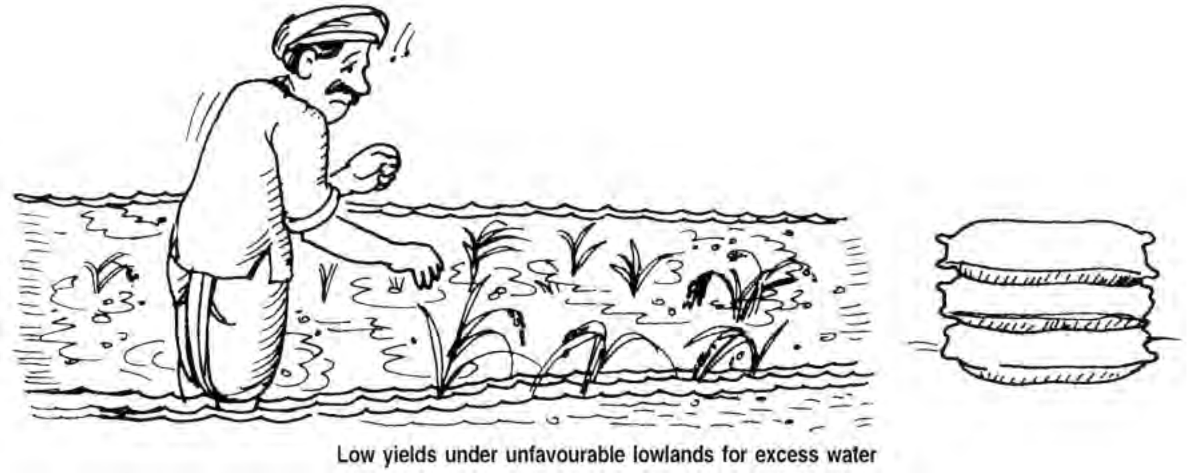
- Submergence for more than a week
- High ufra nematode and stem borer incidence

Technological

Uplands

Constraints	Favourable areas	Unfavourable areas
Variety	Limited varietal options for site-specific situations	Very limited site-specific options for appropriate high-yielding variety
Availability of high-quality seeds	Not available	Not available
Poor plant population	Poor crop emergence	Poor crop emergence
Operational	Difficulty in use of agrochemicals comparatively less for weed control	Difficulty in use of agrochemicals for weed control

Lowlands

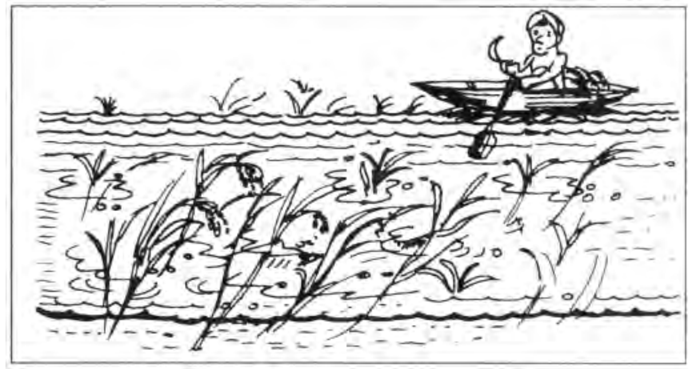


Low yields under unfavourable lowlands for excess water

Constraints	**Favourable areas**	**Unfavourable areas**
Variety	–	Non-availability of superior genotypes with drought or submergence tolerance
Plant population	–	Reduced due to early drought and early submergence, particularly when direct-seeded
Operational	–	Difficulty in application of agrochemicals due to drought and/or excess water
Fertiliser management in lowlands (availability of method for applying 2nd and 3rd dose of nitrogen)	Available	Not available for submergence-prone lowlands

Deepwater situation

- Lack of suitable genotypes tolerant to early drought and subsequent submergence
- Difficulty in maintaining proper plant stand
- Difficulty in tillage operation for nutrient and cultural management
- Difficulty in use of agrochemicals



Flood-prone lowlands with poor crop stand

Constraints common to all

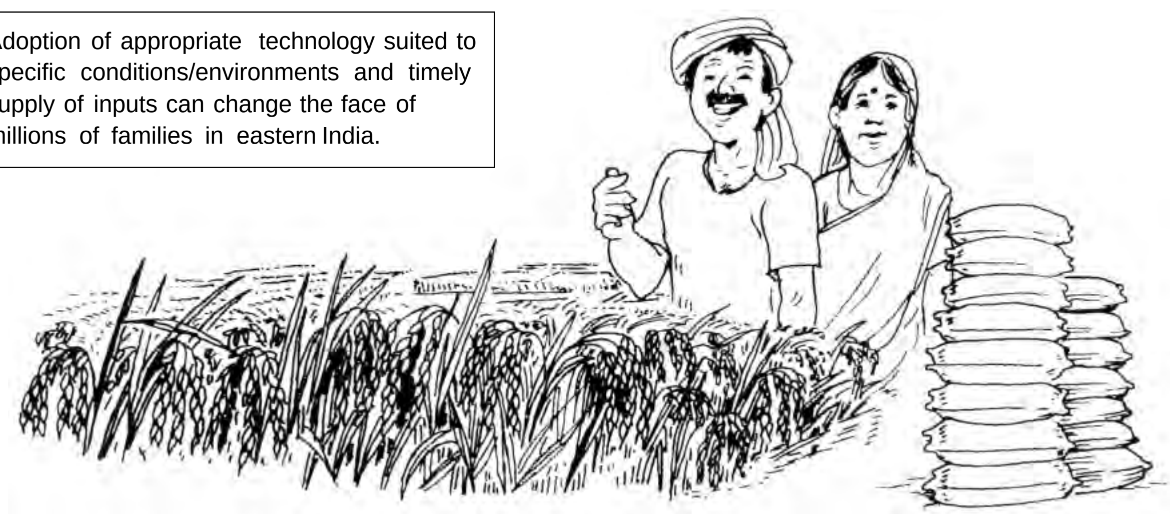
Socio-economic

- Poor and limited resource base of farmers
- Small and fragmented holdings
- Unfavourable land tenure system causing lack of interest
- Low literacy of farming community
- Poor animal draft power
- Scarcity of labour in peak period of operation
- Stray cattle menace

Institutional

- Poor infrastructure such as irrigation, drainage, roads, etc.
- Poor transport and communication system influencing marketing and input flow
- Non-availability of inputs, including credit facility at proper time
- Poor extension reach of agencies
- Lack of coordination between agriculture and allied departments
- Lack of proper facilities for skill upgrading of farmers on risk management

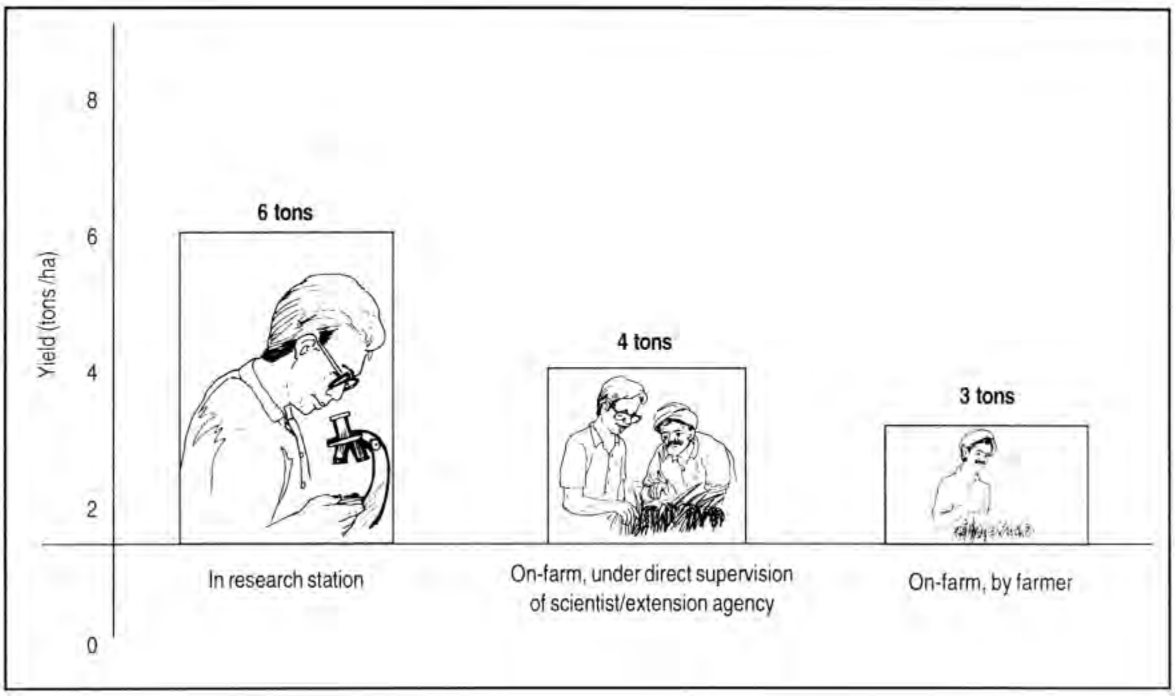
Adoption of appropriate technology suited to specific conditions/environments and timely supply of inputs can change the face of millions of families in eastern India.



Yield gap analysis

- Even though the average yield of the rainfed ecosystem of eastern India is only about 1 t/ha, its potential is very high, as seen from demonstration/ on-farm trials.
- While the relative yield potential of new high-yielding varieties of rice developed for rainfed uplands and lowlands is about 4-5 tons and 8-10 t/ha, respectively, farmers realise only up to 50% of it, as illustrated below:

Gaps between potential yield and yield realised by farmer



- The gap is due to two major factors:
  - ¿ Non-availability of seed and other inputs to farmers in time.
  - ¿ Lack of farmer awareness about new varieties and improved technologies developed for stress environments.

Prepared by:
J. K. Roy, S. K. Mohanty, K. Prasad, R. K. Sahu, H. C. Bhattacharya and N. K. Sarma

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Natural Ecosystems and Agro-Ecosystems in Eastern India

Natural ecosystems

An ecosystem is a functional unit consisting of both living and non-living components. Ecosystems have a number of structured inter-relationships between soil, water, nutrition and climate on one side and producers, consumers and decomposers on the other. Ecosystems, when not modified by human activities, are called natural ecosystems.

Agro-ecosystems

Natural ecosystems managed for agricultural purposes are called ago-ecosystems. The two ecosystems differ in function. For example, in agro-ecosystems, the produce is always directly for human use, whereas, in natural ecosystems, the produce is only sometimes for direct human use.

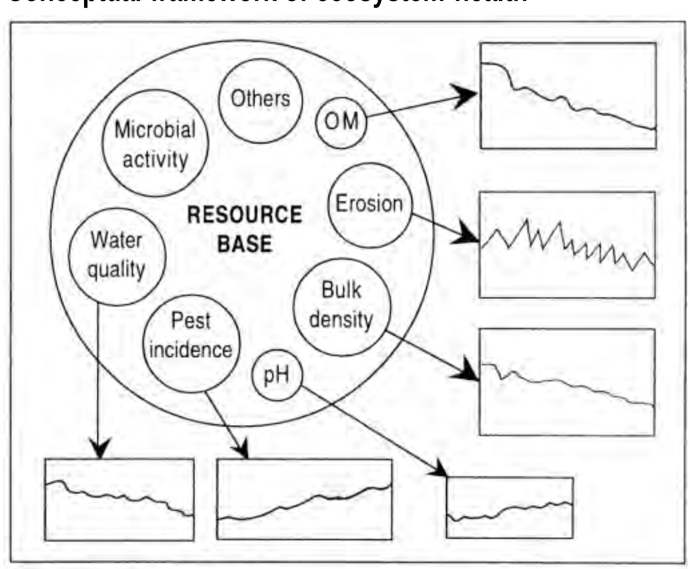
Distinguishing features of agro-ecosystems

- Less diversified species and individuals.
- Relatively homogeneous in their genetic characteristics and physiological cycles.
- The biological process is discontinuous and concentrated on a specific period.
- More uniform than natural ecosystems.
- More dependent on external inputs for their operation and high level of production.

Ecosystem efficiency

Ecosystem efficiency is measured in output/input ratios. If the ratio is <1, the ecosystem efficiency is low and if it is >1, it is not sustainable. Ecologists measure efficiency as an 'energy balance' while planners and economists view it as a 'monetary balance'.

Conceptual framework of ecosystem health



Ecosystem health

The health of ecosystems should be maintained for sustainable productivity. Ecosystem health can also be used as a measure of sustainability. There is no universally accepted set of ecosystem health measures. However, some basic measures of ecosystem health are the temporal changes in soil organic matter (OM) content, soil erosion, microbial activities, incidence of pests and diseases and soil physical and chemical properties.

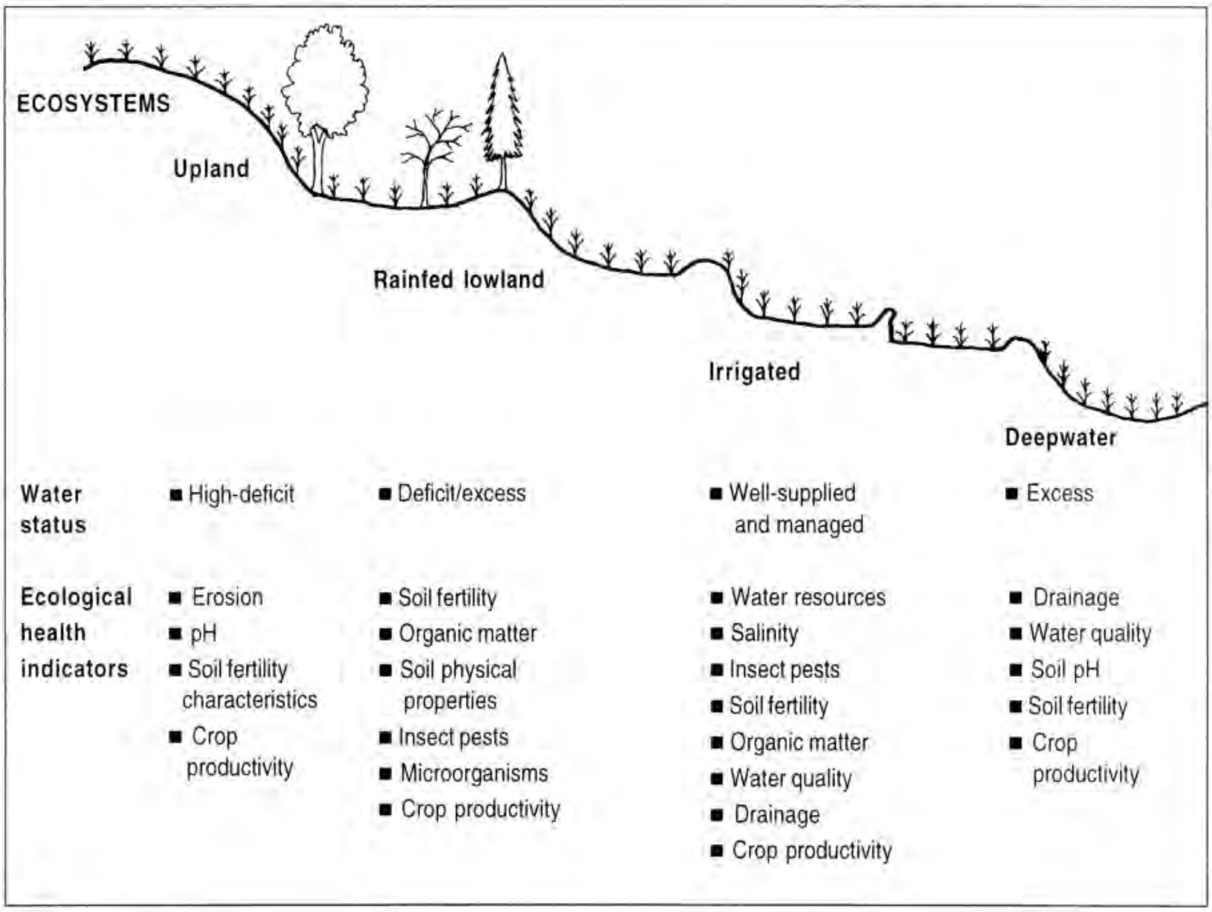
Micro-regional analyses (village or group of villages) help in planning at grass-roots level

- Assess productivity status.
- Identify constraints to high productivity.
- Plan to remove constraints.

Production systems

There are several ways to define and analyse production systems, going from the status of crop yields to the integration of soil, plants and animals.

Schematic diagram of rice ecosystems and their health indicators



Characterising agro-ecosystems

Delineating agro-ecological zones helps assess the production potential of crops in a given area. This has become a prerequisite for improving crop production in rainfed areas.

The basic principles of agro-ecological characterisation are the land

- suitability in relation to specific use;
- suitability to sustainability;
- evaluation for more than one envisaged use;
- use on a simple economic basis; and
- suitability through a multi-disciplinary approach involving ecologists, climatologists, agronomists and economists.

Rice production systems in different ecosystems

Production systems can differ within the ecosystem. For example, in rainfed lowland rice ecosystems, the production system may be low and stable, low and unstable, or even high and unstable. Identifying the production system in each ecosystem helps

- develop location-specific technology and
- adopt the technology developed under such situations elsewhere.

When the rice productivity data were analysed for all the rice-producing districts in eastern India, they showed a large-scale variability in mean productivity and in the coefficient of variability (CV). The variations in mean productivity and CV values set the categories of the production systems in different districts in eastern India.

Rice production systems in different districts of eastern India

Districts	Status
Madhya Pradesh	
All	Low and unstable
West Bengal	
3	High and unstable
Others	Low and stable
Bihar	
1	High and stable
4	Low and stable
5	High and unstable
Uttar Pradesh	
11	Low and unstable
4	High and unstable
Orissa	
	High and stable
	Low and stable
Others	Low and unstable

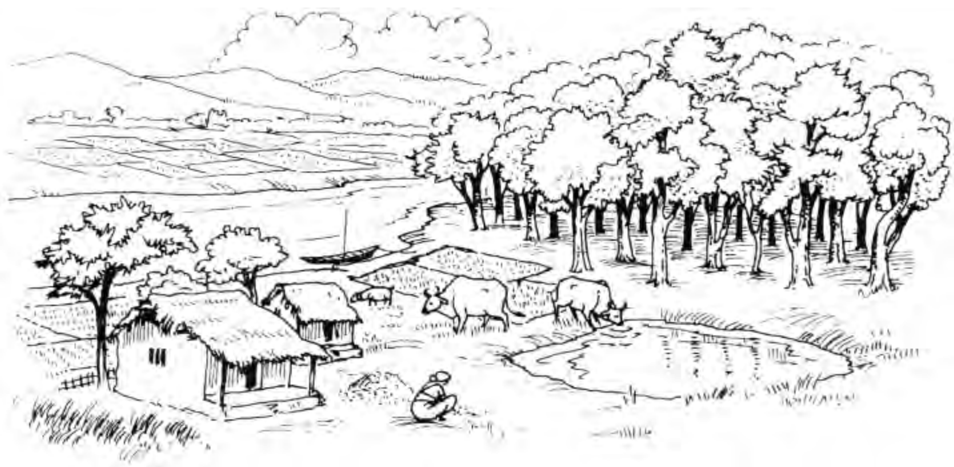
Prepared by:
A.S.R.A.S. Sastri and **V.P. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Utilisation and Management of Natural Resources in Rainfed Areas

What are natural resources?

Natural resources are the resources that are available in nature: land, water, climate and flora and fauna.



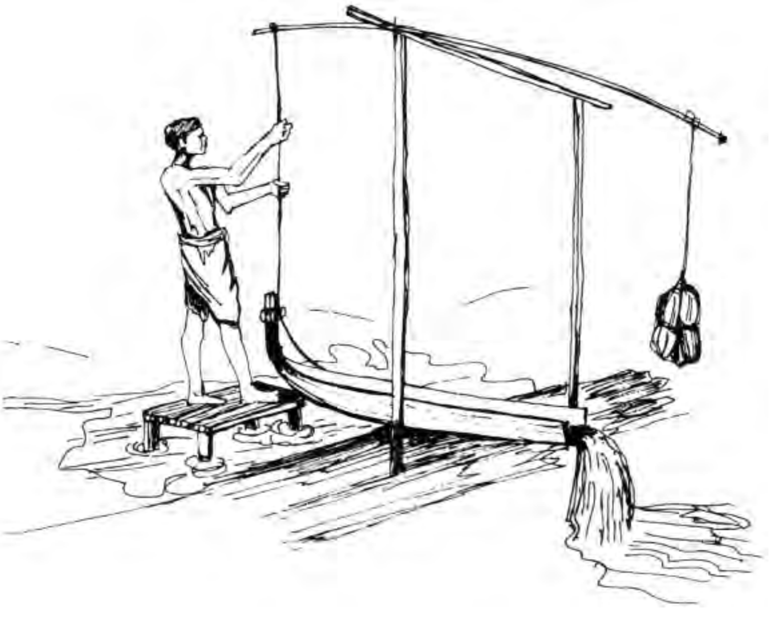
Natural resources and quality factors

Land resources

Factors	Management measures
■ Topography ■ Slope ■ Location, length and courses of drainage lines ■ Productivity ■ Occurrence of hardpan in soil profile **Qualities** ■ Texture ■ Depth ■ Fertility • Acidity • Alkalinity • Salinity	■ Vegetative hedges with ridge and furrows to filter runoff water and control soil erosion ■ Contour cultivation for *in situ* moisture conservation ■ Opening of contour dead-furrows at appropriate intervals to trap moisture for recharge of soil profile ■ Gully control ■ Organic farming and integrated nutrient management system (use of legumes, bio-fertiliser and bulky organic manures) to enhance moisture-holding capacity of soil.

Water resources

Factors	Management measures
■ Average amount and pattern of annual rainfall ■ Amount and nature of surface flow of rainwater ■ Moisture availability ■ Depth and quality of groundwater ■ Hydrological behaviour of drainage lines	■ Clearance of drainage congestion by deepening water bodies and creating a network of ponds to promote fisheries and development in aquatic farming systems in low-lying areas. ■ Stabilisation of nala banks primarily with vegetative measures. ■ Indigenous water-lifting devices are low-cost and useful

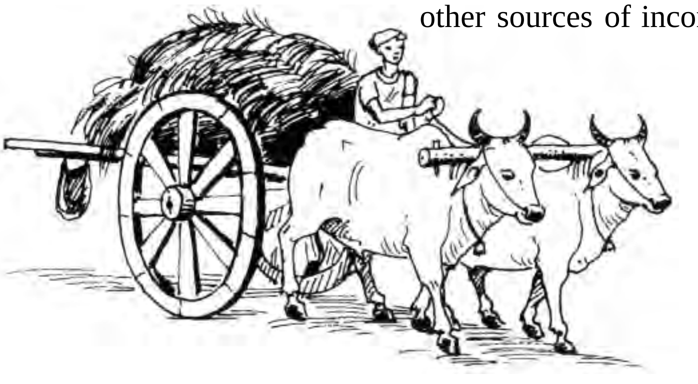


Vegetative resources

Factors	Management measures
■ Climax species ■ Natural vegetation ■ Economic and utility species – medicinal, aromatic, industrial fuel and fodder species	■ Vegetative measures promote agro-industry, horticulture, etc. ■ Especially in hilly areas, terraces fortified with vegetative measures are stable and serve well

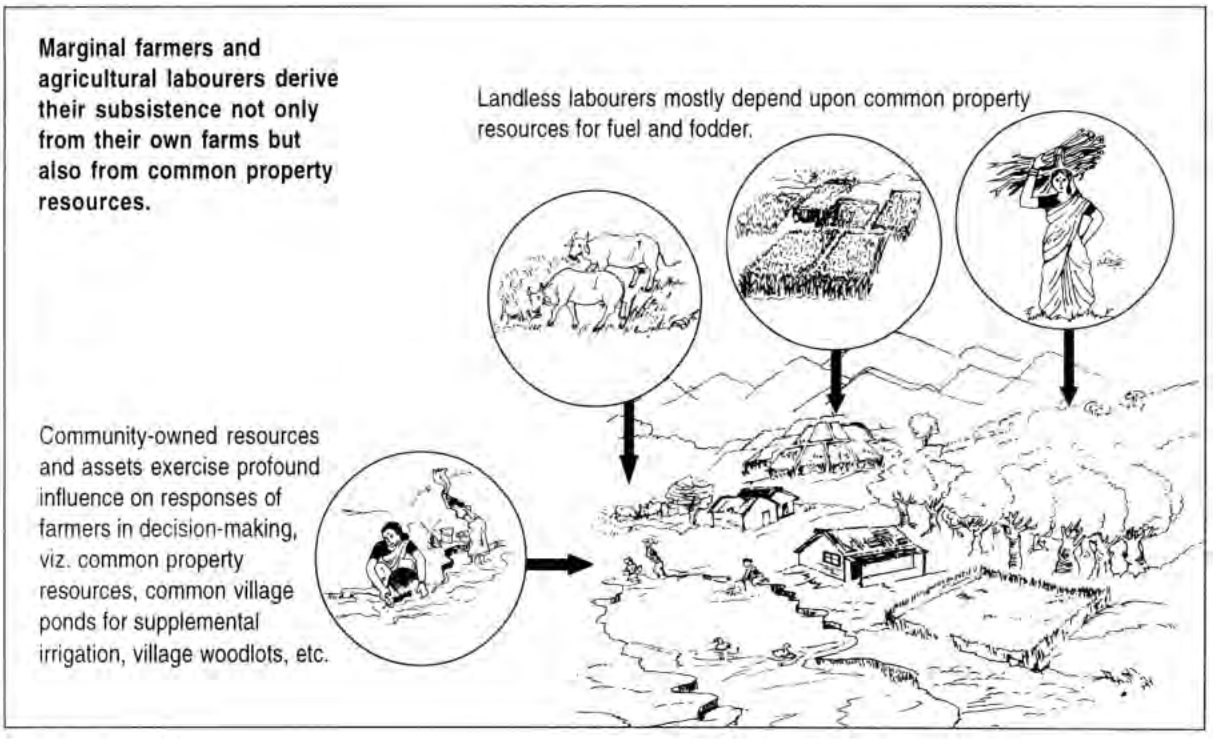
Animal resources

Factors	Management measures
■ Category and number	■ Draft animals required for ploughing, fuel, manure and carrying harvest ■ Animals provide milk, food and other sources of income

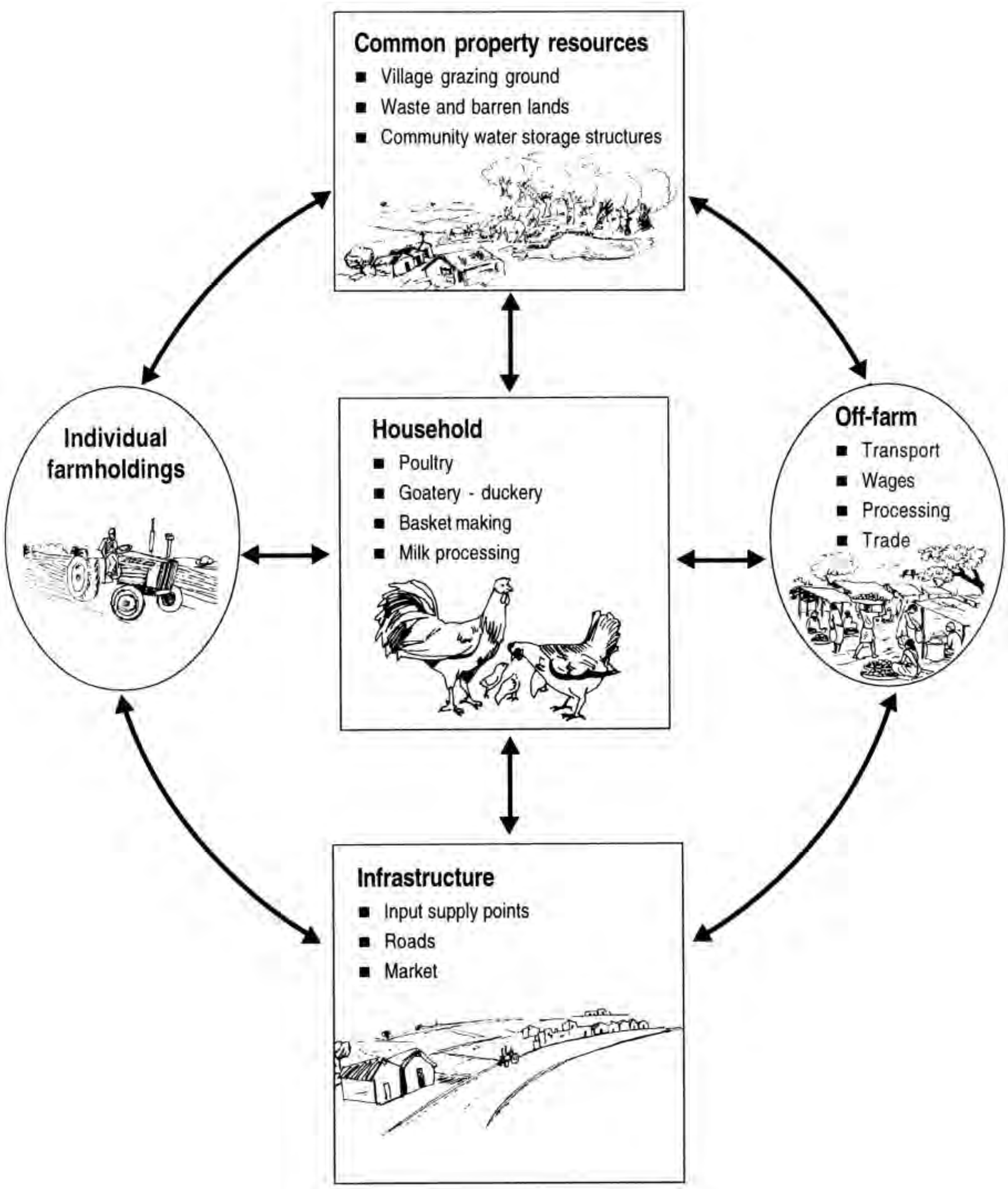


Utilisation and management of natural resources

- Subsistence of rainfed farmers, to a great extent, depends upon livestock resources and off-farm activities such as wages by working as labourers in brick fields, in government projects and also on fields of other farmers.
- Specialised activities like sericulture, beekeeping, poultry, goatery, piggery, duckery, lac cultivation, and cultivation and collection of medicinal and industrial plants also supplement the income of farmers.



Integrated rainfed farming systems



Resource management in rainfed rice culture

Upland

Broadcasting

Broadcasting

Combating drought at different stages of crop growth by

- using high seed rate and management,
- sowing very early duration rice varieties, and
- controlling weeds.

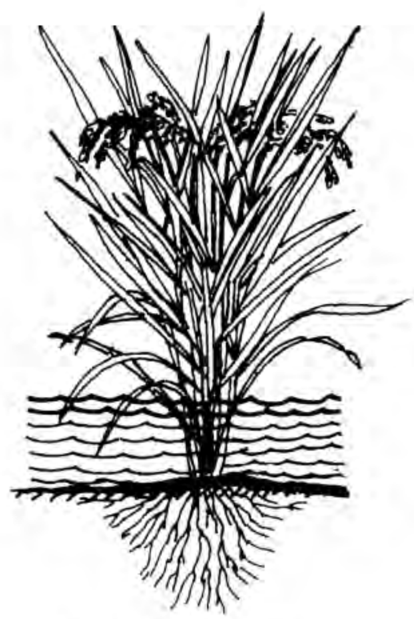
Transplanting

Transplanting

Managing soil moisture stress at the reproductive stage with

- the use of short-duration rice varieties, and
- nursery bed establishment at different times to match the onset of rain.

Lowland



Flood-tolerant variety

Flash flood

Restoring yield loss due to damage to established crop at different stages of intermittent flooding with

- very early duration rice variety cultivation for harvest before the onset of flooding;
- cultivation of a mixture of *aus* (autumn) and *aman* (winter) to ensure harvest of at least a single crop depending on early or late flood;
- nursery sowing at different dates to replant immediately after flood damage;

- double transplanting/splitting of tillers from surviving crop to compensate for the damaged area;
- sowing of extra early rice varieties; and
- transplanting of aged (50-60 days) photoperiod-sensitive seedlings in post-flood conditions.

Submergence/water stagnation

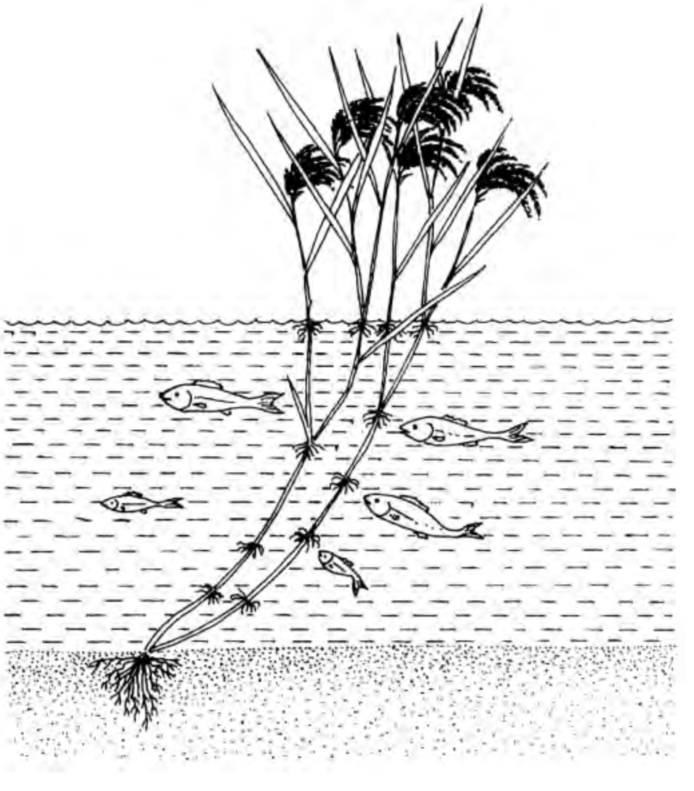
Restoring yield loss due to reduction in plant population through

- use of long-duration submergence-tolerant variety;
- advancement of planting with sub-surface water; and
- planting of aged seedlings/split tillers to cope with complete or partial submergence.

Deepwater-prone

Managing total damage of rice plant for deep flooding through

- flood-tolerant variety use;
- shift to *boro* (summer) rice in flood-free dry season;
- floating rice-boro integration; and
- rice-fish cultivation.



Coastal flooding

Restoring yield loss due to salinity through

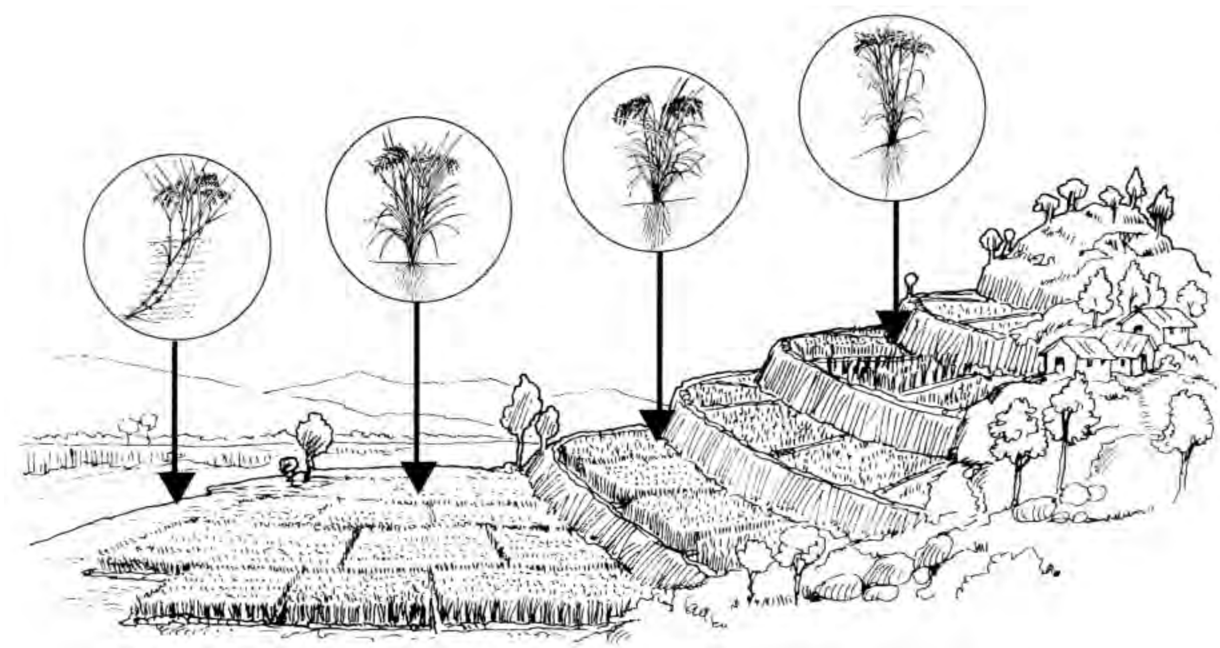
- planting of salinity-tolerant varieties;
- transplanting aged seedling in submerged land;
- using rice-fish cultivation; and
- planting *boro* (summer) rice with backfed water.

Prepared by:
N. K. Saha

Sourcebook produced hy the nternational Rice Research Institute IRRI) and the International Institute of Rural Reconstructml (IIRR).

Rice Biodiversity and Genetic Wealth

Rice biodiversity is the varietal diversity of rice in farmers' fields. It provides the base for genetic improvement by pure line selection (e.g., Basmati 370, the best known aromatic rice variety selected from the local landrace) and hybridisation (e.g., IR8, a high-yielding, fertiliser-responsive, dwarf variety). Also, desirable traits from local germplasm can be transferred by using molecular techniques.



Why do farmers grow more than one variety?

Farmers have played a major role in conserving some of the traditional as well as improved varieties. They have been traditionally growing more than one variety for the following reasons:

- to suit diverse, unpredictable environments within the ecosystems;
- to meet diverse household needs, e.g., food, fodder, medicine and thatching;
- to combat pests and diseases;
- to suit different cropping systems;
- to meet changing market demands; and
- to keep the family pride and tradition.

Remember!

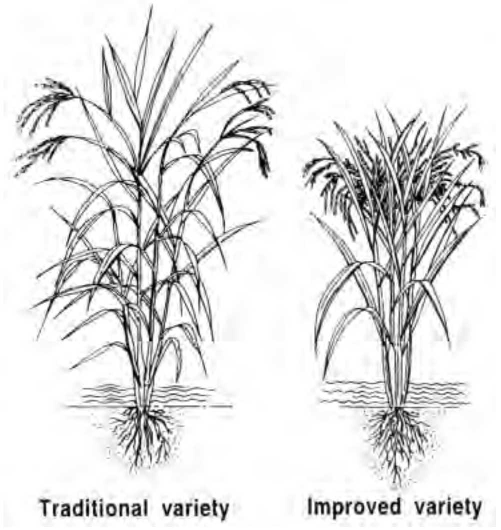
- Loss of biodiversity is a threat to mankind. Save it from extinction through farmers' participation.
- Conserve biodiversity *in situ* and *ex situ.*

Essential varietal characteristics in rainfed rice ecosystems

Upland – Drought tolerance
Lowland – Submergence tolerance
Flood-prone – Fast stem elongation

In situ rice diversity

Farmers in some villages in Orissa grow as many as 30 traditional and 11 improved rice varieties. Most farmers grow more than one variety. The number of varieties grown on each farm ranges from two to more than 10. More than 70% of the farmers grow two to five varieties while 20% of the farmers grow six to eight varieties.



Distribution of rice varieties grown by farmers in different ecosystems in Orissa

No. of varieties grown by each farmer	Farmers (%)		
	Upland	Medium-land	Flood-prone
1	2	0	0
2	2	10	2
3	4	14	2
4	4	10	2
5	0	16	2
6	2	6	2
7	2	6	2
8	0	0	2
9	0	0	4
10 (or more)	0	0	2

Source: *Kshirsagar et al.,* 1997

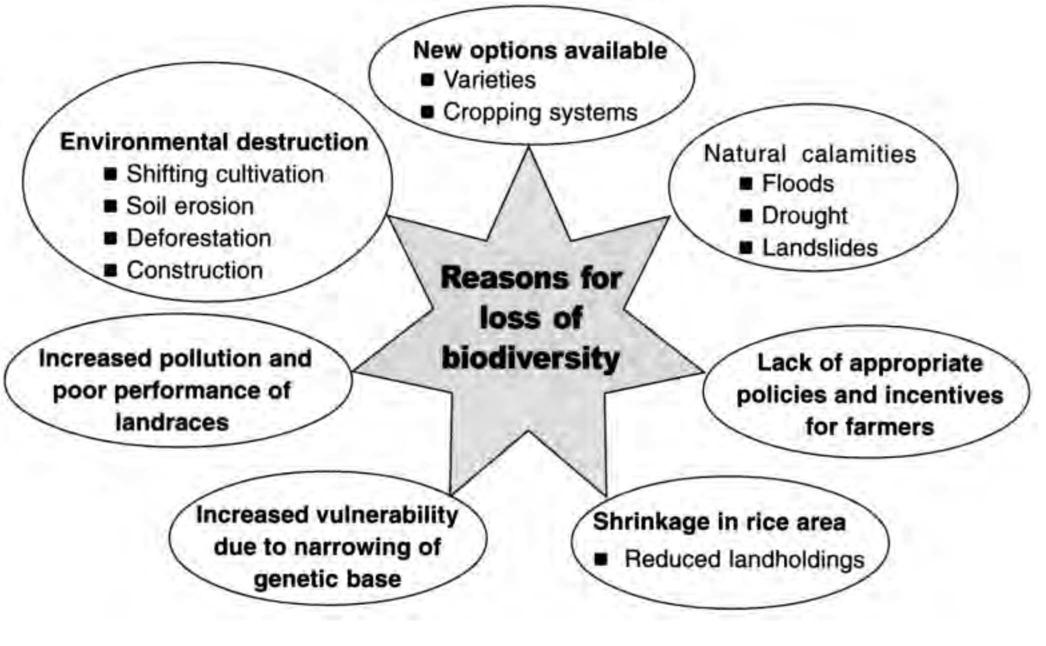
Loss of biodiversity

The rate of loss of diversity in rice has been slower in the rainfed than in the irrigated ecosystem. Among rainfed ecosystems, replacement of traditional varieties has been lower in rainfed lowlands than in other ecosystems.

Varieties lost: an estimate

Uplands	60-70%
Rainfed lowlands (favourable)	70-80%
Rainfed lowlands (unfavourable)	20-30%
Deepwater lands	<5%

About 20-30% more may be lost in the next 10-15 years.



In flood-prone areas, loss of biodiversity is mainly due to changes in cropping patterns; e.g., in West Bengal, fallow-deepwater rice is being replaced by fallow-*Boro* (summer) rice-fallow-late rice. Although varietal composition is changing, farmers grow a larger number of new varieties.

Changing varietal composition over time in different ecosystems in West Bengal

Varieties grown in 1988	Varieties grown in 1999
Rainfed upland	
Rasi, LET 826, CR 126-42-1 (Kalinga I), Palman 579, CR 237-1 (Kalinga Ill), Dular, NC 1626, Badkalamkati, Churnakati	Heera, Kalinga III, Sneha, Aditya, Prasanna, Kalyani II, Khanika, Jamini, Rasi, Tulasi, Kalinga I, Bhupen, Panke, Annada, IET 2233
Irrigated	
Ratna, Lakshmi, IET 2233, Khitish, CNM 25, IR36, Shyashree, Prakash, Kunti, IR20, CNBP 217	PNR 381, PNR 162, PNR 519, IET 4786, IR64, Ratna, Khitish, Bikash, Lalat, IR36, Ajaya, Kunti, Swarna (MTU 7209), Pantdhan 4, Shyashree, Pratap, Prakash, IR20, Surekha, Vikramacharya
Rainfed lowland (up to 50 cm)	
Pankaj, Swarnadhan, Mahsuri, Mandira, Suresh, Biraj, Sabitri, Jogen, Sabita, Nagra, Bhasamanik, Rupsail, Jhingasail, Kalma 222, Patnai 23, Raghusail, NC 678, NC 1281, OC 1393, SR 26B	IR42, Shalibhan, Swarnadhan, Bipasha, Jogen, Mansarovar, Tulasi, Mahsuri, Lunishree, Sabitri, CR 1002, CR 1014, Suresh, Biraj, Utkalprabha, Sabita, Mandira
Deepwater (>50 cm)	
Jaladhi 1, Jaladhi 2, Tilakkachari, Achra, Kumargore	Jitendra, Purnendu, Sudhir, Golak, Sunil, Mahananada, Dinesh, Jalaprabha, Saraswati, Bhagirathi, Hanseshwati, Ambika

Farmers select new varieties depending upon land type, soil type and water availability. The release and spread of high-yielding varieties have fast replaced the low-yielding, locally grown cultivars and landraces, e.g., the scented rice varieties of Uttar Pradesh.

Status of aromatic rice cultivars and landraces in Uttar Pradesh

Cultivar	Region	Districts
Popular and grown in large areas		
Kalanamak	Tarai	Basti, Sidharthanagar, Maharajganj, Gorakhpur, Gonda
Hansraj	Tarai	Dehra Dun, Rampur, Pilibhit
Badshah Pasand	Central Plain	Pratapgarh, Allahabad, Raibareilly, Bareilly
Popular but grown in small areas		
Basmati safeda	Tarai	Bareilly, Nainital, Saharanpur, Haridwar, Bijnor, Muzaffarnagar
Tilakchandan	Tarai	Nainital, Pilibhit, Rampur
Lalmati	Central Plain	Barabanki, Faizabad
Presently not grown		
Ramjawain	Tarai	Basti, Sidharthanagar, Saharanpur, Rarnpur, Pilibhit
Shakkar Chini	Tarai	Gonda
	Central Plain	Varanasi
	Vindhyan	Mirzapur, Sonbhadra
Dhaniya	Tarai	Basti, Gorakhpur, Gonda
Kanakjeer	Tarai	Basti, Sidharthanagar, Bahraich
	Central Plain	Barabanki
Bhataphool	Tarai	Basti, Sidharthanagar
	Central Plain	Azamgarh, Mau, Sultanpur
Duniapat	Tarai	Basti
Rambhog	Tarai	Bahraich, Gonda
Vishnuparag	Central Plain	Barabanki, Bahraich
Selhi Dulahniya	Central Plain	Mau, Azamgarh
Benibhog	Central Plain	Barabanki
	Tarai	Bahraich
Moongphali	Ganga Basin	Ghajipur
Tulsi Manjari	Ganga Basin	Ballia
Tulsi Prasad	Ganga Basin	Ballia
Phool Chameli	Vindhyan	Mirzapur, Sonbhadra, Varanasi

The trend is higher in areas with better access to seed sources such as agricultural universities and research stations than in remote areas.

Traditional and improved varieties grown by farmers in three villages of eastern Uttar Pradesh[1]

Varieties	Basalatpur		Sariyawan		Mungeshpur	
	No. of farmers	Area (ha)	No. of farmers	Area (ha)	No. of farmers	Area (ha)
Traditional	44	24.75 (52)	21	4.31 (18)	14	2.53 (11)
Improved	30	23.42 (48)	43	19.47 (82)	48	18.42 (89)

Survey conducted by Narendra Deva University of Agriculture and Technology (NDUAT), Faizabad, Uttar Pradesh. Sariyawan and Mungeshpur are close to NDUAT whereas Basalatpur is a remote village.

Figures in parentheses indicate percentage.

Traditional storage methods

Earthen pots (aboveground and underground)
Bamboo baskets
Straw tomb (*olia*)
Earthen bins (*kothies*)
Hanging panicle bundles

What can be done to conserve rice biodiversity?

- Provide varietal options to farmers to suit their diverse on-farm situations.
- Give incentives and recognition to farmers for maintaining diversity (farmers' rights).
- Initiate on-farm participatory plant breeding in marginal areas to add value to local cultivars.
- Organise seed production of selected local cultivars to be made available to farmers.
- Train selected farmers and create gender awareness in germplasm maintenance and utilisation.
- Conserve duplicate collections *ex situ* to save them from natural calamities.
- Provide public support and community storage facility.
- Develop new markets for local varieties and diversity-rich products.

Germplasm collection and assessment in eastern and central India

- During 1955-60, the Jeypore Botanical Survey initiated a systematic exploration. About 1745 cultivars were collected from south Orissa and adjoining areas of Madhya Pradesh.

  The first national-level venture to collect rice germplasm in northeastern India was initiated by the late Dr R. H. Richharia [former Director, Central Rice Research Institute (CRRI), Cuttack] in 1965 and 874 accessions were collected from Manipur.

Dr Richharia's collection

The late Dr R. H. Richharia, while collecting rice germplasm from Madhya Pradesh, found that rice varieties belonged to different groups and different names were given by farmers depending upon grain characteristics such as colour, size and taste. He cfassificd them into eight major groups, of which three groups – Phul, Chattri and Scented – are mainly aromatic cultivars. He observed wide Variation within Phul and Scented groups. The dominant varieties are:

Phul group	Ajwain Phul, Badal Phul, Kendu Phul, Sewanti Phul, Tulsi Phul
Scented group	Tulsi Manjari, Kali Moonch, Chinnor, Vishnu Bhog, Badshah Bhog, Dubraj

- During 1965-72, 6630 accessions were collected by the Indian Agricultural Research Institute (IARI), New Delhi, in cooperation with the International Rice Research Institute (IRRI), Philippines. The collection was known as the **Assam Rice Collection** (ARC).

Status of rice germplasm collected/maintained and evaluated in eastern India

Institution	No. of accessions collected/ maintained		No. of germplasm accessions evaluated
IGU (Raipur, Madhya Pradesh)	21268		13000
NDUAT (Faizabad, Uttar Pradesh)	690		350
OUAT (Bhubaneshwar, Orissa)	840		400
CRRI (Cuttack, Orissa)	22000		12000
RAU (Patna, Bihar)	2020		
RAU (Pusa, Bihar)	812	4392	
CRURRS (Hazaribagh, Bihar)	1205		2150
BAC (Sabour, Bihar)	355		
RARS (Karimganj, Assam)	2892		
RARS (Titabar, Assam)	1381	4654	2000
RARS (North Lakhimpur, Assam)	381		
RRS (Chinsurah, West Bengal)	2150		
ARS (Bankura, West Bengal)	980	3730	2530
ARS (Hathwara, West Bengal)	600		
All India	71 950		

- About 19,116 accessions collected under the leadership of Dr R. H. Richharia from Madhya Pradesh formed the **Raipur Collection.**
- Joint exploration of CRRI with state agricultural universities resulted in the collection of about 7000 accessions during 1978-80 and 447 accessions during 1985.

National genebank

The National Bureau of Plant Genetic Resources (NBPGR) has one of the world's largest genebanks. More than 45,000 accessions of rice germplasm are conserved here as base collections in cold storage modules at -20° C.

Restoration of germplasm

Several accessions of traditional cultivars in Assam and neighbouring regions in northeastern India were jointly collected by IRRI and national scientists in India. Much of the original Assam Rice Collection had deteriorated or had been lost. A duplicate set of 5311 accessions from the collection was sent by IRRI to NBPGR. The collection maintained by CRRI was also duplicated by IRRI and sent to NBPGR.

Role of women in rice biodiversity conservation

- Selection and conservation of different varieties.
- Seed exchange with neighbours and relatives.
- Evaluation of varieties using post-harvest criteria.
- Conservation of varieties for specific purposes such as use in religious rites, e.g., Nuakhai, an extra-early cultivar used for religious offerings in Orissa.
- Collection of wild rice (*Oryza nivara* and *O. rufipogon*) by tribal women.

Future concerns

- Continued erosion of the diversity of rice genetic resources.
- Conservation cannot be isolated from evaluation and use.
- Political sensitivities, geographical barriers and plant health requirements that prevent exchange of germplasm.
- On-farm conservation and farmers' participation.
- Dwindling financial support.

Prepared by:
R.K. Singh, N.K. Sarma, S.R. Das, J.K. Roy, R.K. Sahu, K. Prasad and S. Mallik

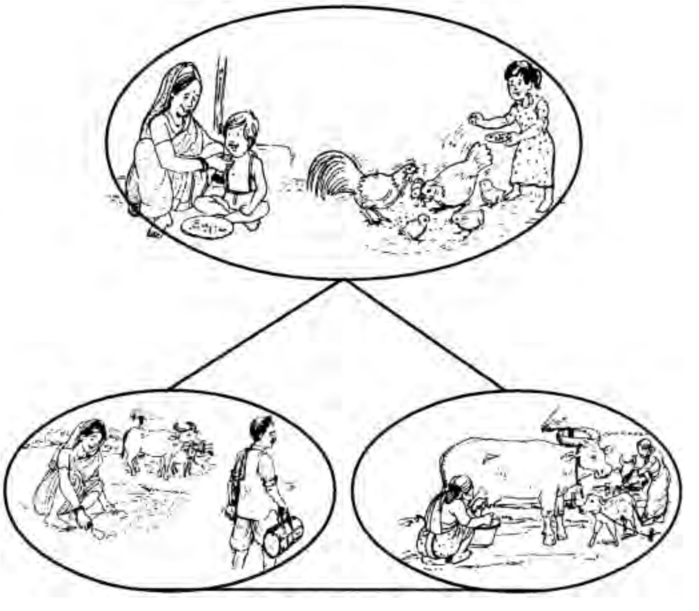
Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Gender, Labour and Rainfed Technology

Gender and labour

Women play an important role in rainfed agriculture. In recent years,there has been a greater focus on complex, diverse and risk-prone (CDR) agriculture in areas where poor people (low-resource farm households) are located. Although rice is the staple food and main crop grown during the wet season, farmers do grow other mixed or sequential crops like wheat, mustard, oilseed, pulses and vegetables after the rice is harvested. But the livelihood of 500 million people in eastern India depends on rice farming.

Due to the unfavorable conditions for production and the increasing pressure of population, families tend to overexploit the use of natural resources. Moreover, due to the migration of men to the cities for better job opportunities, the demand for labour, particularly during the peak season, is met by the increasing participation of women, including children. Certain farming activities, such as transplanting, weeding, harvesting, threshing and other post-harvest activities, are mostly done by women.



The women attends to manifold duties at home and on the farm while the man migrates in search of a better job.

Predominant labour system

Labour can be categorised as (male and female):

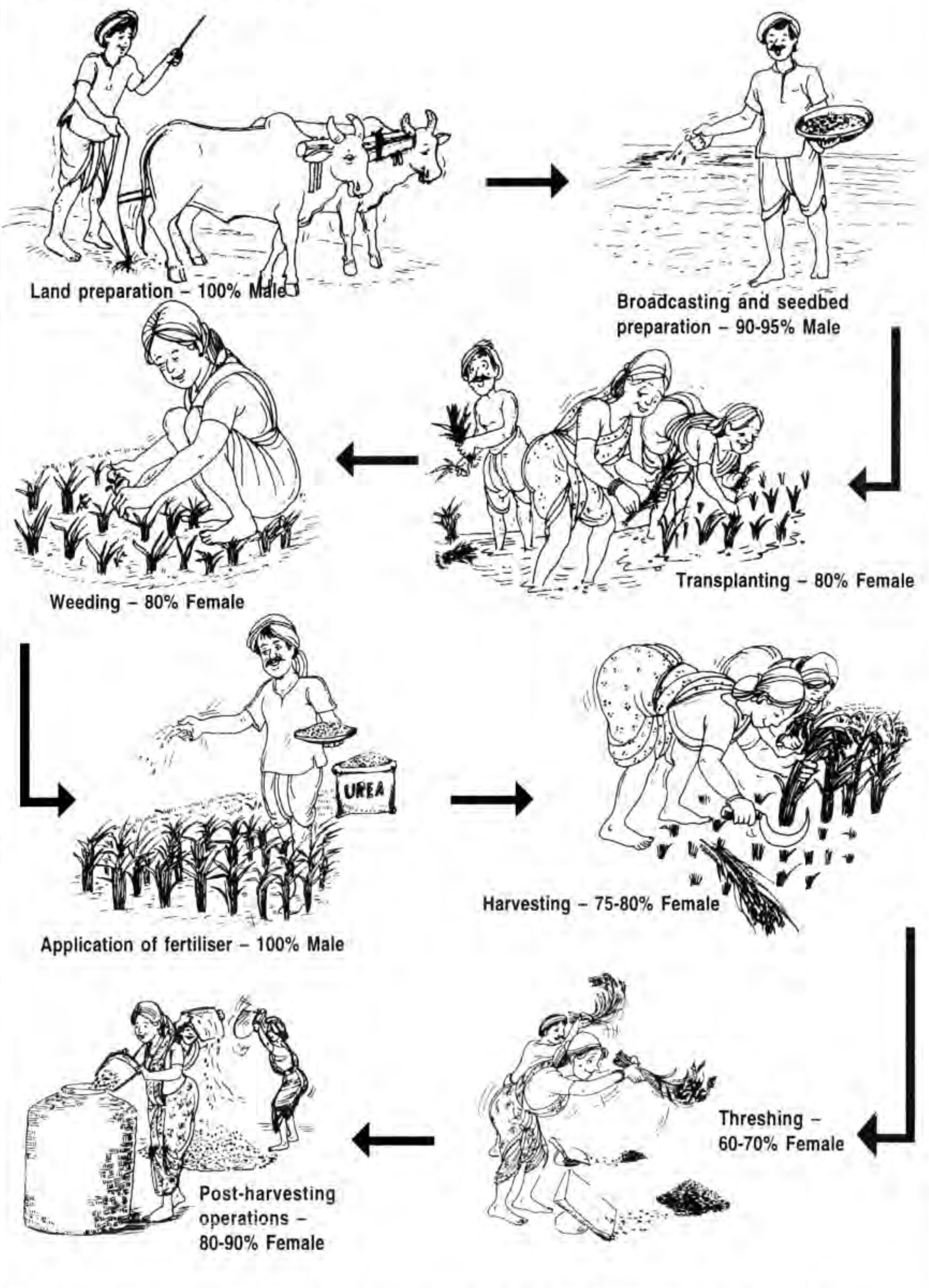
Family	Unpaid labour
Exchange	Through mutual understanding
Hired	Payment in cash or kind

Activities

On-farm	Activities on own farm
Off-farm	Activities on other farms
Non-farm	Activities outside the farm

With the recognition of the important roles of women in agriculture, research on gender concerns in rainfed rice farming in eastern India has begun in different rice ecosystems.

Gender division of labour



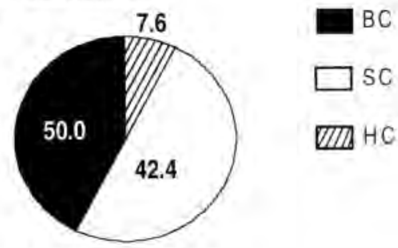
The above illustrations show that women perform most of the activities in rice farming which involve more drudgery and are time-consuming. Thus, in rainfed environments, where the socio-economic conditions of farmers are not good, it is necessary to develop low-cost and gender-specific technologies in crop operations.

Features of some typical rainfed villages of eastern Uttar Pradesh

- The majority of households belong to the lower castes having small and medium landholdings.
- Farmers diversify crops for food and animal fodder.
- Participation of women in rice farming is based on caste.
- There are gender-specific tasks or degrees of work specialisation in rice production.
- Men have higher off-farm earnings in cities/ towns than women.
- More men in villages near the cities are engaged in non-farm employment.
- There is a wide gender gap in education and women's lack of access to technical knowledge.
- Animals constitute an integral component of a mixed system.

- Women from higher class (HC) families do not participate in physical activities in farming.
- Most of the women in backward class (BC) work on their own farms and in the fields of farmers of the same class as exchange labour.
- Women in scheduled class (SC) work on their own as well as in others' fields as hired labour.

Caste composition



Women's activities in animal management

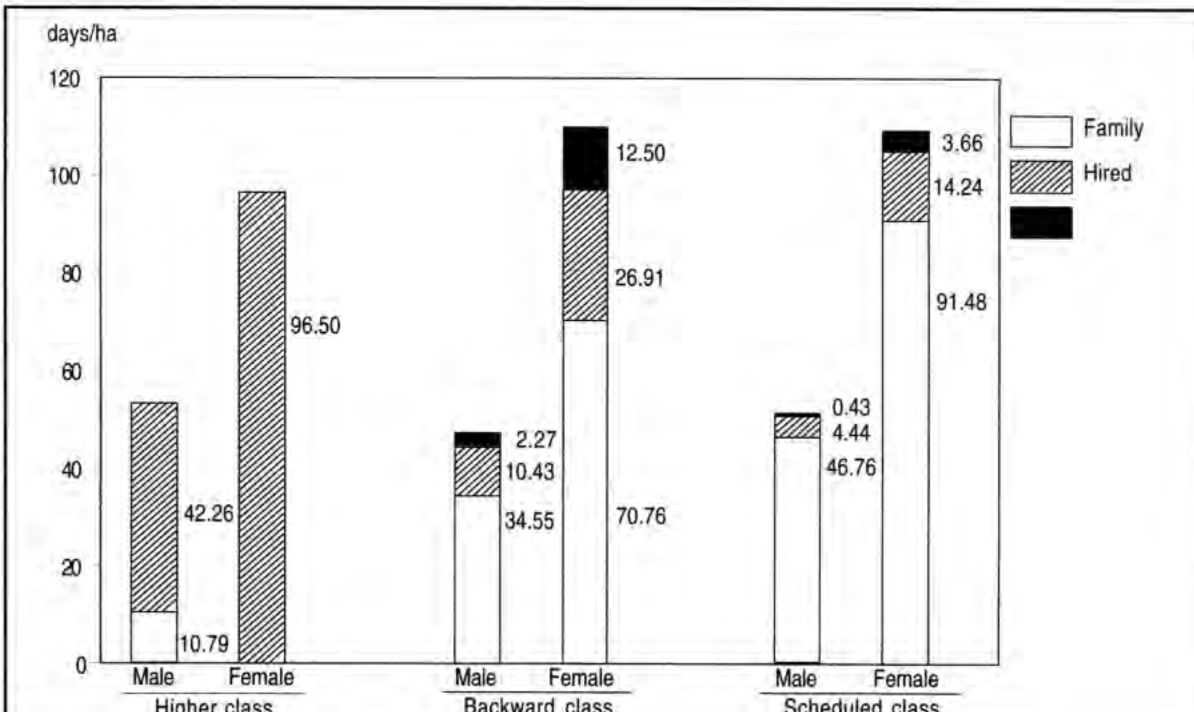
Taking charge of dairy animals for additional source of income.

Collecting daily green fodder and grazing the animals.

Collecting cow dung, making cow dung cakes and sticks to save fuel costs for the family.

The number of animals raised per household and the lack of green animal fodder have many implications for women's time and labour.

Labour use in rice cultivation according to gender and class in Mungeshpur village



Gender-based crop calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kharif (rice)												
Land preparation for rice						M						
Farmyard manure carrying and clearing field						F>M						
Uprooting of seedling and transplanting							F>M					
Land preparation for transplanting							M					
Weeding									F>M			
Harvesting											F>M	
Threshing of rice												F>M
Rabi												
Land preparation for potato, lahi, pea									M			
Sowing of potato, lahi, pea, berseem (fodder)										M>F		
Land preparation for and sowing of wheat, gram, etc.											M	
Sowing of wheat, harvesting of sugarcane, potato irrigation and weeding												M>F
Irrigation, fertiliser application for potato and harvesting of lahi	M>F											
Harvesting of potato and mustard, land preparation and sowing for sugarcane		M>F										
Harvesting of pea and mustard			F>M									
Harvesting of wheat and sowing of sugarcane				M=F								
Harvesting wheat, pigeonpea, gram				M=F								
Threshing of rabi crops				M>F								

M = Male; F = Female; ——— = Activities

Do you know that?

On average, women spend half a day walking long distances to collect green fodder and gather weeds when working in others' fields. Thus, they are the worst affected when drought occurs because this means that they have to walk farther to collect animal fodder. There have been cases where poor, landless women have been paid lower wages because they have been given the weeds after weeding by the owners of the farms for use as fodder.

The more animals raised, the more farmyard manure and dry cow dung cakes are made available for fuel. Dry cow dung cakes not only provide fuel but are also a cash-generating source for daily expenditure. A decline in the animal population will result in increasing demands on women's schedules as they will have to travel farther into the forests in search of fuel.

Future scenario

- Economic development will lead to a general withdrawal of labour from the agricultural sector to the industrial and urban sectors.
- Increasing population pressure and opportunity costs of male family labour will result in men's withdrawal from labour-intensive activities with low returns.
- This, in turn, will lead to women being forced to spend more time working in the fields and with animals in addition to their household chores. Even female members from the upper caste families might be forced to break social norms and work in their own fields.

The emerging component technologies in farming systems in eastern India will require changes in the allocation of land, labour and cash. This will directly and indirectly affect female family members on account of their active involvement in almost all crop operations as these technologies will require new knowledge and a new cultural orientation.

Research needs

- Assessment of the likely implications of emerging component technologies of farming systems for men and women.
- Special efforts have to be made to develop skills in women and educate them about the latest technologies in rainfed rice farming.
- Assessment of the implications of male migration for the workload and welfare of female family members and children.
- Assessment of female participation in rice farming.
- Inclusion of women (knowledge, attitudes and perceptions) in the selection of breeding lines for different qualities.
- Development and testing of agricultural/mechanical implements/ tools for women.
- Ways to optimise the use of rice by-products and home-based technologies.

It will be difficult to achieve the goal of increasing rice productivity if rice farm management is left only to female workers who do not have access to technical knowledge that can help reduce the work burden of female landowners and cultivators.

When women were asked which operation they found the most laborious, they mentioned weeding as being not only the most laborious but also the most monotonous.

Prepared by:
A. Singh and **Thelma Paris**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Socio-Economic Constraints in Rice Production in Eastern India

Rice is the principal staple food in eastern India and this area's agricultural system is largely dominated by rice-based cropping systems. Eastern India comprises Assam, West Bengal, Bihar, Orissa and the eastern parts of Madhya Pradesh (MP) and Uttar Pradesh (UP). The region is inhabited by nearly 500 million people and accounts for 63.3% of the total rice area in India but produces only 50% of the total rice output because of lower productivity.

Unlike other parts of India where rice is grown under irrigated conditions, rice farmers of the region depend mainly on the unpredictable monsoon rains.

Rice production in eastern India during the last two decades grew at a satisfactory rate of about 2.7% per year. The growth was uneven across states and districts, particularly in Bihar, Orissa, Assam and eastern MP, where rice production failed to keep up with the population and demand. Production performance was variable even within homogeneous agroecological zones. Performance was particularly poor in the subhumid plateau regions of Chhotanagpur and Chhatisgarh, which also have a high rate of rural-urban migration.

Poverty and food insecurity are widespread in the eastern region. According to recent estimates, the poverty ratio is nearly 60% in Bihar, Orissa and West Bengal, compared with less than 20% in Punjab, Haryana and Gujarat and less than 30% in Tamil Nadu, Andhra Pradesh, Karnataka and Kerala. The daily calorie intake is less than 2000 per capita in Bihar and Orissa, compared with 2700 in Punjab and 2400 to 2600 in Haryana, Rajasthan, Gujarat, Kerala and Andhra Pradesh. The high incidence of poverty can be partly related to the poor performance of the rice crop which is not only the principal food but also an important source of employment and income for the rural population.

Variations in production performance

Production performance was also uneven across the states in eastern India. With increasing population and shrinking availability of land for agriculture, future growth in agricultural production in the region must come from growth in land productivity. The growth in rice yield was higher than population growth only in Uttar Pradesh and West Bengal. In other states, productivity growth was less than 2%. Assam, with a growth in yield of less than 1% per year, had the most dismal performance in raising productivity.

An important characteristic of the rice sector in eastern India is the large year-to-year fluctuation in rice production due to unreliable monsoon. The production shortfall can sometimes be astronomical, leading to severe food insecurity for small and marginal farmers.

Farmers also suffer from both floods and droughts in the same season because of heavy early season rains and/or prolonged droughts during the end of the monsoon. This makes rice cultivation a risky venture, especially for most subsistence farmers.

Rice productivity and migration

Eastern India experienced considerable rural-urban migration of population (Table 1). The average population growth rate over the last two decades was 2.2% per year, while the rural population grew at 1.8%. This suggests that rural-urban migration is partly related to the performance of the rice sector.

The growth in rural population was almost the same as the total population in UP and West Bengal, which experienced impressive growth in rice production. On the other hand, in Bihar and Orissa, which had poor growth, 0.3-0.4% of the people migrated every year to urban areas in the last two decades. An improved performance of the rice economy can therefore contribute to a reduction in rural-urban migration and help ease pressure on overburdened cities and urban areas.

Table 1. Growth in rice production and productivity in eastern India, by states, 1970-91.

States	Rice growth (%/year)			Population growth (%/year)	
	Area	Yield	Production	Rural	Total
Assam	0.94	0.92	1.86	n.a.	2.1
West Bengal	0.45	2.27	2.72	2.1	2.2
Bihar	0.04	1.55	1.59	1.8	2.1
Orissa	-0.34	1.88	1.54	1.4	1.8
Madhya Pradesh	0.62	1.68	2.30	1.5	2.4
Uttar Pradesh	1.03	4.28	5.31	1.9	2.1
Eastern India	0.44	2.27	2.71	1.8	2.2

Note: *The growth rates are obtained by estimating semi-logarithmic trend lines on time series data.*

Source: *IRRI Rice Statistics Database.*

Impact of agro-ecological and socio-economic factors

To assess the importance of different agro-ecological and socio-economic factors in explaining variation in the level and growth of rice yield across districts, researchers of the rainfed rice project carried out a multivariate regression analysis in eastern India. The socio-economic factors considered in the analysis are:

- The average size of the farm in the district;
- The pattern of distribution of land (measured by the share of landless agricultural labourers and tenants in total farm population);
- The incidence of poverty (measured by the per capita calorie intake of the population for the base period); and
- The economic capacity of the farmers (measured by the amount of chemical fertiliser used per hectare of land in the district).

Analysis

- The smaller the size of the farm, the higher the pressure of population on land and the need to increase productivity.
- Farm size also determines the availability of labour input and its opportunity cost to the farm household.
- Small farms may use more labour and thereby achieve higher levels of productivity than large farms.
- Small farms may not be economically able to afford relatively capital-intensive modern technology. This factor may be responsible for the slower rice yield growth in districts with smaller farms.
- The effect of farm size on productivity will depend on the relative strengths of the two above-mentioned opposite factors.
- Unequal land ownership and high tenancy factors may act as a disincentive to production, which, in turn, will affect growth of rice yield.
- The subsistence pressure on rice growth production is also expected to be highly influenced by poverty at the base level.

Results of the regression analysis

- Water control and the level of fertiliser use, which are highly correlated, were important factors behind the spatial variation in productivity growth.
- The level and growth in rice yield were negatively correlated with the amount of rainfall, which suggests poor drainage and waterlogging as a significant constraint to growth in rice production.
- Land tenure is a special social problem as districts with a higher incidence of tenancy and landlessness had lower rice yields and slower growth.
- An inverse relationship is found between farm size and level and growth in rice yield, suggesting that the small farm size in the region is not a serious constraint to the adoption of input-intensive technology.
- Farm size, incidence of irrigation and instability in rice yield are important factors behind the spatial variation in fertiliser use and growth in rice yield.

Prepared by:
Mahabub Hossain and **Alice Laborte**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

9 Sustainability Issues in Rainfed Rice Farming

Sustaining Rice Farming in Eastern India

The concept of sustainability

Intensive agriculture takes its toll on natural resources and on the environment. This means that farmers have to produce more from less and deteriorating resources. Keeping this in mind, the sustainability of rice farming under existing conditions in this region is not assured without special efforts. To develop specific plans to enhance the level of sustainability in priority ecozones, one must understand what sustained rice farming means.

Understanding sustainability is a complex matter and it can be defined and interpreted in several ways. For a subsistence farmer, sustainability means survival of the family. An economist, on, the other hand, may define sustainability as living on the interest but not on the capital, while an environmentalist may look at it as the preservation and conservation of natural resources and non-degradation of the environment.

Sustainability is a complex matter

Sustainable rice farming

Sustainable agriculture in a broad sense means management of resources for agriculture to satisfy changing human needs, maintaining or enhancing the quality of environment and conserving natural resources.

We cannot assume what sustainable rice farming means to eastern Indian farmers, but we know it includes:

- a level of income from rice farming that could meet their household needs; and

Sustainability, for practical purposes, can be defined as striking a balance among productivity, natural resources, and the environment at different levels of equilibrium for different agro-ecological situations. This can be basically achieved through the application of eco-technologies, which are rooted in the principles of ecology, economics and equality and equity. This would mean analysing:

- the farming environment where rice farming is done;
- trends of productivity and input use; and
- the level of benefits derived and the damage done to the system, and accordingly designing a suitable production farming system, rather than improving commodities.

- technologies that would provide the desired level of income and enhance the productivity/commercial efficiency of the available farm resources and have the least negative influence on the environment.

However, in this scenario, the rice farmer is not the sole player. The farmer is basically concerned about the profitability of farming and the least use of resources in that farming. Environmental consequences are not necessarily the farmer's direct contribution, but may result from the application of technologies usually designed for wider application by someone else.

Let us look at the prospects for "super rice", which has a potential yield of over 12 t/ha. Such a plant will need a minimum of 200 kg N/ha together with other major and micro nutrients and pest control measures. Adding such quantities solely through mineral and synthetic sources will certainly lead to some environmental problems.

The eastern India context

Eastern India is homogeneous for low productivity and a high degree of poverty. For other bio-physical and socio-economic factors, it is highly variable and heterogeneous over short physical distances. Average rice productivity is low at about 1.0 t/ha and its causes are many, ranging from very low inputs due to poor socio-economic conditions to floods and drought during the cropping season.

Agro-ecological analysis of eastern India

Agriculture in eastern India is largely rainfed, even if the possibilities exist to meet crop water needs through supplementary water resources. Rainfall, being the only source of water, is thus a crucial resource for crop production. What is needed, therefore, is an in-depth analysis of rainfall, including moisture patterns. Appropriate crop production strategies also need to be developed for making the most effective use of available water resources.

Parameters used in analysis

- Annual rainfall
- Number of rainy days
- Solar radiation
- Minimum temperature
- Maximum temperature
- Potential evapotranspiration
- Moisture availability and water balance analysis
- Moisture availability, water balance and crop planning
- Rice productivity pattern

Production systems vs ecosystems

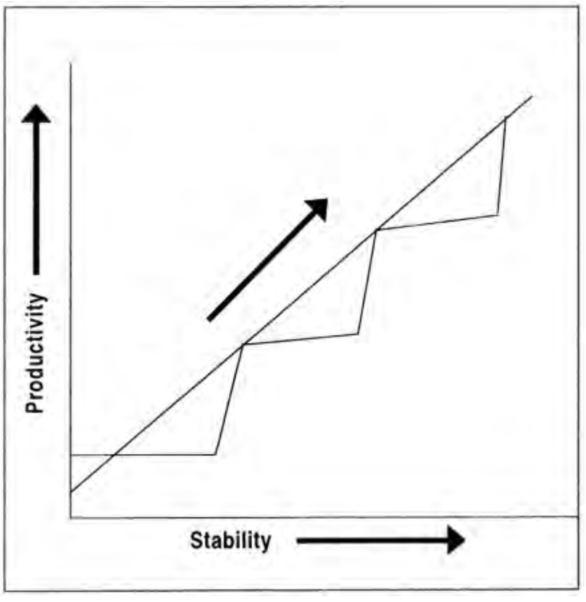
To develop sustainable rice production systems, the different rice-growing ecosystems must be analysed, characterised and quantified. In view of this, the rice area in eastern India was classified under each ecosystem into different categories of production systems for all six states. From this analysis, excluding Assam, it can be seen that 11.74 million ha of rice in five states are under the low and unstable category, of which 74.4% of the area is under the rainfed ecosystem and 8.3% is under the deepwater ecosystem. The remaining 17.3% is under the irrigated ecosystem, which needs a thorough examination to find out why productivity, in spite of irrigation facilities, is low and unstable.

Extent of rice ecosystems and productivity categories in eastern India

Productivity category	Ecosystem	Bihar	Orissa	Eastern UP	Eastern MP	West Bengal	Total
Low and unstable	Rainfed	1586 (62.8)	2483 (71.1)	1318 (70.8)	3351 (86.0)	–	8738 (74.4)
	Irrigated	452 (17.9)	844 (24.9)	189 (10.2)	543 (14.0)	–	2028 (17.3)
	Deepwater	485 (19.3)	135 (3.9)	354 (19.0)	–	–	974 (8.3)
	Total	**2523**	**3462**	**1861**	**3894**	–	**11740**
Low and stable	Rainfed	1054 (84.6)	651 (92.1)	–	–	890 (69.3)	2595 (80.2)
	Irrigated	83 (6.6)	41 (5.8)	–	–	253 (19.7)	377 (11.6)
	Deepwater	110 (8.8)	15 (2.1)	–	–	140 (11.0)	265 (8.1)
	Total	**1247**	**707**	–	–	**1283**	**3237**
High and unstable	Rainfed	343 (38.3)	186 (51.2)	346 (62.9)	–	2517 (63.4)	3392 (58.7)
	Irrigated	538 (60.1)	177 (48.8)	97 (17.6)	–	1040 (26.1)	1852 (32.1)
	Deepwater	14 (1.6)	–	107 (19.5)	–	413 (10.5)	534 (9.2)
	Total	**895**	**363**	**550**	–	**3970**	**5778**
High and stable	Rainfed	14 (7.1)	–	–	–	–	14 (7.1)
	Irrigated	164 (83.7)	–	–	–	–	164 (83.7)
	Deepwater	18 (9.2)	–	–	–	–	18 (9.2)
	Total	**196**	–	–	–	–	**196**

Values in parenthesis are percentages of the total rice area.

Keeping this in view, the rice productivity status and stage of sustainability in each of the districts in the five states have been worked out using four productivity level categories. This analysis shows that all the districts below the "sustainability ladder" need efforts to increase productivity and the districts above this ladder need efforts to stabilise productivity (enhancing stability). To increase productivity, priority must be given to those districts that have a lower level of stability. Likewise, to enhance stability, priority should by according to the level of productivity.



Sustainability of rice farming

There is no reason why rice productivity should be low and unsustainable in irrigated ecosystems. In rainfed ecosystems, with more than 1000 mm of seasonal rainfall, there is great potential to increase productivity. However, while developing plans to increase productivity, stability, which is a component of sustainability, should also be considered. In other words, sustainability can be achieved only through a step-by-step process of increasing and stabilising productivity.

Sustainability can be achieved by emphasising both productivity and stability, i.e., a continuous process of increasing productivity in steps: before going to the next level of productivity, stabilise it at the first level, and then increase productivity and stabilise it at the next level, and so on. In this way, increasing productivity during one period would provide options for building the resource base to some extent, which can be used to increase productivity to the next level, and so on. Though this is time-consuming, in areas like a stern India with poor socio-economic conditions, this process alone can help the farmers, who always try to minimise risks in increasing farm output.

Strategies for sustainable rice farming

To effectively address the trilemma of productivity, environment and natural resources in eastern India, it is essential to develop improved technologies that enhance crop productivity through efficient resource use in a stable manner. It should be emphasised that this can not be fully realised by making adjustments in only one or a few components in the existing technology package(s).

Another aspect which needs adequate attention is that of resource generation and recycling. At least a portion of needed inputs can be generated within the system or a portion of output can also be used as an input with value addition. For example, supplemental nitrogen sources – green manures, azolla, etc., and planting material (seed, etc.) can be produced on the farm, and crop residues and fodder crops, after going through the livestock system, can also contribute to fertiliser input as manure. This will be more feasible if the crop and livestock systems are physically integrated on the farm rather than having them isolated at distant places because that would add to the cost of transportation of inputs, outputs and by-products.

Developing technologies

No single disciplinary research can produce crop production technologies. They require multi-disciplinary research contributions, the results of which, when developed into applicable forms, become technologies. If the contributions from different disciplines complement each other, only then can the technologies become appropriate.

Achieving sustainable rice production in complex systems like those of eastern India would undoubtedly need intensive efforts to identify the location-specific (inter- and intra-district) constraints for developing the technologies.

Prepared by:
V.P. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Developing Sustainable Technologies

Technology is an important component of agricultural development. It is a synthesis of research results into an applicable form, application of which allows achieving the desired results. There are various forms of technologies, but those which could be applied on a sustainable basis are the most desirable.

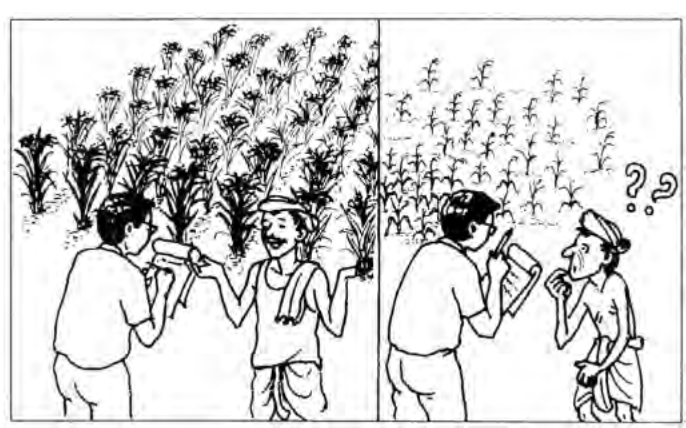
Research findings vs technology

Research is a systematic investigation in a field of knowledge to establish facts or principles. A technology is the application of research findings to the requirements of day-to-day life. But all research findings are not technologies.

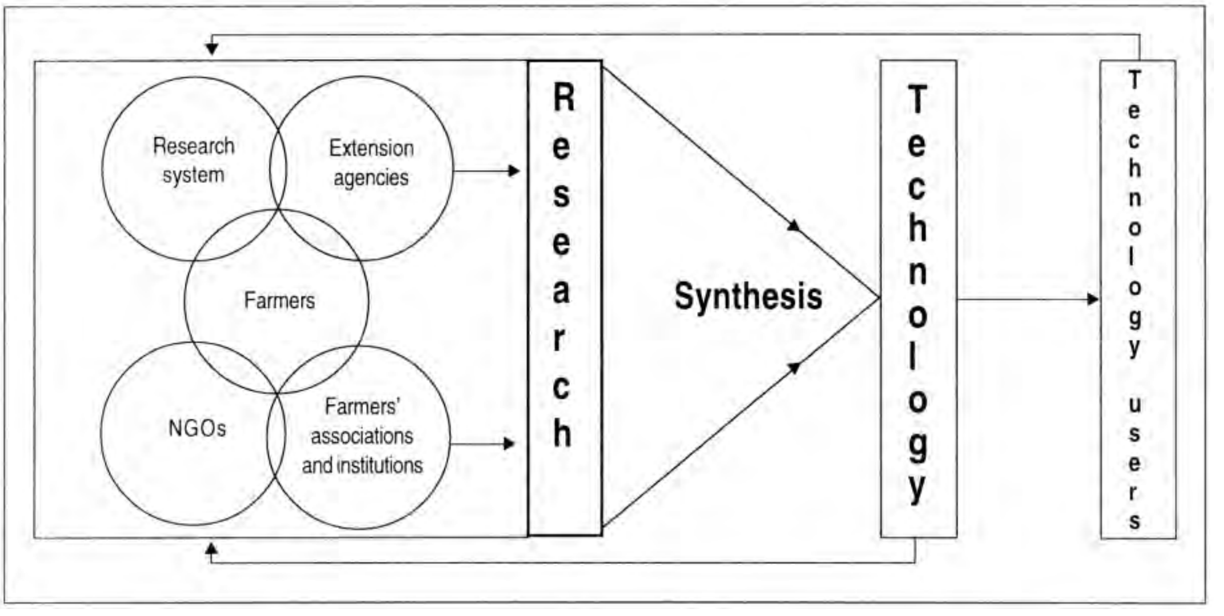
While research is an important precursor of technology, not all research efforts result in technologies, e.g., fundamental or basic research develops principles and theories only and not technologies. But basic research is the basis of all applied research. Technologies are the synthesis of research done in various related disciplines. Therefore, only the integration of inter-disciplinary research culminates in usable technologies.

Multi-disciplinary research

Useful research is that which can add to knowledge and/or solve a problem. No single research can develop into a technology package. From the technology point of view, agricultural research (for that matter, research in all areas) is multi-disciplinary in nature. A usable technology has to be in a package form, having a back-up of multi-disciplinary research.



Farmers' perceptions of technologies may be incompatible with those of scientists



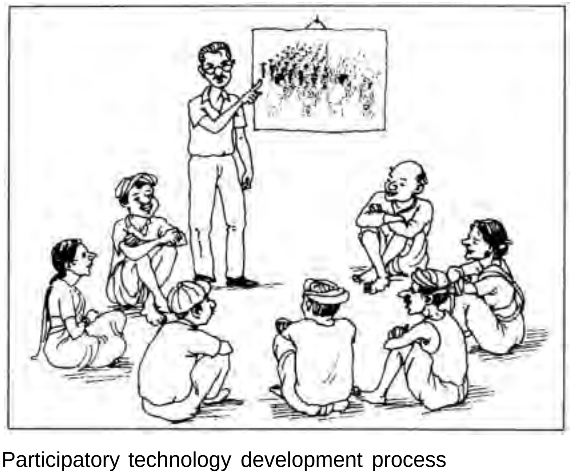
Since agricultural research is multi-disciplinary in nature, it calls for an inter-disciplinary approach and multi-institutional cooperation. Therefore, technology development in agriculture is a partnership of the scientists/ disciplines representing various specialisations, farmers and their associations and institutions. All those involved in the process of technology development are accountable for the results. The team owns the problems and the solutions.

Technology development

Technology development is a process of synthesising research results into packages and integrating them with other enterprises like dairying, poultry keeping, etc. Then the technology is extrapolated to where it has to be applied. It should be promoted through extension means in areas identified as extrapolable domains and be promoted to a commercial level because subsistence orientation alone will not lead to long-term and sustainable development.

Technology has to be:

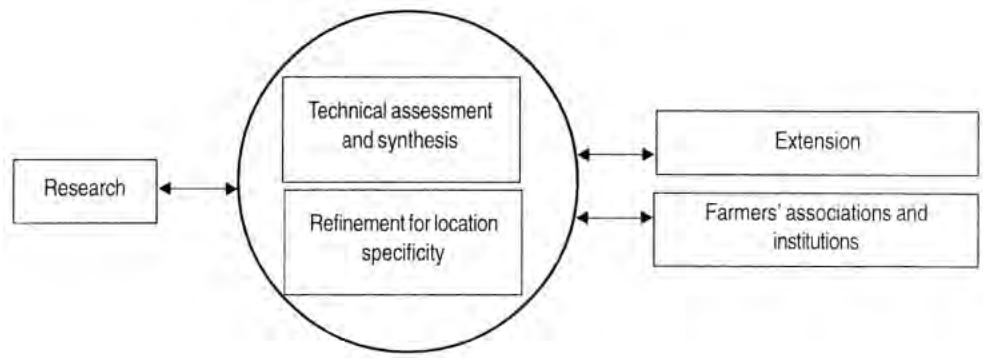
- Developed
- Synthesised
- Extrapolated
- Promoted
- Commercialised



Participatory technology development process

Who will synthesise technologies?

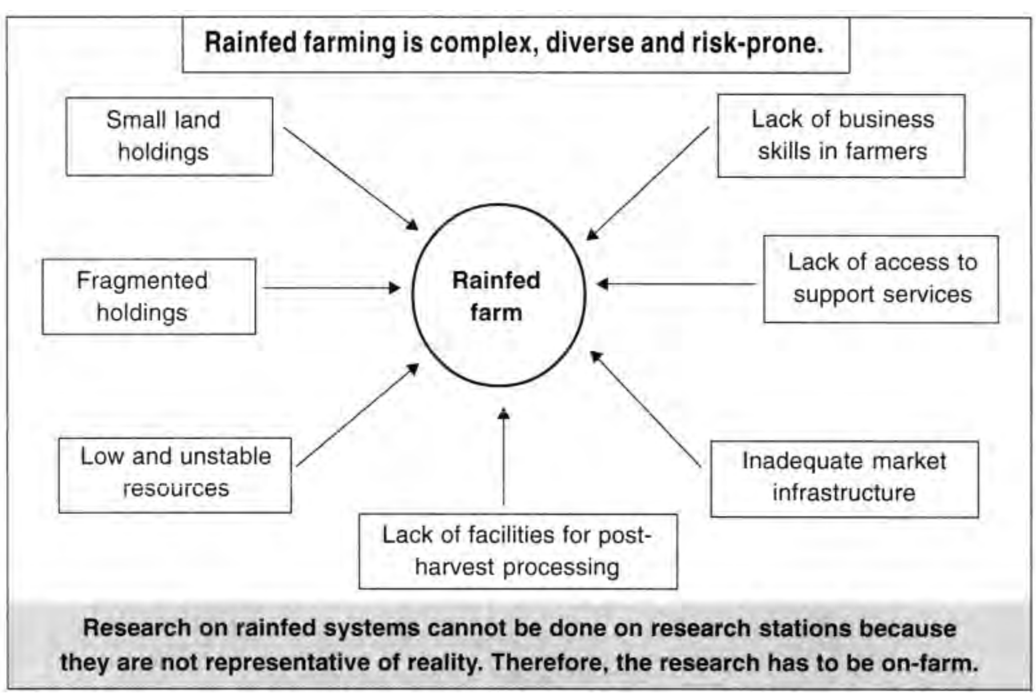
The roles of research and extension systems have undergone a sea-change in the recent past. According to traditional understanding, a researcher's main responsibility is to conduct research, while an extension agent extends technologies to users. Modern strategists see this demarkation as hypothetical and unworkable as the process of synthesis of technologies involves both researchers and extension agents.

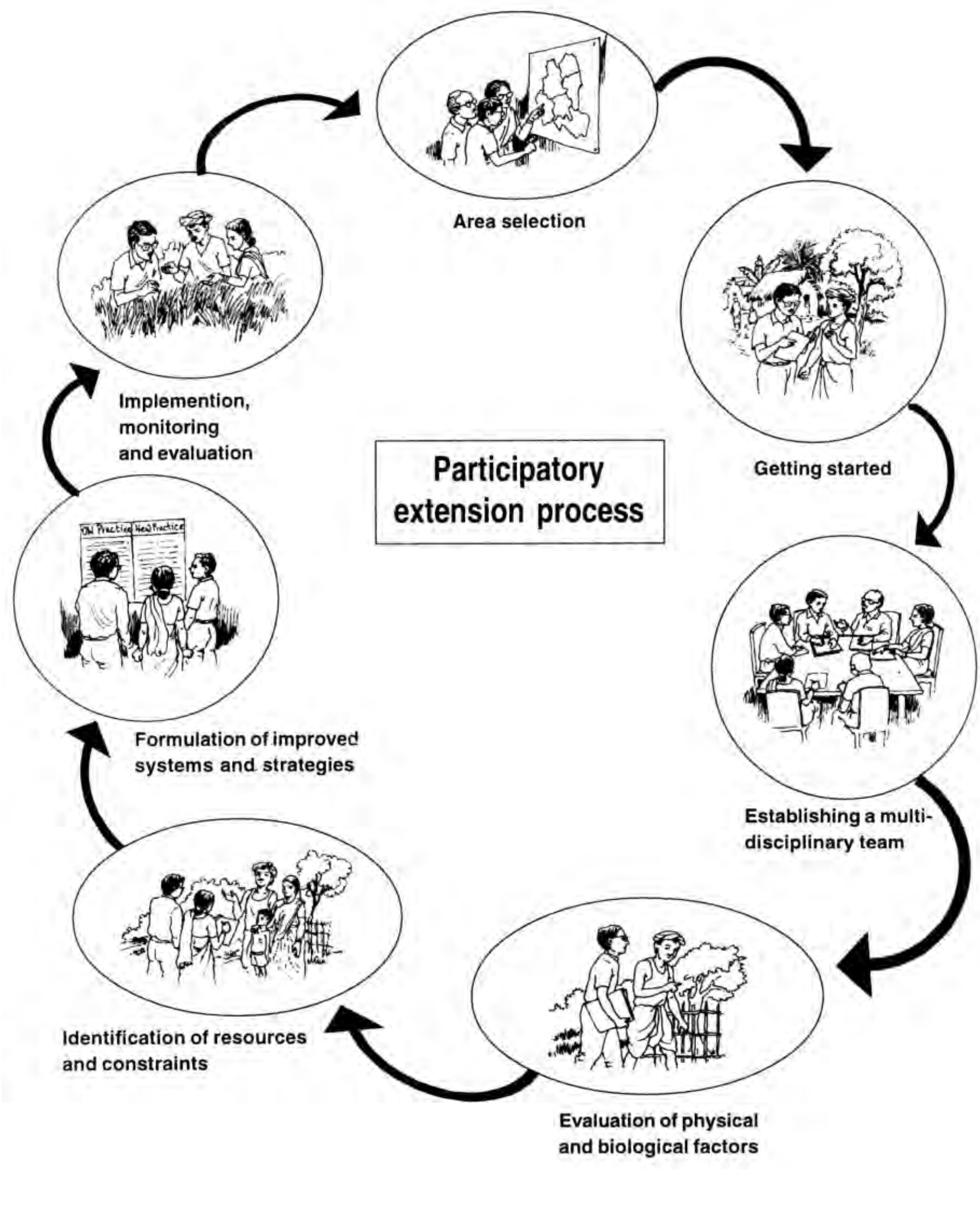


How to synthesise technologies

Important components of synthesis of technology are assessment and refinement to suit local conditions. These are the two important steps in technology development which call for an inter-disciplinary approach. Along with researchers and extension agents, participation of farmers, local associations and institutions is also considered important.

The process of "participatory technology development" enhances the cooperative approach in research and the synthesis of technologies.





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Prepared by:
V. P. Singh

Rainfed Rice Ecosystems

Agro-Ecosystem Analysis for Rainfed Environments

Rice ecosystems

Ecosystems are separated based on irrigation, hydrology and landform. The subdivision of ecosystems into sub-ecosystems is based on flooding, drought, water depth, length of growing season, climate and soil and water quality parameters.

There are five rice ecosystems: irrigated, upland, rainfed lowland, deepwater and tidal wetlands.

Rice-growing environments

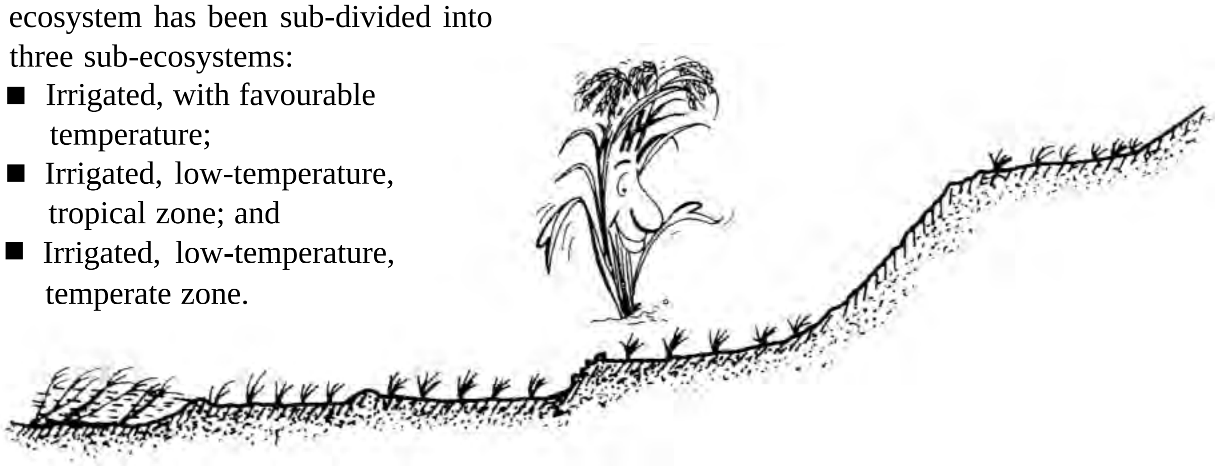
The rainfed rice ecosystem is characterised by diverse agro-climatic and socio-economic conditions. It covers areas with favourable as well as unfavourable environments, e.g., drought, submergence/flood, adverse soils, etc., which are complex, variable and heterogeneous.

Rice area has been estimated to be about 148 million ha, 95% of which is in South and Southeast Asia. Rainfed lowlands cover about 27% of the world's total rice area and contribute 18% to the total rice supply.

Irrigated

Irrigated ecosystems have good water control, thereby allowing high-yielding, fertiliser-responsive varieties to provide higher yields. This ecosystem has been sub-divided into three sub-ecosystems:

- Irrigated, with favourable temperature;
- Irrigated, low-temperature, tropical zone; and
- Irrigated, low-temperature, temperate zone.



Upland

Rice in the upland ecosystem is grown in rainfed bunded or unbunded fields, with naturally well-drained soils, without any surface water accumulation.

Upland ecosystem

- Favourable upland with long growing season (>110 days)
- Favourable upland with short growing season (90-110 days)
- Unfavourable upland with long growing season
- Unfavourable upland with short growing season

The upland rice ecosystem is characterised by extreme diversity of soils and topography that ranges from sloping, terraced lands to well-drained flatlands. Traditional germplasm and its associated farming practices add to the system diversity. It is marked by varying degrees of degradation and has low and variable productivity.

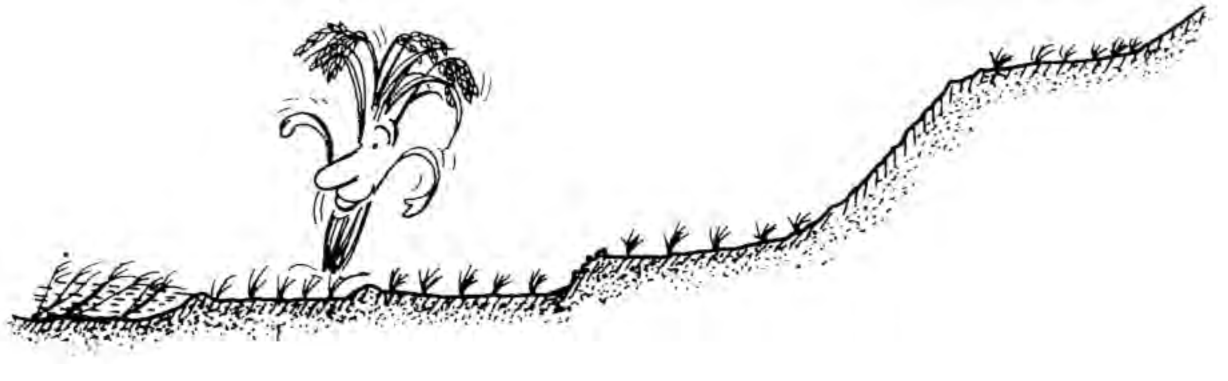
Rainfed lowland ecosystems

Rainfed shallow, favourable
Rainfed shallow, drought-prone
Rainfed shallow, drought- and submergence-prone
Rainfed shallow, submergence-prone
Rainfed medium deep, waterlogged

Rainfed lowland

Rice in this ecosystem is grown in bunded fields that are flooded for at least part of the season at a water depth that does not exceed 50 cm for more than 10 consecutive days. Fields are not irrigated but may have on-farm rainwater conservation facilities.

Any or a combination of drought, flooding and adverse soils constrains the adoption of high-yielding cultivars and use of high-input levels in this ecosystem. The rainfed lowlands do not encompass a homogeneous class of ricelands. They include a large array of unique physical environments.



Major environments in the rainfed lowland ecosystem

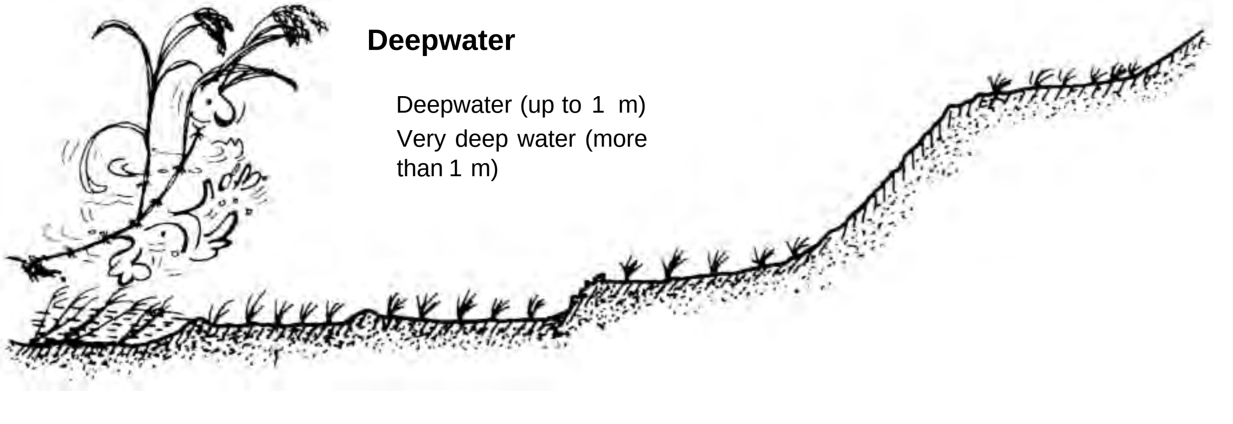
There are five major environments identified within the rainfed lowland ecosystem based on two major hydrological stresses and inadequate or excess moisture.

- **Rainfed Shallow, Favourable Environment**
  - Areas in which drought or submergence is not a serious constraint to using high-yielding modern varieties and management practices that are essentially similar to those in fully irrigated systems.
- **Rainfed Shallow, Drought-prone Environment**
  - Areas in which frequent and severe water deficit may occur at any crop growth stage. The rainy season may be short (90-100 days), as is common in central and eastern India.
- **Rainfed Shallow, Drought- and Submergence-prone Environment**
  - May experience both water deficit and short-term flooding on a frequent basis.
- **Rainfed Shallow, Submergence-prone Ricelands**
  - Frequent short-term flooding that may damage or destroy the crop when varieties and management practices other than those specifically adapted to this environment are used. Otherwise, the water regime is generally favourable in these areas.
- **Rainfed Medium Deep, Waterlogged Ricelands**
  - Accumulate water at depths of 25-30 cm for a substantial period of the growing season. One of the major problems associated with this condition is growth depression or toxicity caused by stagnant water remaining in the field for months during the crop season. Short-term crop submergence may also occur.

Deepwater

Deepwater rice areas are those where rice grows as rainfed dryland or under shallow flooding for the first one to three months or for a little longer duration in its growth, and is then flooded to depths that exceed 50 cm for a month or longer.

The area with water stagnation up to 1 m depth is categorised as the deepwater sub-ecosystem and the area with more than 1 m as the very deep water sub-ecosystem.



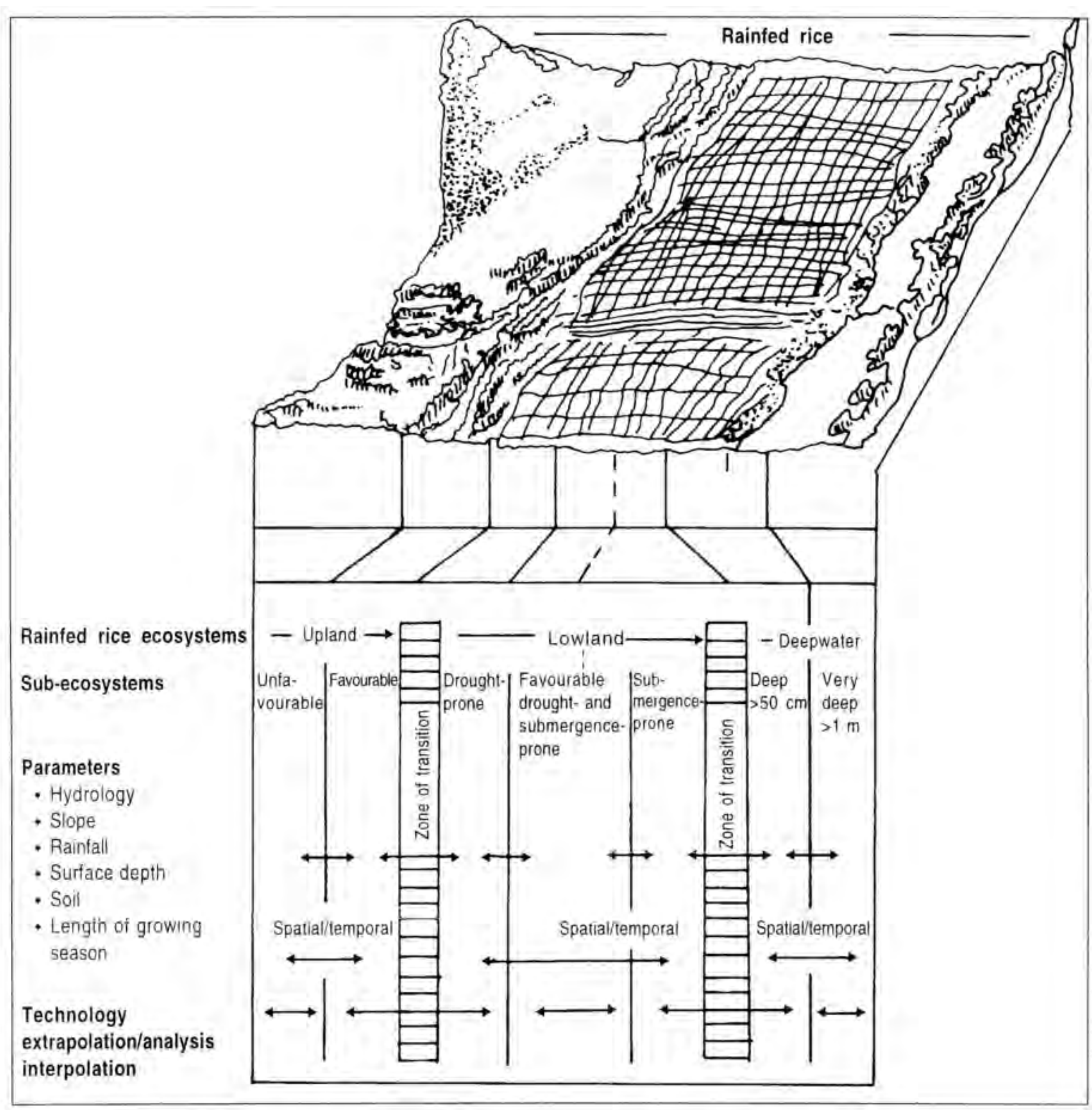
Tidal wetlands
■ With perennial freshwater ■ With seasonally or perennial saline water ■ With acid sulfate soils ■ With peat soils

Tidal wetlands

Tidal wetlands occur on the coastal belts where the water level in fields fluctuates because of the tidal movement. Based on the ingress of saline or freshwater and soil characteristics, this ecosystem has been divided into four sub-ecosystems. The area under this ecosystem is very small in eastern India.

Schematic diagram for rainfed rice agroecosystems

Arrows indicate the range and limits of variability. Vertical dashes in rainfed lowland rice are for favourable sub-ecosystems, where variability is least.



Agro-ecosystem analysis

Agro-ecosystem analysis helps in classifying rice area into different ecosystems and sub-ecosystems. Characterisation involves:

- knowing the characteristics of the agro-ecosystems;
- identifying problems and prioritising them;
- identifying development needs;
- selecting representative sites for multi-location trials; and
- identifying geographical areas (villages, blocks, districts where a technology can be extrapolated).

Agro-ecosystem analysis levels

Four broad levels of agro-ecosystem analysis exist. The scope of geographical coverage, map scale and parameters used in the analysis is as follows:

Level	Geographical coverage	Map scale	Activities/parameters used
Mega	National and international	1:1M or 1:5M	Key ecological
Macro	Whole country and group of states	1:250,000 to 1:1M	Dominant ecological
Meso	District and group of districts	1:50,000 to 1:250,000	Selected
Micro	Village and group of villages	1:5000 to 1:50,000	All prevalent

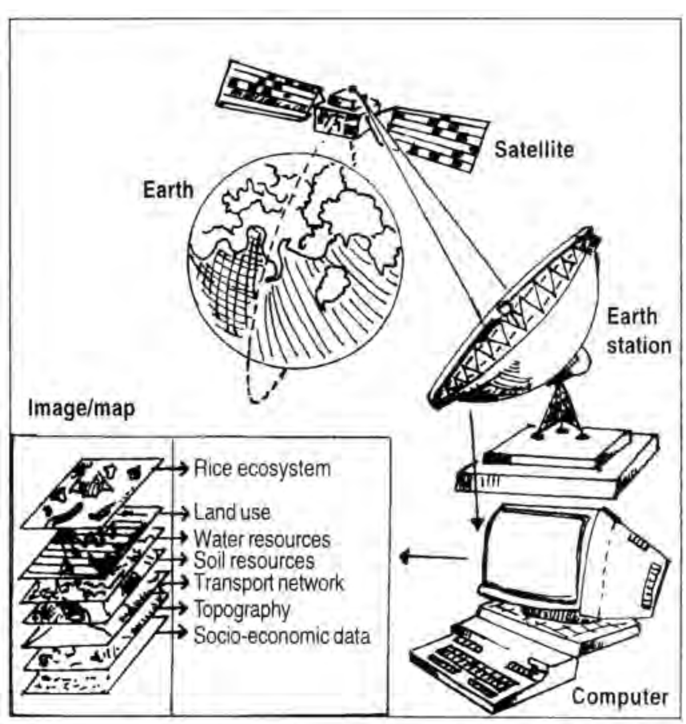
Agro-ecosystem analysis methods

Parametric method

Secondary data on important parameters and factors are used as an index for agro-ecosystem classification. Parametric methods are generally used for mega- and macro-level (international, country or state) analyses.

Remote sensing method

This method uses data from remote sensing satellites and aerial photographs to characterise bio-physical parameters, supported by ground truth for agro-ecosystem classification. Remote sensing-based methods are generally used for mega, macro and meso levels of analysis and to some extent in micro-level analysis.



Satellite image interpretation, ground truth and available ancillary information for ecosystem analysis

In the parametric method for mega-level analysis of South Asia, empirical values have been assigned to the different parameters of classification of upland rice ecosystems. Regions have been classified into specific rice ecosystems.

The relative advantages of remote sensing methods are higher in mega, macro and meso levels than at the micro level due to the information need for a larger number of parameters, many of which are not amenable to remote sensing. Some of the new satellites, such as RADARSAT, can collect data even during rains by penetrating clouds.

Participatory and rapid rural appraisal

These appraisals use ground-based farmer participatory surveys to characterise ago-ecosystems and identify constraints. The rapid rural appraisal (RRA) has been used for micro-level analysis in more than 100 villages of eastern India where rainfed rice is grown. This method uses direct surveys of a village and households for the analysis.

The RRA and participatory appraisal techniques have been used extensively in eastern India for micro-level agro-ecosystem analysis. The agro-ecosystem of the village is characterised in a farmer participatory mode and social maps, a soil and hydrology map, an enterprise map, crop calendars and village transects are prepared. Production constraints are discussed, problems are identified and ranked by farmers and recommendations for the village are made.

The different studies carried out in eastern India have shown that, of the three methods used, the remote sensing-based method may be considered the best for integration of analysis of different levels due to its "spatial-continuum" nature.

GIS in extrapolation of location-specific technology

Any agricultural technology generated from a research station is location-specific. Extrapolation of a technology over larger areas can be successfully done only in similar environments. Hence, there is a necessity to characterise crop-growing environments on a scientific basis before embarking on the technology extrapolation phase as the success of technology utilisation largely depends on location characteristics. The geographic information system (GIS) helps in the use of ecosystem data in agricultural technology extrapolation. A methodology for technology extrapolation has also been developed.

An effort towards rice technology extrapolation based on micro-level ecosystem analysis data was made in the 20 villages of Milkipur block of Faizabad district, Uttar Pradesh (UP). Rice cultivars were tested in farmers' fields. Results showed that ecosystem-specific cultivars were more successful in these predominantly drought-prone rainfed lowlands, indicating the utility of ecosystem analysis data in obtaining stable yields.

A Remote Sensing-Based Micro-Level Analysis: The Case of Milkipur (UP)

A remote sensing-based methodology has been successfully applied for micro-level ecosystem analysis of a group of 20 villages in Milkipur block of Faizabad district, Uttar Pradesh. The methodology used aerial photographs as a base map for collecting information on topography, slope, physiography, flooding, water stagnation and drought pattern and making field visits to check this information at selected locations to delineate rice ecosystem units. Interviews with farmers were done to collect information on rice cultivation practices, varieties grown, use of inputs and problems encountered. Available reports on soil, groundwater, meteorological parameters, infrastructure and socio-economic conditions were collected and integrated into the rice ecosystem units to characterise the study villages. The ecosystem maps have been prepared on a 1:10,000 scale and an effort was made towards extrapolating rice technology based on micro-level ecosystem analysis.

Components of agro-ecosystems

The components of agro-ecosystems can be grouped into biotic and abiotic. The most commonly used parameters in different levels of analysis – meso level (district and group of districts) and micro level (village and group of villages) – are given below:

Parameters used for meso-level rice ecosystem analysis (district and group of districts)

- Physiography and drainage
- Soils, land capability and suitability for rice and soil problems
- Irrigation source and extent, including availability of power and diesel for irrigation
- Groundwater depth, fluctuation and availability
- Climate (rainfall, temperature, length of growing season)
- Land use
- Cropping pattern, area and productivity
- Area under traditional and HYV rice and productivity trends
- Land and crop management practices
- Flooding and drought: frequencies, duration and extent of partially and completely affected areas and crop losses
- Population and number of households

- Landholdings, distribution pattern in relation to population size
- Levels of input use, fertiliser, pesticides, herbicides (also ecosystem-wide)
- Agricultural implements
- Number of agricultural and non-agricultural workers
- Cultivators and hired labour
- Number of livestock
- Household manufacturing, processing and servicing industry
- Marketing and infrastructure facilities

Parameters used for micro-level rice ecosystem analysis (village and group of villages)

- Land types
- Climate (rainfall, temperature, length of growing season)
- Hydrology/water table and depth of surface water
- Cropping pattern
- Soil fertility
- Input use and varieties
- Irrigation sources, extent
- Major diseases, insect pests and weed species, relative infestation and crop losses
- Land use
- Household information
- Alternative income sources
- Education level
- Social classes
- Landholding size in relation to population size and social classes

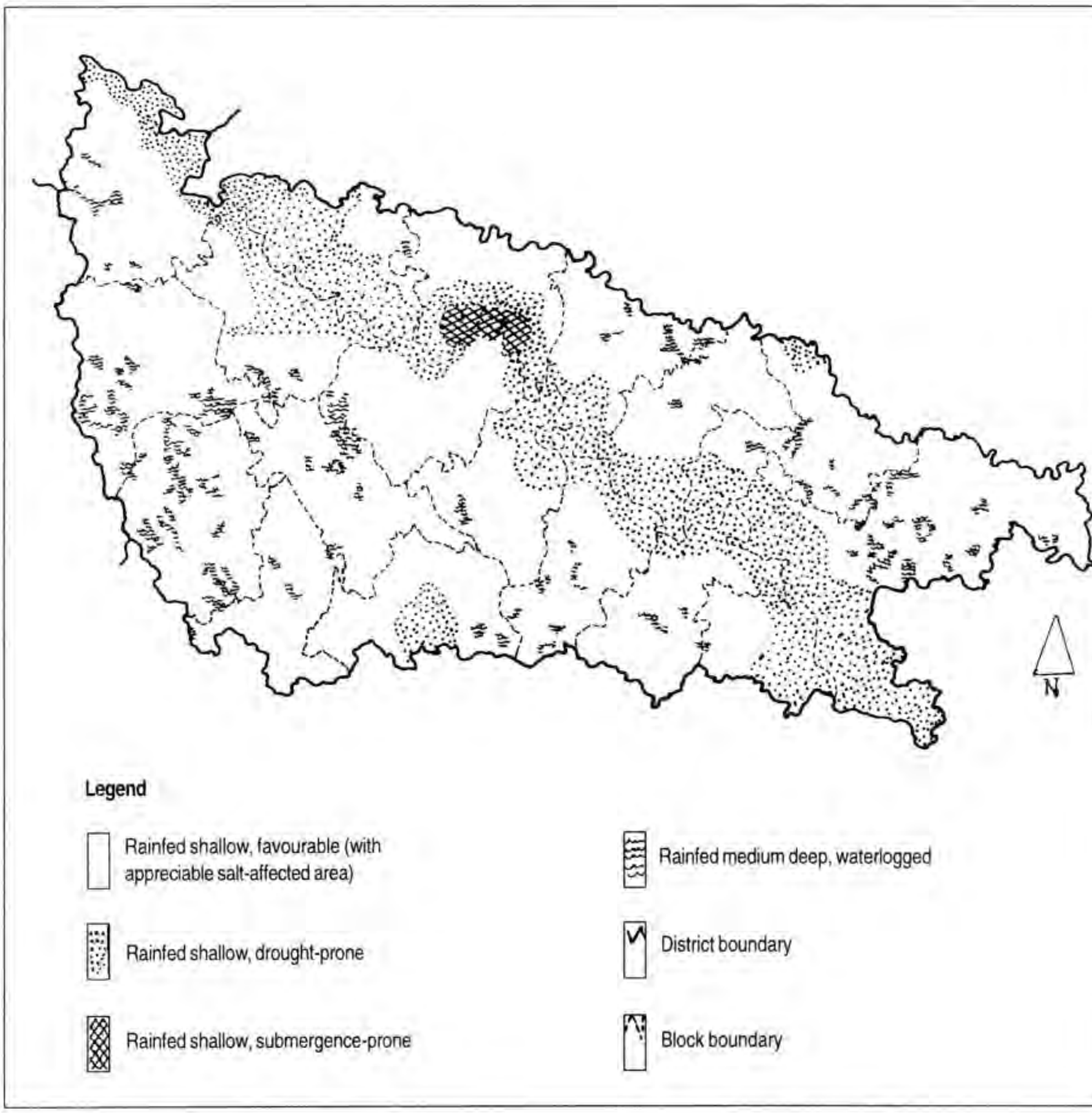
Case study

The outputs of agro-ecosystem analysis are generally provided as maps and agro-ecosystem characterisation details. An example of district-level agro-ecosystem analysis carried out for Sultanpur District of Uttar Pradesh, where ecosystems have been delineated by development blocks, is provided in the map and table below.

Rice-growing sub-ecosystems in Sultanpur District, Uttar Pradesh, India

Rice sub-ecosystem	Area (ha)	% Geographical area of district
1. Rainfed shallow, favourable lowlands (with occasional salt-affected area)	317,482	71.6
2. Hainfed shallow, drought-prone lowlands	103,455	23.3
3. Rainfed shallow, submergence-prone lowlands	4,726	1.1
4. Rainfed medium deep, waterlogged lowlands	17,937	4.0
Total	443,600	100.0

Rice-growing sub-ecosystems in Sultanpur District, Uttar Pradesh, India



Prepared by:
A.N. Singh and V.P. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Influence of Agro-Ecosystem Components on Rice Production

Rice yield can be affected by several components of agro-ecosystems that are inter-related; for example, landform and rainfall are both responsible for different hydrological conditions in a rainfed area. Some important components and their inter-relationships are discussed below.

Landform and rainfall

A schematic presentation showing the influence of varying amounts of rainfall under different landforms leading to varying water accumulation is given in Table 1.

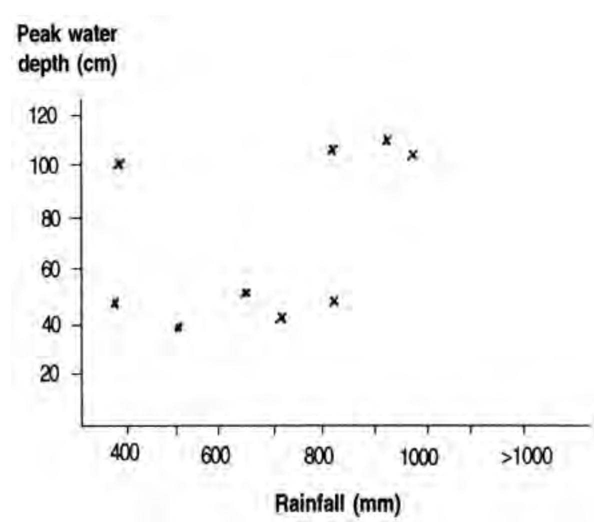
Table 1. Influence of rainfall and landform/physiography on the hydrology of rainfed rice lands

Rainfall (amount/intensity)	Landform/physiography		
	Plains	**Gently sloping**	**Low-lying**
High amount			
High intensity	Abrupt accumulation but slow recession (flood: intermediate duration, and depth).	Abrupt accumulation but fast recession (flood: shorter duration and shallow).	Abrupt accumulation but slow recession (flood: longer duration and deep).
Low intensity	Gradual accumulation but fast recession (flood: intermediate duration and depth).	Gradual accumulation but fast recession (flood: shorter duration and shallow).	Gradual accumulation and slow recession (flood: longer duration and deep).
Normal amount			
High intensity	No accumulation (no flood and no drought).	Gradual accumulation but fast recession (no flood and no drought).	Abrupt accumulation but slow recession (flood: longer duration and deep).
Low intensity	No accumulation (no flood and no drought).	No accumulation (no flood and no drought).	Gradual accumulation and slow recession (flood: shorter duration and intermediate depth).
Low amount			
High intensity	No accumulation (flood, but may have drought)'.	No accumulation (no flood, but drought occurs).	Abrupt accumulation (also because of drainage from catchment) but slow recession (flood: longer duration and intermediate/ shorter depths).
Low intensity	No accumulation (no flood, but drought occurs).	No accumulation (no flood, but drought occurs).	Gradual accumulation, slow recession (flood: shorter duration and shallow).

1 *Amount refers to total annual rainfall and intensity refers to one occurrence.*

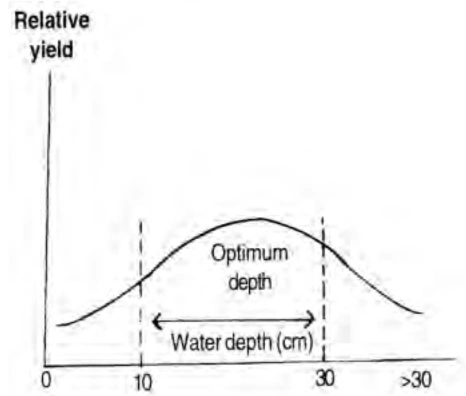
Rainfall and water depth

The rainfall in June-October during 1984-92 and peak water depth accumulation in Ghaghraghat, Bahraich District, show that accumulation of water depends not only on total rainfall in an area, but also on the duration, intensity and period of rainfall as well as drainage from the catchment area.



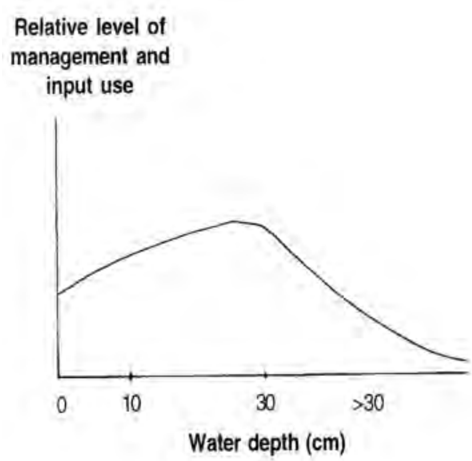
Water depth and yield

The optimum water depth in rainfed rice fields is 10-30 cm. Water depth of >30 cm or <10 cm generally decreases rice yield.



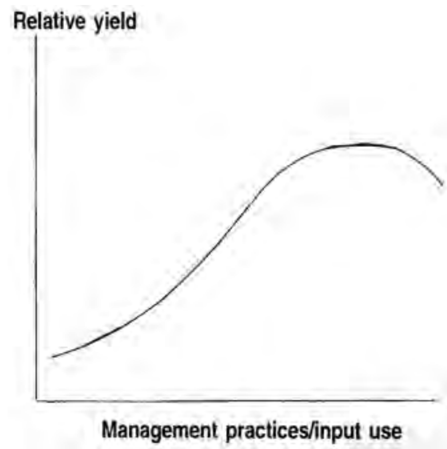
Water depth and management practices

With increasing water depth beyond 30 cm, management practices and input use decrease and also become difficult. Under <10 cm sustained water depth, the application of inputs is lower due to risk factors as occurs above 30 cm water depth.



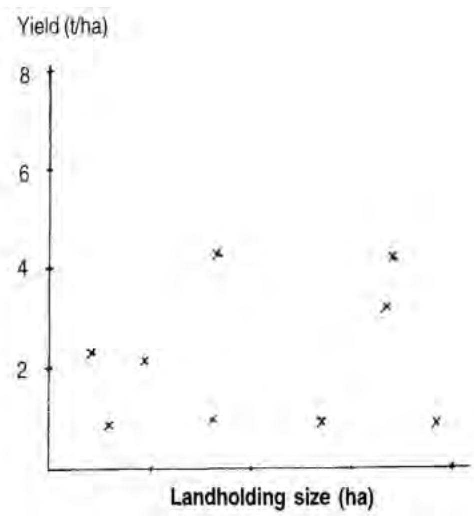
Management practices and yield

Management practices have an important role in input use and yield increase. Yield increases correspondingly with better management/input use. However, when yield reaches a plateau, the crop does not respond further and, in fact, yield decreases.



Landholding size and rice yield

The effect of landholding size on rice yield is more related to the level of input use in specific environmental situations.



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Prepared by:
A.N. Singh and **V.P. Singh**

Rainfed Rice Farming Systems

Principles for Improving and Stabilising Crop Yields

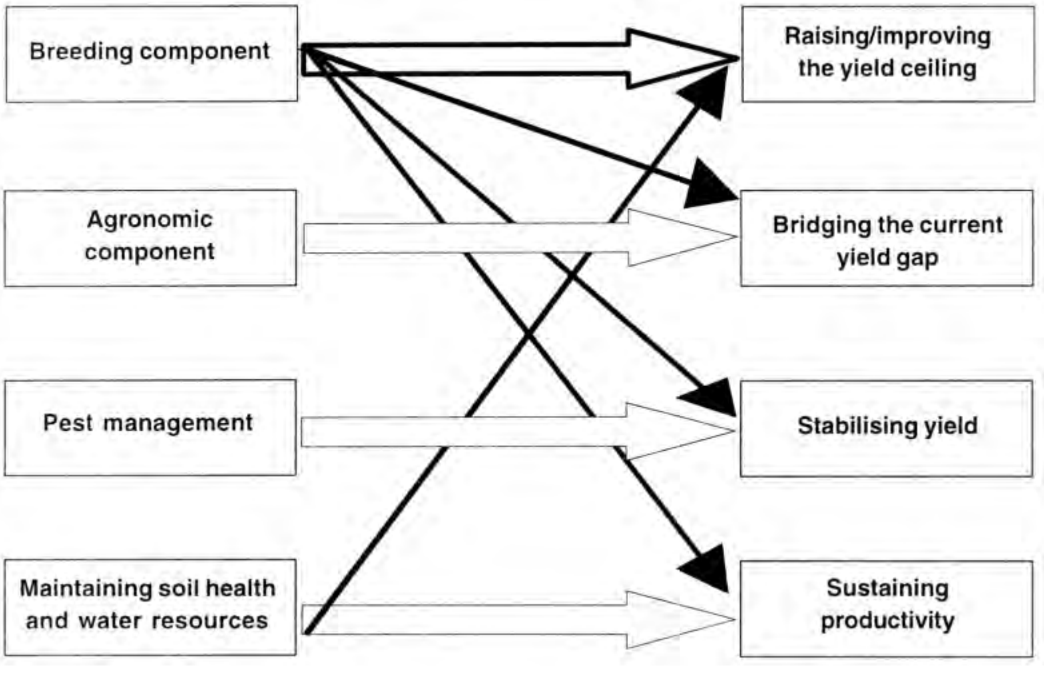
The average yield of upland rice is 0.8 t/ha and 1.5 t/ha for lowland rice. These yields are far below the yield of irrigated rice (2.5 t/ha) and the national average (1.9 t/ha).

Addressing these issues is highly pertinent in the context of systems performance, farmer income and broadening of the resource base. The basic requirements for improving rainfed rice are:

- Varietal improvement
- Water management
- Pest management
- Soil and nutrient management

If the above factors are taken care of, the country can fulfill its future food requirement.

Improving and stabilising yield



Yearly fluctuation in rice fields must be stabilised to ensure adequate food supply to rice farmers and consumers.

Productivity constraints

- Erratic rainfall resulting in drought or flood
- Weed infestation
- Low input use
- Disease and insect pests
- Use of low-yielding variety

Improving yield

Breeding components	Agronomic components
■ Identify an appropriate variety through on-farm selection for site-specific uses. ■ Use the selected variety, for example: • Short-duration variety (85-95 days) for uplands • 110-115 days rice variety for shallow lowlands ■ Use a rice variety having early vigour for weed suppression.	■ Seeding at proper depth (4 cm deep). ■ Ensure optimum plant population through appropriate crop establishment practices. ■ Keep the field free from weeds up to 45 days after seeding/transplanting. ■ Fertilise the crop on soil-test basis. ■ Follow integrated pest management throughout crop growth. ■ Keep fields free from water/moisture stress. ■ Avoid harvest and post-harvest losses.

Stabilising yield

Pest management	Maintaining soil health
■ Adopt integrated pest management • Grow resistant rice variety in endemic and problematic areas • Apply biological control measures • Use mechanical means, such as traps • Practice agronomic/crop cultural manipulations, such as crop rotation, moisture conservation, planting, spacing, etc • Use chemical means only when absolutely necessary	■ Adopt integrated nutrient management • Monitor productivity and fertility trends • Assess processes of soil degradation • Follow soil-test recommendation for fertiliser applications • Use both organic and inorganic sources, including green manures • Recycle all available organic matter in the field • Take care of critically limiting nutrient elements • Avoid nutrient losses as much as possible, for example, suspend irrigation and drainage at the time of fertiliser application or apply chemical fertiliser after incubating with farmyard manure, etc. • Include leguminous crop in the cropping system

Water management

- Adopt efficient water conservation and use measures.

- Apply *in situ* water conservation practices:
  - Check runoff losses through bunding and increased bund heights, contour ploughing, terracing.
  - Store runoff water in on-farm or community reservoirs, runoff interceptor trenches.
  - Reduce moisture stress in the soil and enhance profile recharge by improving infiltration through deep ploughing, summer ploughing.

- Reduce losses of conserved moisture.
  - Check seepage.

- Make stored water available for use during the critical stages of crop growth in water-stress situations.

- Apply community-based drainage practices in excess water situations.
  - Use natural drains.
  - Rehabilitate and maintain such drains through desilting, removing vegetation and clogs, etc.

Prepared by:
R. K. Singh and **V.P. Singh**

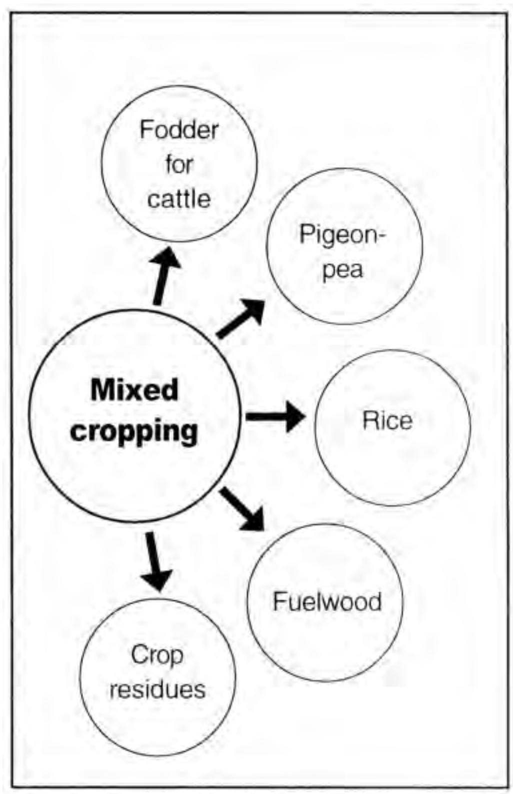
Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Major Cropping Systems and Their Management

Cropping systems technologies

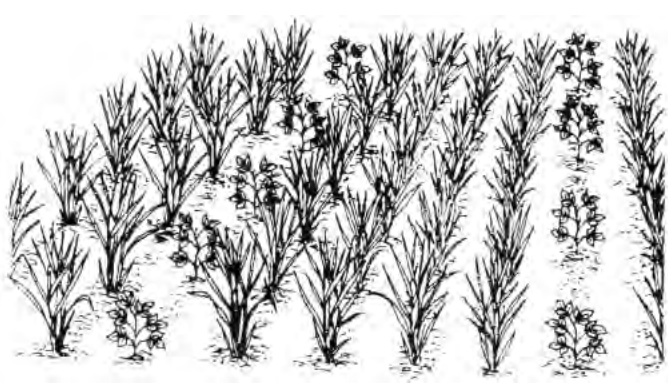
Insertion of an additional crop before, after or during the main kharif rice or together with it, with the attendant management schemes appropriate to specific cropping patterns and management capabilities of farmers is expected to result in crop intensification and increased farm profit. Current work in eastern India focuses on identifying better crop genotypes for the existing cropping patterns as a whole rather than dealing with each crop separately. Likewise, different crop combinations and their management practices are also being investigated to compare their economic viabilities.

Cropping systems



Mixed cropping

The surveys reveal that the most common rice-based mixed cropping combinations farmers use are wheat + mustard, gram + mustard, wheat + barley, wheat + linseed after rice in lowland situations, and rice + pigeonpea, rice + green gram, rice + black gram, rice + sesamum, pigeon-pea + black gram, pigeonpea + sorghum, and pigeonpea + sunhemp in upland situations. Early rice + maize, or moong, or sesamum before flood and jute + rice mixed cropping during flood are common in deepwater areas.



Mixed cropping

Intercropping

A number of crops are grown as intercrops with upland, lowland and deepwater rice, depending on farmers' preferences/needs and length of the growing period.

In an upland situation, intercrops include pigeonpea, soybean, amaranthus, cowpea, black gram and groundnut. The results of these combinations show rice and pigeonpea to be the most promising intercrop combination for the plateau region of Bihar, while rice and groundnut intercropping is the most promising for Orissa.

Under a deepwater situation, ahu rice grown with bao rice (3:1) is the most promising intercropping system for Assam, whereas *Boro* rice with bao is the most promising for West Bengal. Extra early maize in deepwater rice before flooding is the most promising in eastern Uttar Pradesh and northern Bihar. In rice and pigeonpea intercropping, the growth patterns of both crops are complementary. Rice and pigeonpea are planted at the same time and the juvenile phase of pigeonpea coincides with the senile phase of rice. Rice growth is faster than that of pigeonpea and rice is harvested before pigeonpea flowers.

Sequence cropping

Growing crops after rice is determined by the availability of soil moisture, runoff water for recycling, soil texture, length of the rainy season and farmers' other resources. Various crops after rice have been tested in sequence/rotation throughout all the states in the region under two or three crop sequences. The crops after rice include wheat, linseed, mustard, lentil, safflower, rapeseed, green gram, pea, niger, sesamum, ahu rice, potato, jute, horse gram, black gram, chickpea, cauliflower, wheat, faba bean, cabbage and tomato.

Utera system

Under the rice-utera (paira) cropping system, rice-linseed, rice alone, rice-lentil and rice-chickpea have been extensively investigated at Patna in the lowland ecosystem, along with rice-fallow, rice-lentil, rice-mustard and rice-linseed at Ghagharaghat in the deepwater ecosystem. In deepwater areas, rice-fish farming has also been evaluated at several places in the region.

In the utera system, rice-linseed and rice-lentil are the most promising in eastern Uttar Pradesh and northern Bihar, along with rice-lathyrus and rice-linseed in eastern Madhya Pradesh and rice-pea and rice-faba bean in Assam. Rice-mustard is very economical in all states.

Rice-wheat system

This cropping system is predominant in large areas of eastern Uttar Pradesh, Bihar, West Bengal and Madhya Pradesh under rainfed shallow lowlands. The average yield of wheat varies between 1.1 and 2.6 t/ha. Variety evaluation conducted at Chinsurah, Masodha and Patna revealed 40% higher yields with selected varieties than with those commonly used by farmers. The selected varieties are also suitable for late planting, have resistance to major diseases and thus fit well in areas with a long rice and short wheat growing season in the cropping system.

Rice-lentil system

This is one of the common cropping patterns in Uttar Pradesh and Bihar. On-farm variety evaluation trials have identified a promising lentil variety ("Arun") which had 44% higher yield (0.85 t/ha) than the farmers' traditional variety (0.59 t/ha) in Bihar and a variety (PN 406) for Uttar Pradesh with an average yield of about 1.2 t/ha.

Rice-chickpea (gram) system

This cropping pattern appears to be feasible in the drought-prone areas of eastern Madhya Pradesh where more than 95% of the area is monocropped with rice. Some area planted to chickpea suffers from wilt diseases due to poor resistance of local varieties. On-farm trials have failed to identify any varieties yielding better than those used by some farmers at Raipur. Two varieties (JG74 and JG315) were only marginally better than the local varieties in grain yield, both with 1.6 t/ha vs 1.5 t/ha. However, both these varieties have wilt resistance, and they have bolder grains than the local variety. At Paha, variety RAU-52 was superior to the local variety in grain yield. For rainfed submergence-prone lowlands with high soil moisture after the rice harvest, variety BG14 was promising for late planting.

Rice-mustard system

This is a common pattern in Uttar Pradesh, Bihar, West Bengal, Assam and Orissa. On-farm variety evaluation has identified new mustard varieties which produced significantly higher yields than the local ones, with a yield advantage of about 80%.

Rice-linseed system

On-farm trials have identified linseed varieties (shubhra, mukta, kiran, R552) which produced 40% higher grain yield than the local variety T-397 (0.95 t/ha vs 0.68 t/ha). Even with high profitability, linseed is not becoming popular among farmers because of its allelopathic effect on succeeding upland crops such as maize (personal observation). Farmers also confirm this observation. Its roots secrete hydrocyanic acid and probably other toxic compounds.

Rice-rice system

A considerable number of rainfed lowland and deepwater farmers in Bihar, West Bengal and Assam practice this cropping system by utilising accumulated surface water. The low air temperature (10°C) prevailing in December and January causes injury to the seedlings of the second crop (*Boro*), thus prolonging crop maturity. As a consequence, the delayed second crop suffers from high air temperature (35°-40°C) during the reproductive stage, resulting in yield loss. To remedy this situation, research emphasises identifying suitable cold-tolerant, early maturing rice varieties. Results of on-farm trials have identified two rice varieties — UPR103-80-1-2 for West Bengal and Swarnaprova for Assam — which escaped these hazards and thus produced better yields than the farmers' varieties.

Jute-rice system

Rainfed lowland farmers in West Bengal and Orissa also plant jute before rice. This practice is also followed in Assam and Bihar. The yields of local jute varieties are quite low. Identifying suitable high-yielding varieties is expected to increase the system's productivity. Trials conducted at Chinsurah have identified two jute varieties (Nabin and Basudev) which produced higher fibre yields (2.3 and 3.8 t/ha, respectively) than did the local varieties (1.4 to 2.3 t/ha). Higher fibre yield (by 64%) was also noted by the use of improved seed quality at Chinsurah.

Cropping systems management

Aside from identifying suitable varieties for the different cropping systems, emphasis is also given to management practices to improve the systems' productivity. The priority issues addressed are discussed below.

Crop establishment

In rainfed lowland areas, especially with puddled transplanted conditions, establishment of succeeding crops in the cropping pattern is a major problem faced by farmers throughout the region. The common establishment practice for chickpea, mung, pea, lentil and mustard is to broadcast seeds on the soil surface with or without fertiliser. In this method, poor germination and uneven plant stand are common consequences. In the utera system, the seed rate of these crops is increased by 30%.

On-farm tillage studies conducted at Raipur using “Navagaon plough” showed better yield of chickpea with tillage due to improved tilth and soil-seed contact and improved moisture availability. Likewise, the yield of lentil and wheat was also superior with two ploughings than without it at Masodha. The effects and interaction of land preparation and crop establishment methods of rice on succeeding upland crops, especially wheat, have been examined in detail. In high moisture areas, lentil sowing in furrows (behind plough) without tillage was superior to the conventional method. This advantage is also found with advanced sowing as no tillage was required for seeding the crop.

Nutrient management

Trials at Masodha have shown that the application of 40-20-0 kg N-P_2O_5-K_2O/ha to wheat increased grain yield by 61% over the control and by 14% over 40 kg N alone. Application of 20-40-0 kg N-P_2O_5-K_2O/ha using single sources or diammonium phosphate (DAP) increased the yield of gram and lentil by 32% and 14%, respectively, at Patna over the farmers' practice without fertiliser application. Likewise, the results indicate a significant increase in yields of barley as well as mustard with the increasing rates of N application. The response was significant up to 50 kg N/ha for both the pure crops and their mixtures in broadcast or in row-seeded systems. In mung trials in Orissa, application of 10-20-20 N-P_2O_5-K_2O (all basal) increased yield by 50%.

Economics of different cropping systems

Systems comparison

The comparison of different systems included: (a) cropping systems in rotation and (b) mixed cropping. In mixed cropping, the wet season (kharif) crop was a monocrop in the Gangetic plains, whereas the dry season (rabi) crop was a monocrop in the Chotanagpur plateau.

Crop rotation

Six rice-based cropping systems were evaluated in farmers’ fields in the Gangetic plains. The results indicated that the rice-mustard system was highly profitable, giving a net return of Rs. 6062/ha. It was followed by rice-linseed (Rs. 4966) and rice-lentil (Rs. 4762). The other systems gave break-even returns and were rated economically less viable.

Mixed cropping

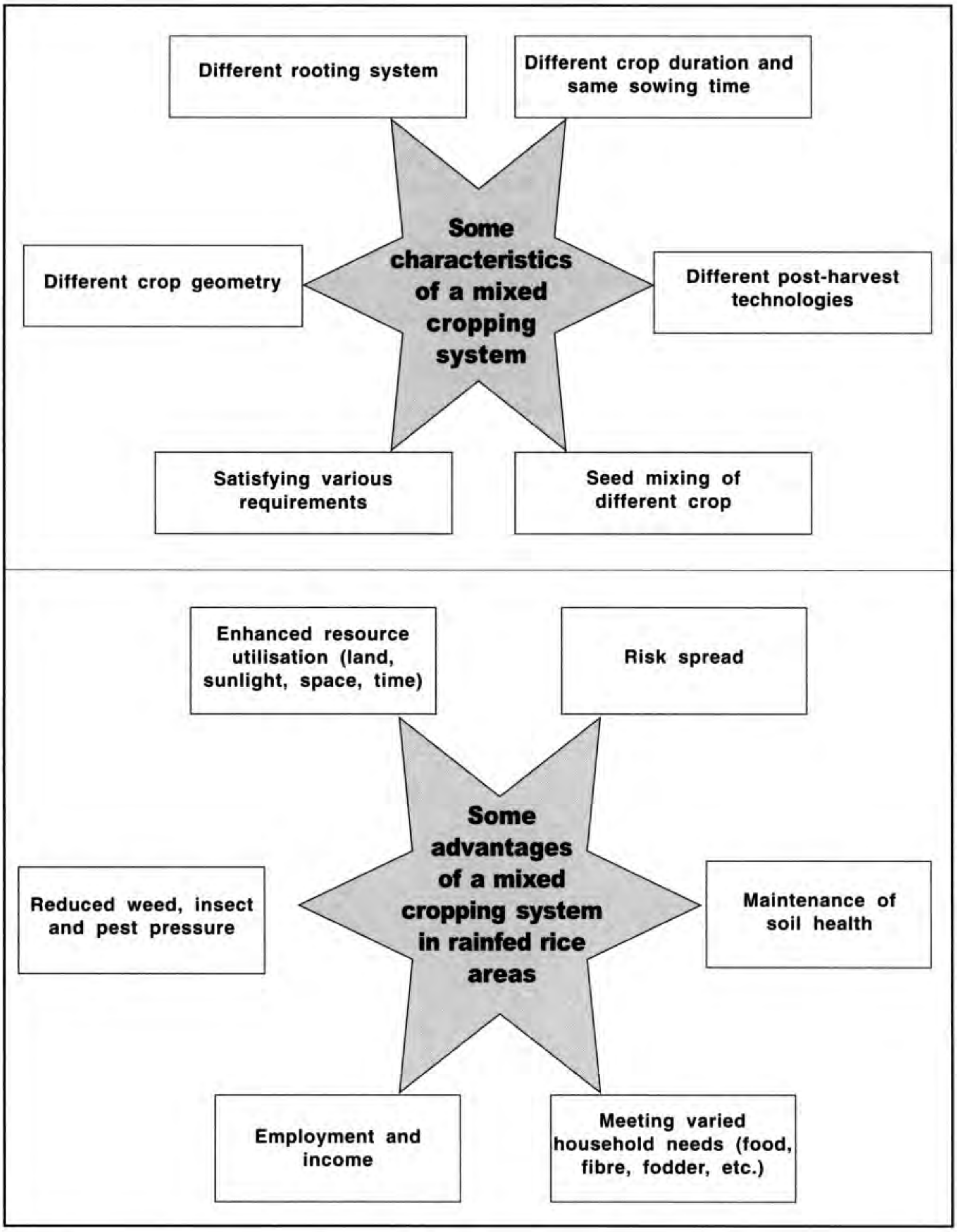
Because of its higher profitability, mustard was evaluated with barley in rainfed drought-prone lowlands and with wheat where supplementary irrigation was possible in farmers’ fields in broadcast and row-seeded mixed cropping. The equivalent yields of mustard were significantly higher in the pure mustard crop than mixed with barley in broadcast, but were close to mustard mixed with barley in the row-seeded system. The pure-crop barley yields were lower than those of pure mustard or mustard mixed with barley. These results indicate that, for higher income, farmers have two options. They should take either a pure crop of higher value mustard or a mustard + barley mixed crop with row seeding. The wheat + mustard system was better in the broadcast and row-seeded system than either of these pure crops.

In the plateau uplands, several options of mixed cropping of rice with legumes or cereals, especially drought-tolerant crops and varieties, were evaluated in farmers' fields. These included green gram, black gram, pigeonpea, soybean, groundnut, cowpea and ragi (millet) and their methods of establishment and spacing. Rice plus red gram and rice plus black gram were profitable but unstable over time. Rice + ragi was stable as well as somewhat economical. From last year's results, it is concluded that mixed cropping in uplands during kharif provides a measure against crop failure due to drought rather than higher productivity and profitability.

The agronomic feasibility (higher yield) of a cropping system does not necessarily mean higher income on a sustained basis. Therefore, one of the issues dealt with in cropping systems research is to determine the profitability and sustainability of different cropping systems.

Economic analyses of different systems tested show jute-rice-lentil to be the most profitable, followed by jute-rice-wheat in submergence-prone lowlands in West Bengal. For the rainfed lowlands of Orissa, it is jute-early rice-sesamum, followed by jute-late rice-mungbean. In Assam, it is rice followed by pea. In submergence- and drought-prone lowlands of Uttar Pradesh and Madhya Pradesh, it is rice-wheat, followed by rice-lentil and rice-linseed in Uttar Pradesh and rice-horse gram in Madhya Pradesh.

Characteristics and advantages of mixed cropping systems



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V. P. Singh

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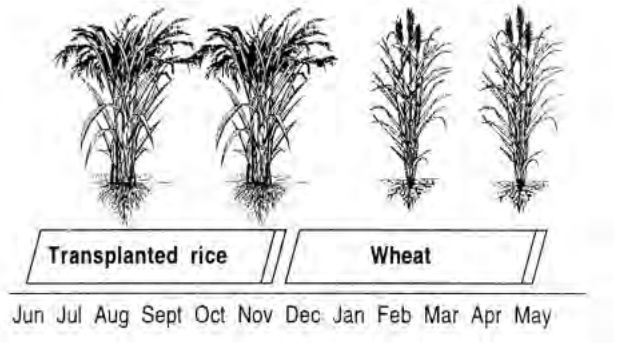
Comparative Analysis of Different Cropping Systems

A cropping system is the crop production activity of a farm. It comprises all components required for the production of a set of crops and the relationship between them and the environment. There are two major types of cropping systems: monocropping and multiple cropping.

Multiple cropping systems

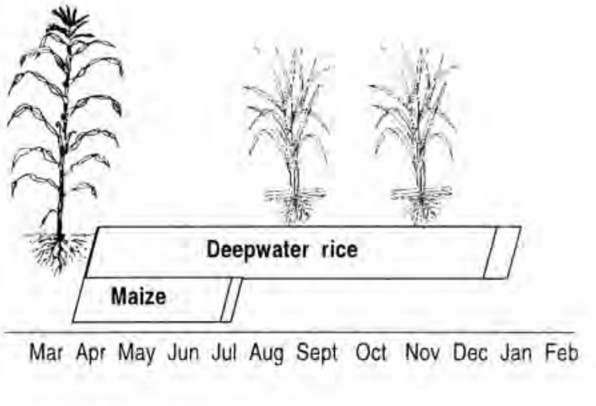
Sequential cropping

Two or more crops are grown in a sequence in the same field within a 12-month period, the succeeding crop being sown only after the preceding crop has been harvested. This enables farmers to manage only one crop at any one time in the same field.



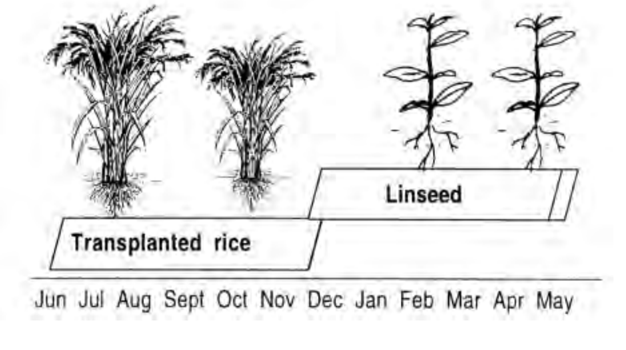
Intercropping

Two or more crops are grown simultaneously in the same field so that the period of overlap is long enough to include the vegetative stage.



Relay (utera) cropping

Two or more crops are grown together, but the succeeding crop is sown after flowering and before the harvest of the former crop.



Rainfed rice ecosystems

Rainfed rice is grown on land that is dependent on rainfall or harvested rainwater. The rice ecosystems are:

■ Upland	No water stagnation
■ Lowland	Water stagnation
• Shallow	0-30 cm
• Semi-deep	30-50 cm
• Deepwater	50-100 cm
• Very deep water	>100 cm
Flood-prone	Uncertain flooding

Cropping systems in different rainfed situations

Upland

Except for limited periods, the land does not hold moisture in the rooting zone in excess of that held at field capacity.

CROP SEQUENCE

The crop sequence can be rice-chickpea, rice-pea, rice-mustard and rice-barley. Rice-chickpea is more remunerative than the other cropping systems.

CROP MANAGEMENT

Use a drought-tolerant, deep-rooted rice variety of 80-100 days duration with fertilisers at 40 kg nitrogen (N)/ha and 30 kg P_2O_5/ha. Apply ¼ dose of nitrogen and full dose of phosphorus (P) at sowing, half of N at tillering after weeding and ¼ at flag leaf stage. Sow *rabi* (post-rainy season) crops such as pea and mustard when the residual moisture is adequate and chickpea and barley when the residual moisture is less.

Lowland

The rooting zone in these lands can be kept saturated for a substantial part of the rice-growing season, where necessary.

CROP SEQUENCE

SHALLOW LOWLAND

Rice-wheat, rice-lentil, rice-linseed, rice-mustard, rice-pea, rice-sunflower, rice-mungbean and rice-chickpea are commonly practiced. Rice-wheat is more remunerative than other cropping systems. Use a rice variety of 100-120 days duration.

TIPS:

- ■ In shallow deep and semi-deep lowlands, transplant at least 48-52 seedlings of rice in 1 m^2 (i.e., 15 cm × 15 cm plant spacing).
- ■ Use khesari varieties which are low in biotic histidine-free amino acid (BHAA).

SEMI-DEEP LOWLAND

Rice-lentil and rice-linseed can be practiced in excess moisture where tillage operations are impossible for *rabi* crops. Rice-wheat, rice-mustard and rice-mungbean can be adopted in well-prepared soil. Use a rice variety of 120-140 days duration.

Crop management

In shallow deep and semi-deep lowlands, apply 80 kg N/ha and P at 40 kg P_2O_5/ha. Apply a half dose of N and full dose of P at transplanting/seeding, half of the remaining N at tillering, and half at panicle initiation.

Deepwater lands

Crop sequence

Rice-linseed, rice-lentil, rice-mustard and rice-khesari (*Lathyrus sativus*) are used as relay (*utera*) crops.

Crop management

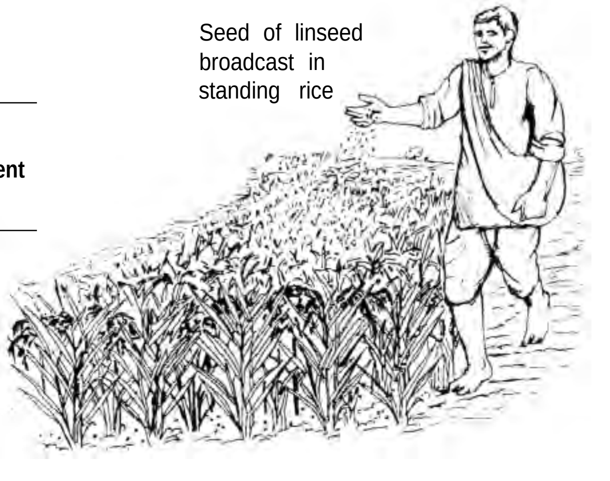
Transplant 30- to 40-day-old seedlings of a rice variety of 140-160 days duration. Transplant five to six seedlings in one place at 20 cm × 20 cm spacing. Use fertilisers at 60 kg N/ha and 30 kg P_2O_5/ha. Use a half dose of nitrogen and full dose of phosphorus at transplanting. Use half of the remaining nitrogen at tillering and half at panicle initiation.

Relay *(utera)* cropping in deepwater

Use 50% extra seed of linseed/lentil/mustard/khesari. Broadcast the seed in a standing rice crop five to 10 days before or after harvest in muddy or well-moistened soil, where tillage operations are not possible. Apply only half of the recommended dose of fertiliser at the time of broadcasting.

Economics of relay *(utera)* cropping systems in deepwater

Crop sequence	Gross income (Rs/ha)	Benefit:cost ratio	Rice equivalent (t/ha)
Rice-fallow	7050	1.70	2.35
Rice-lentil	10150	1.99	3.86
Rice-linseed	10550	2.22	3.51
Rice-mustard	8894	1.98	2.96

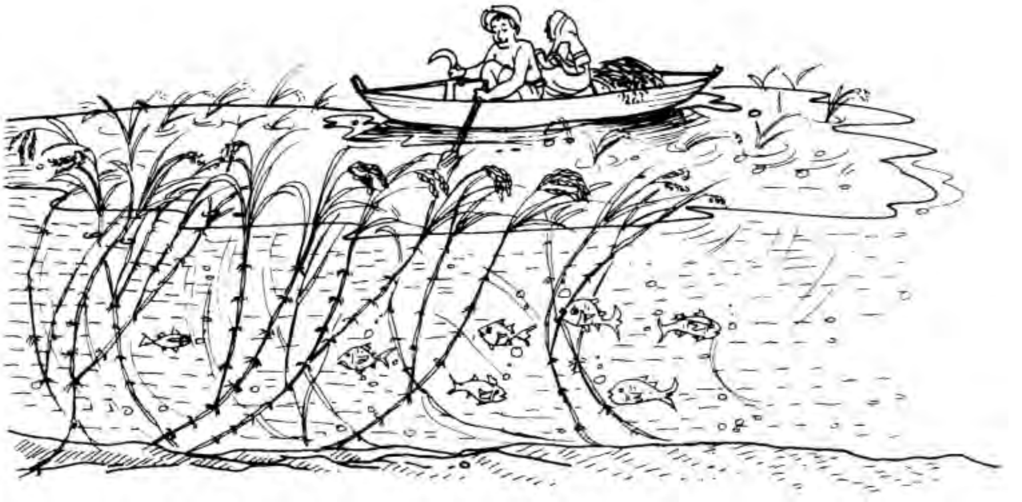


Seed of linseed broadcast in standing rice

Aquaculture in very deep water (floating rice) areas

Raising fish in ricefields is profitable in very deep, controlled water conditions. Grow late-maturing (180-210 days) rice varieties Jalmagna, Jaisuria, or Jaladhi and Indian carps. Catla (40%), Rohu (30%) and Mrigal or Rata (30%), grass carp and common carp fingerlings (4000-5000/ha; each 3-4 g and 5-6 cm long) are stocked in July-August. Feed fish with mustard oilcake and rice bran. Harvest fish from pond refuge in February-March.

Do not use pesticides in rice-fish culture ponds. Adopt integrated pest management practices.



Economics of intercropping with rice in very deep water

Crop sequence	Gross income (Rs/ha)	Benefit:cost ratio	Rice equivalent (t/ha)
Deepwater rice	7902	1.80	2.63
Deepwater rice + maize	10471	1.91	3.49
Deepwater rice + jute	8206	1.58	2.74

Very deep water (floating rice) areas

Monocropping of rice (200-210 days) is the only alternative. The crop is sown in April-May and is harvested in December-January. Mixed/intercropping of maize, jute, and mungbean is feasible as a pre-flood crop (April-June). Extra-early maturing maize is the best intercrop.

Fish, common carp or major Indian carp, can be easily raised in a pond refuge simultaneously with rice. Nitrogen is applied at 20 kg N/ha at sowing.

Flash-flooded undulated area

This land is adjacent to river banks, undulated with various soil types carrying silt and sand deposits due to frequently changing water currents. Sugarcane is a major crop in some areas. Rice varieties having submergence tolerance are also grown. The cropping systems of the area can be diversified with banana and paragrass. Banana (plantain type) can be grown on the upper portion of the upper lands with 50 kg compost per pit. Paragrass (fodder) root slits (each with three to four buds) can be planted only on sloping lands.

Flood-prone areas

Flood-prone areas are subjected to fluctuating waterlogging/stagnation during heavy rains. The stagnation, in general, starts in the last week of July and continues until the end of September. During the rainy season, four to six floods occur with different water levels. These areas can be classified into two types:

- flash-flooded undulated area; ana
- flash-flooded flat area.

Crop cafeteria for flood-prone areas

Flash-flooded flat area

This area is elevated and less frequently flooded. The river water spreads due to floods in the area. Since the land is flat, farmers grow sugarcane and rice as rainfed crops.

Rice varieties with submergence tolerance, such as the Janki, Sudha, Jalplaban, Madhukar, Bhaislot, or Barh-avarodhi, can be direct-seeded before floods or after the onset of monsoons using 100 kg seed/ha with row spacing of 20 cm. Apply fertilisers at 60 kg N/ha, 30 kg P_2O_5/ha and 20 kg K_2O/ha. Apply half of the nitrogen and a full dose of phosphorus and potassium at sowing and the remaining half of the nitrogen at tillering and panicle initiation in two equal splits based on water recession. After rice, crops such as wheat, yea, barley, lentil, linseed, mustard and sunflower can be grown with harvested water.

Agronomic practices recommended in flash-flooded undulated deep areas

Crop	Seed/ha	Spacing (cm)	Fertiliser (kg/ha) N	P_2O_5	K_2O
Banana	2,500 (suckers)	200 x 200 (plant)	150	150	200
Paragrass	25,000 (root slits)	80 x 50 (plant)	150	80	60
Sugarcane (COS 8118)	6t (stem)	75 (row)	150	80	60
Rice	100 kg (seed)	20 (row)	60	30	20

Economics of crop sequences in flood-prone areas

Crop sequence	Gross income (Rs/ha)	Benefit: cost ratio	Rice equivalent (t/ha)
Rice-wheat	12039	2.03	7.16
Rice-barley	7759	1.49	5.73
Rice-mustard	5861	1.40	5.11
Rice-lentil	6951	1.58	5.46
Rice-linseed	5646	1.35	5.03
Rice-pea	6601	1.43	5.35
Sugarcane-ratoon	66526	2.81	20.78
Banana-banana	47000	2.55	14.68
Paragrass	26760	2.02	8.36

In Assam, delayed transplanting of 45-60-day-old seedlings of traditional photoperiod-sensitive varieties, such as Manoharsali and Andrewsali, can be done after the monsoon (September) at closer spacing (20 cm x 20 cm). Recommended levels of fertiliser are applied as basal.

Recommended crop rotations in eastern India

Ecosystems	Rotations	Location
Upland	Rice-chickpea, rice-barley Rice-chickpea Rice-fallow Rice-mungbean/black gram Niger+sesame	Eastern Uttar Pradesh and northern Bihar Orissa Eastern Madhya Pradesh Assam Western Bihar
Shallow lowland (0-30 cm)	Rice-wheat, rice-lentil Rice-chickpea, rice-mungbean, rice-mustard, rice-groundnut Rice-chickpea Rice-khesari, rice-mustard, rice-linseed Rice-rapeseed Jute-rice	Eastern Uttar Pradesh and northern Bihar Orissa and west Bengal Western Bihar Eastern Madhya Pradesh Assam Assam, Orissa
Semi-deep lowland (30-50 cm)	Rice-wheat (prepared soil), rice-lentil (moist soil) Rice-rice, Boro (summer) rice-fallow	Eastern Uttar Pradesh and northern Bihar Assam
Deepwater (50-100 cm)	Rice-linseed (relay), rice-lentil (relay) Rice-fallow	Eastern Uttar Pradesh and northern Bihar Assam
Very deepwater (>100 cm)	Rice + maize Boro rice-fallow, ahu + bahu	Eastern Uttar Pradesh and northern Bihar Assam
Flash-flood flat area	Rice-wheat, rice-lentil Rice-groundnut Rice-toria/potato	Eastrern Uttar Pradesh and northern Bihar Orissa Assam
Flash-flooded undulated area	Sugarcane-ratoon, banana-banana, paragrass Rice-fallow-mustard/toria rice-fallow-vegetable	Eastern Uttar Pradesh and northern Bihar Assam

Prepared by:
O.P. Singh, G. Singh and **V. P. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

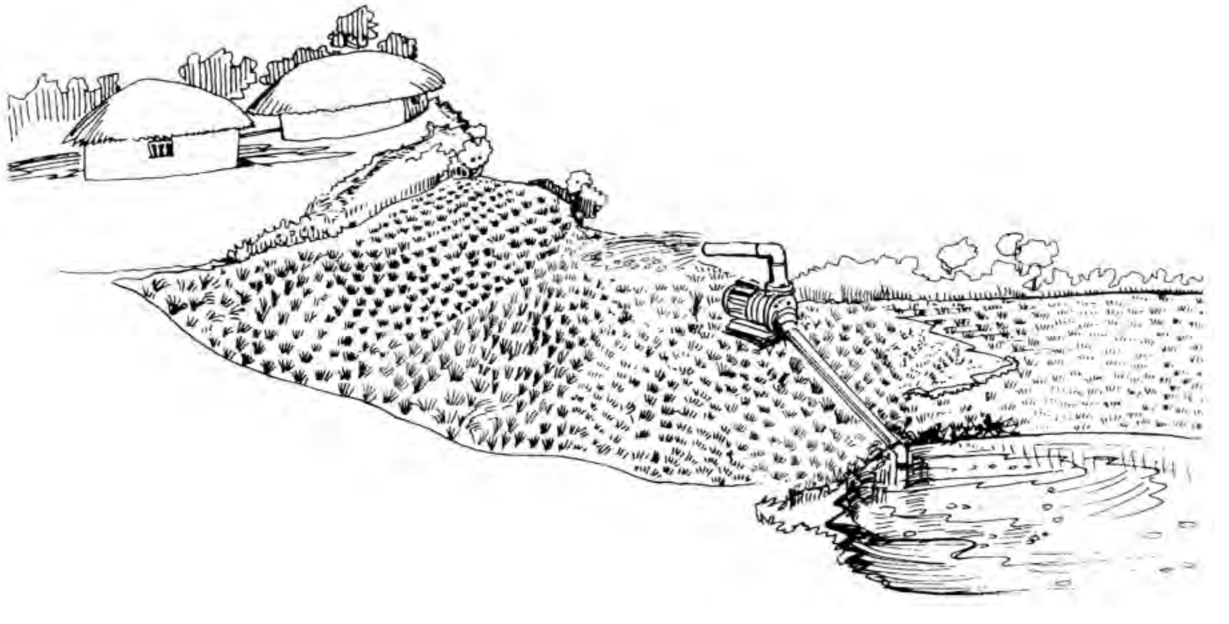
Boro Rice Cultivation

Boro rice cultivation is a special system of rice cultivation in waterlogged low-lying or medium land areas with irrigation during November to May. The *Boro* rice system takes advantage of:

- residual moisture in lands after the harvest of kharif paddy;
- longer moisture retention capacity of the soil; and
- surface water stored in nearby low-lying ditches, areas adjoining canals, roads, chaur lands, etc.

Traditionally, *Boro* rice was cultivated in river basin deltas where water accumulated during monsoons and could not be drained out in the winter months. The system of *Boro* rice cultivation has been an age-old tradition in Bangladesh and eastern India and is now spreading fast even outside traditional areas where irrigation is assured.

Boro rice is known for high productivity (5-6 t/ha) in deepwater areas of eastern India, where productivity has traditionally been very poor (<1 t/ha) during the kharif.



Boro rice cultivation in waterlogged low-lying and medium areas with irrigation

Types of cultivars used

Traditional

- Tall, weak-stemmed and awned cultivars with poor grain quality were cultivated, as these were considered to have good tolerance to cold temperatures at the seedling stage.
- Though the yields might not be high, they helped subsistence farmers.

High-yielding varieties (HYVs)

- Except in a few pockets, traditional cultivars are being replaced with both early and mid-early HYVs.
- The high-yielding varieties becoming popular are *Gautam, Prabhat* and *IR36,* along with, of late, *Joymati, Vishnu Prasad, Joyti, Prasad, Chinsura hybrid -3* and some other irrigated varieties.
- Yields are three to four times more than those of kharif rice.

Reasons for high yield of ***Boro*** rice

- Better water management during crop growth
- *Bora* rice responds to higher doses of fertiliser, resulting in higher production
- Less insect/pest infestation on the crop helps reduce damage
- Higher solar radiation available to the crop
- Lower night temperature during the early stages of crop growth in winter facilitates the accumulation of photosynthates, thereby increasing the carbon-nitrogen ratio
- Favourable higher temperature at ripening period

The variation in these parameters explains variation in yield across the region. With increasing *Boro* rice areas, both within and outside its traditional boundaries, new cropping patterns have also emerged and are adopted as per local conditions.

Boro -deepwater rice (DWR) system

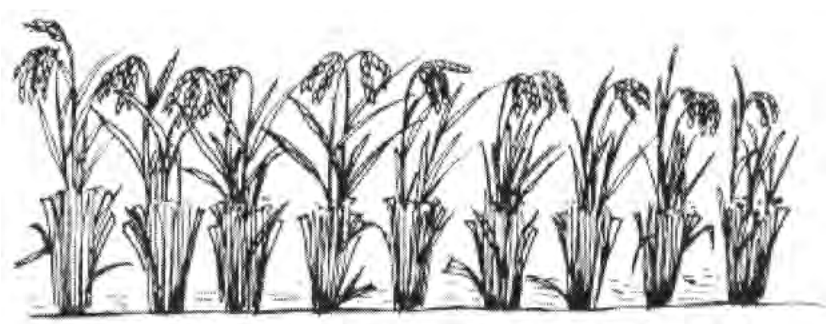
- *Boro* rice can be grown after harvest of kharif season DWR in the stagnant water and residual moisture.
- Various techniques are employed to adjust these two crops within a year in a same piece of land:
  - selection of appropriate Boro varieties;
  - early transplanting and harvest; and
  - transplanting of aged DWR seedlings in the field.

Integration of *Boro* with DWR

- When there is sufficient moisture in the soil, DWR can be grown by broadcasting germinated seeds in the standing *Boro* crop before maturity.
- After the Boro rice harvest, weeding and a topdressing of 20 kg N/ha are required for a good DWR crop.
- Through this system, additional yield of 1.5-2.0 t/ha can be harvested without much extra investment.

Boro-Boro ratoon

- *Boro* ratoon refers to the crop which grows from the stalk left after harvest of the main *Boro* rice crop. Ratooning ability is a varietal characteristic and is therefore important for this system.
- The ratoon crop becomes ready within five to six weeks.
- Ratooning is possible where *Boro* rice is harvested early and there is sufficient moisture in the field, and the farms have irrigation facilities.
- Additional yield of 2.0-2.5 t/ha may be obtained from *Boro* ratoon under favourable conditions.



Boro-Boro ratoon: crop growing from stalk left after harvest

Boro rice or wheat

- *Boro* rice or wheat can be grown in the same season. *Boro* is grown as an alternate crop where wheat cannot be grown due to excess water in the field.
- It is not profitable to grow *Boro* rice where wheat can be grown because *Boro* rice, unlike wheat, requires frequent irrigation.

Major constraints in *Boro* rice cultivation

Seedling stage

At this stage, low temperature causes:

- poor germination;
- slow and stunted seedling growth;
- yellowing of leaves;
- leaf spots; and
- slow and delayed tiller production.

Plant protection measures

Gundhi bug and leaffolder may be controlled by applying the recommended insecticide in the morning as and when required.

The cumulative effects of these constraints lead to non-synchronous and delayed flowering of the *Boro* rice.

Ripening stage

In this stage, hot weather causes:

- grain sterility;
- drought when an irrigation facility does not exist;
- leaffolder and Gundhi bugs, two major insect pests; and
- drying of the harvest in early monsoon areas.

Healthy seedlings ensure a better crop. Transplanting must, therefore, be done when:

- seedlings have the requisite height;
- temperature is favourable; and
- the field has adequate water.

Seedling management

Sow seeds in October-November to avoid the cold period during crop growth. This ensures that the seedlings have sufficient growth before winter. There are many ways to protect seedlings from cold injury.

Raise seedlings near river banks, swampy lands or in the periphery of chaur lands where warmer soil temperature ensures proper root growth.
Prepare the seedbed in low-lying areas near the source of irrigation.
Grow seedlings for *Boro* even in the shade.
Add sufficient organic manure to the seedbed (1-1.5 kg/sq m).
Dust the seedling leaves periodically with fuelwood ash, straw ash, cattle dung ash, etc.
Shake off dew drops from the tips of the seedlings every morning.
Place a polythene sheet cover just above the seedlings at night to avoid yellowing.

Prepared by:
R. Thakur and **V. P. Singh**

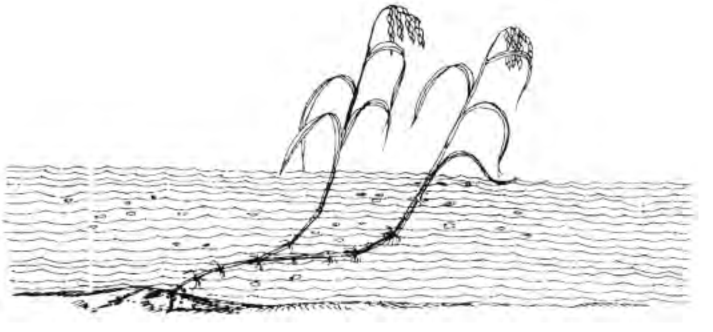
Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Management of Rice in Flood-Prone Areas

About six million hectares of lowlands in eastern India are subjected to annual flooding. Farmers in these areas had been using indigenous technologies to grow rice. Improved practices are now available to farmers for growing better crops.

Rice in flood-prone areas is grown in two situations:

- deepwater situation (stagnant flood); and
- rainfed shallow lowlands (with flash flood).



Deepwater rice

Deepwater situation (stagnant flood) (DWS)

Occurrence of flood and inundation is a regular feature in the deepwater situation throughout the monsoon period.

Rice culture options in DWS

DEEPWATER RICE

Deepwater rice varieties are either sown directly in the dry soil during the dry season (February-March) or transplanted in fields in May before the floodwater accumulates.

Direct seeding in dry fields

BORO RICE

After water recedes, *Boro* rice is grown from November – December to April – May.

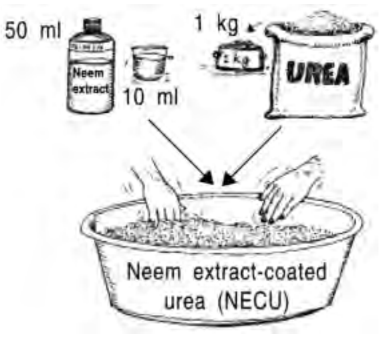
During February-March, crop mixtures of *ahu/aus* and *bao/aman* are broadcast in the dry field so that ahu/aus can be harvested before flooding in DWS.

MIXED CROPPING OF *AHU/AUS* AND *BAO/AMAN* CROP

Mixed seeds specific to these seasons are sown during February-March so that the short duration *ahu/aus* rice can be harvested before flood occurs and the *bao/aman* continues thereafter.

Preparation of neem extract-coated urea

Add 10 ml of neem extract (available locally) to 1 kg of urea. Mix the extract and urea by hand until urea becomes pink.



TIP

Sow the seed when the soil has adequate moisture. The soil is ready for sowing when a piece of clod can be broken by pressing between fingers.

Methods of crop establishment and management (DWS)

DIRECT-SEEDED RICE

- Prepare the fields well before the onset of monsoon by repeated, cross ploughing.
- Prepare neem extract-coated urea (NECU) using a locally available neem extract.
- Apply 50% of nitrogen as NECU and mix in the soil at final ploughing or apply a full dose of nitrogen as NECU at sowing.
- Drill the seeds in rows 25 cm apart. Alternatively, broadcast seeds at 90-100 kg/ha depending upon the situation.
- Apply 50% of nitrogen as NECU at tillering stage if water regime is favourable.
- Remove weeds by hand or *bindha* or ladder (*patta*) when the seedlings are 30-35 days old.

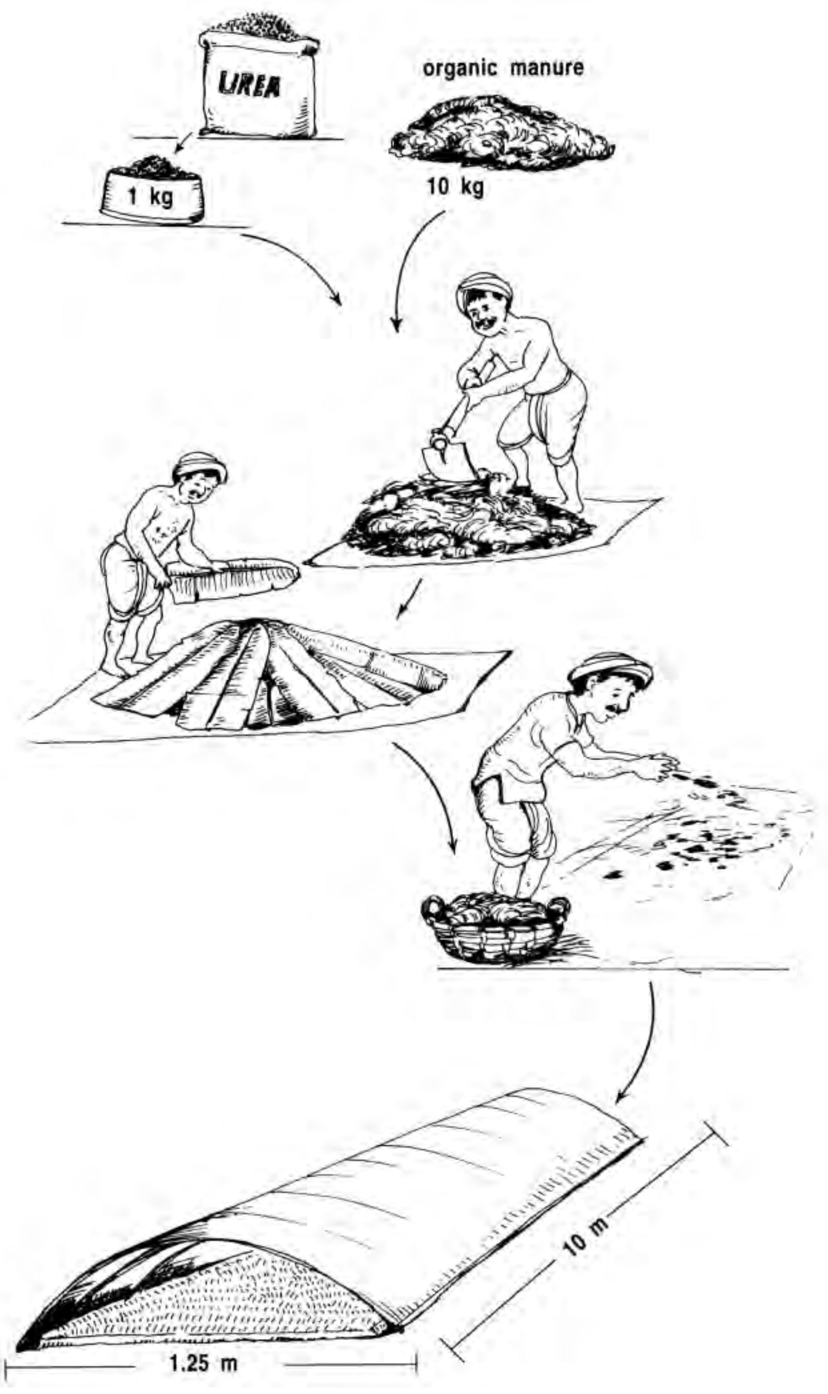
TRANSPLANTED RICE

- Prepare the seedbed and raise seedlings about 45 days before the scheduled transplanting.
- Apply all the recommended NPK as basal dose at the time of final puddling and mix with the soil.

■ Transplant 35-45-day-old seedlings with five to six seedlings/hill.

Seedbed preparation

1. Seedbed area should be 1/10 of the main field.
2. Add organic matter to the seedbed.
3. Puddle the bed and level it properly.
4. Prepare strip beds of 10 m x 1.25 m.
5. Apply 80 g urea, 80 g SSP and 40 g MOP in each bed.
6. Soak seeds for 24 hours (48 hours for *Boro*) and incubate for 48 hours.
7. Sow 1 kg of sprouted seeds uniformly on each seedbed.



If yellowing appears in *Boro* seedlings:

- Add organic matter to the seedbed.
- Irrigate the seedbed at night and drain out the water in the morning.
- Shake off the dew drops from the leaf tips.
- Use low plastic tunnel.

ESTABLISHMENT OF *BORO* (SUMMER) RICE

- Prepare seedbed during October – December.
- Take steps to control yellowing in the seedlings.
- Prepare the field for transplanting.
- Transplant two to three seedlings per hill of four- to six-leaf stage using locally practiced spacing.

MIXED CROPPING OF *AHU/AUS* + *BAO/AMAN*

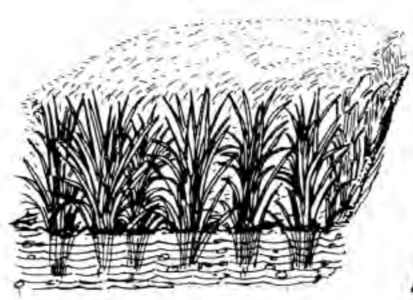
- Prepare the land during February-March.
- Apply 50% nitrogen as NECU and a full dose of phosphorus and potassium at final ploughing.
- Sow the seed mixture of *ahu/aus* + *bao/aman* at a 4:l ratio (total 70-80 kg/ ha).
- Cover the seed by a shallow ploughing and laddering.
- Apply the remaining nitrogen (50%) at maximum tillering as NECU or farmyard manure incubated urea.

Rainfed shallow lowlands (flash-flooded) (RSL)

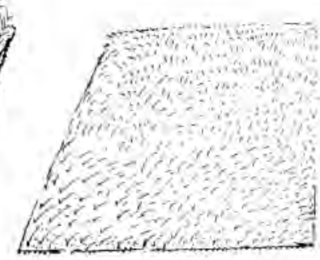
Heavy monsoon showers during June-August cause water stagnation up to 50 cm depth. These areas are also sometimes affected by flash floods. As a result, timely transplanting is not possible and standing crops are damaged. The options for growing rice in such situations are the following:

- delayed transplanting using aged seedlings of long duration (160 days), traditional photoperiod-sensitive varieties such as Manohar sali, etc., in Assam
- post-flood broadcast of sprouted seeds on wet soil of very early maturing (70-85 days) varieties

Damaged by flood



Delayed transplanting of long duration varieties



Direct sowing

Delayed transplanting

- Seedbed preparation and seedling raising start in June-July with available rainwater.
- Apply all the locally recommended dose of NPK at final puddling in September after the recession of flood.
- Transplant 45-60-day-old seedlings at four to six seedlings/hill.

Post-flood broadcast (wet sowing)

- Select a very early maturing variety suitable for direct seeding.
- Soak seeds for 24 hours and incubate them for 48 hours.
- Puddle the land and level properly.
- Apply half of the recommended nitrogen and full phosphorus and potassium at final puddling to facilitate mixing with the soil. Top-dress the remaining 50% nitrogen at panicle initiation stage.

Some improved varieties for flood-prone environments of eastern India

Situation	Cultural type	Improved varieties	Growing period
Deepwater (100 cm water depth)	Direct seeded/ transplanted	Padmanath, Panindra, Jitendra, Purnendu, Sudha jalamagna, Jalanidhi	March-December
	Boro rice	Gautam, Jaimati, Prabhat, Bishnuprasad, Biplab, Joyti, Prasad, IR36, IET 4094, Lalat and Chinsura hybrid-3	November-May
Flashflooded rainfedlowland	Transplanted	Maguribao, KDML105, JM 50 Barjahingia, Panidhan, Tulasi, Sabita, Manoharsali, Barh-Avarodhi	June-December
	Direct seeded Kopilee, Heera	Kalinga-III, Neela, Luit, December	Late August-

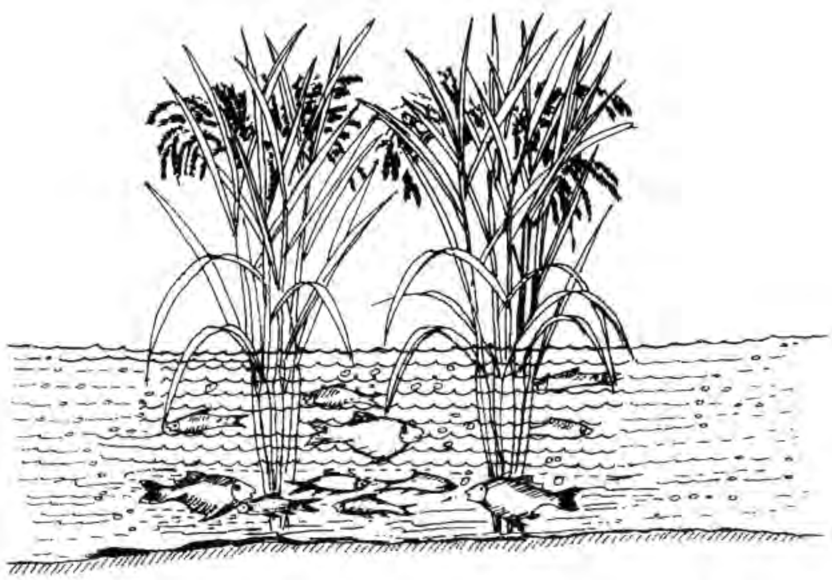
Prepared by:
H. C. Bhattacharya, V. P. Singh, S. K. Mohanty, N.K. Sarma and **G. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Integrated Rice-Fish Culture

What is integrated rice-fish culture?

Integrated rice-fish culture is a farming system where both rice and fish are raised simultaneously in the same field to increase farm income.



Benefits of the system

- Fish consume aquatic weeds, phytoplankton, photosynthetic bacteria, etc., which compete with the rice crop for food.
- Fish work like biological control agents by eating pests such as stem borers, hoppers, leaffolders, etc.
- Fish loosen the soil while swimming and searching for food. This aerates the soil and helps decompose organic matter, which promotes nutrient availability to the plants.
- The fish excreta directly fertilises the ricefield.
- Fish provide additional income.
- Fish supplement the family's diet.

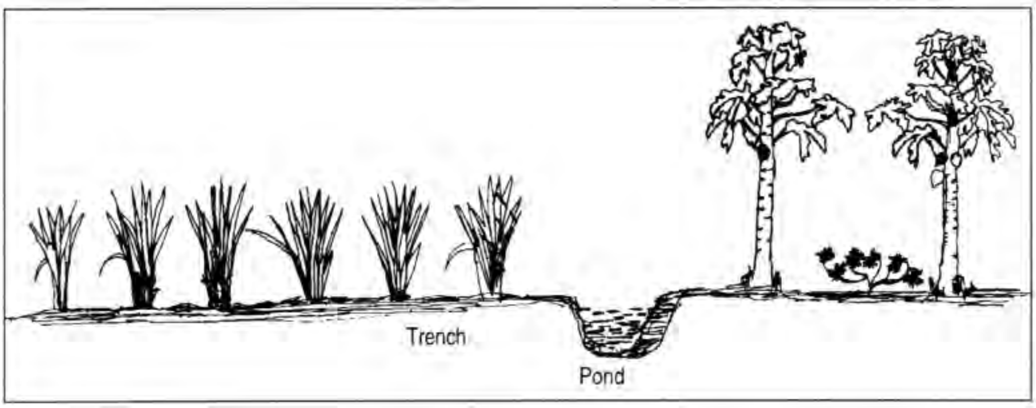
Selecting a site for the system

- in the rain zone of 800 mm and above;
- that retains water between November and January; and
- that is less prone to flooding.

Preparing a site

Field dikes

1. Prepare a dike 1 m wide at the top at a slope of 1:2 all around the field. Keep the height of the dike sufficient to keep off the floodwater, if any.
2. Construct drains in the dikes to remove excess water and save the fish from overflowing.
3. Use the dikes to grow fruits and vegetables, such as papaya and cucurbits (bottle gourd, pumpkin, snout gourd, etc.).



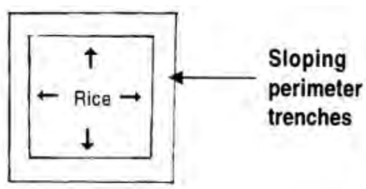
Grow fruits and vegetables on dikes

Refuge pond

Construct a refuge pond/trench/sump in the rice-fish field to shelter fish during dry days. The design of the refuge pond varies with the land contour. Generally, one tenth of the field is used to construct a refuge pond. Some designs are given below:

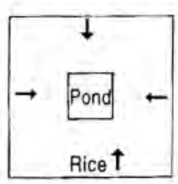
Perimeter type

The rice-growing area is placed in the middle, with ground sloping on all sides as perimeter trenches.



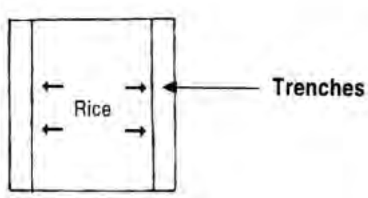
Central sump or bowl type

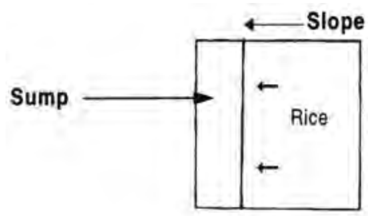
The rice-growing area is kept on the fringes of the field and the pond is dug in the centre of the field.



Lateral sump type

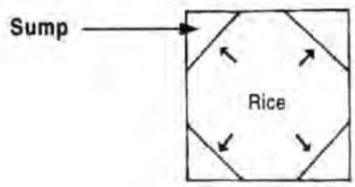
Trenches are excavated at any two opposite sides of the field and rice is grown in the rest of the area.





Slopy sump type

The water is used to raise fish in the deeper side of the field where water gets collected.



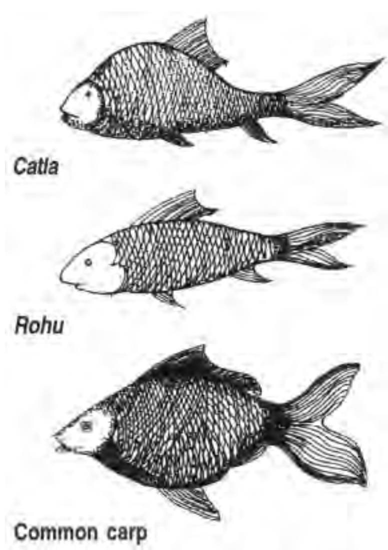
Corner sump type

Trenches are dug in the corners of the field and rice is grown in the rest of the field. The trenches cover 10% of the total field.

The sumps are normally 1 m deep. Remove the silt from the bottom of the sump each year to maintain its depth.

Managing a rice crop

1. Select a rice variety which has good elongation ability, a strong stem and tolerance for insect pests, such as Tall Mahsuri, Jal Lahri, Jal Priya, etc.
2. Transplant kharif rice in June/July. Before transplanting, add 10 t/ha farmyard manure and 60 kg/ha each of nitrogen, phosphorus and potassium.
3. Transplant rice seedlings at a distance of 20 cm x 20 cm.

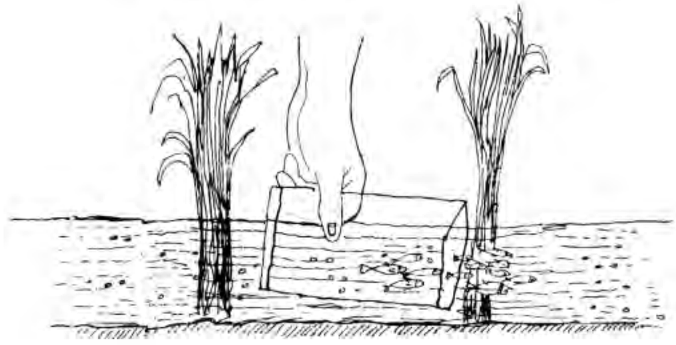


Choice of fish species
Common carp *(Cyprinus carpio)* is the best suited species for this system. This fish breeds prior to the monsoon season, so fingerlings are the desired size for stocking by June/July. This hardy fish also tolerates high turbidity.

Fish management

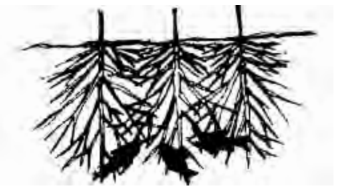
1. Select fish species which thrive in shallow water, tolerate high turbidity and high temperature and grow fast. Indian major carp (*catla* and *rohu*) and common carp are suitable species.
2. Stock the fish (release fingerlings in the field) when rice plants attain a greenish color.
3. Use 8-10-cm-long fingerlings to avoid mortality. Use about 5,000 to 6,000 fingerlings/ha.
4. Proper feeding of stock-fish is important. Feed them with a mixture of rice bran/rice polish and mustard cake/groundnut cake or soybean meal (1:1) in dough-like balls. Feed at 2-3% of the average body weight of the fish.

5. Put the feed in hanging trays in the refuge pond.
6. Dewater the field and harvest the fish after harvesing the rice crop between November and January.

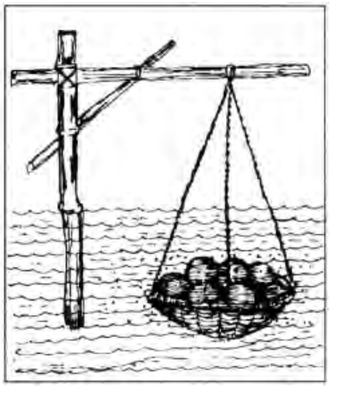


Stocking fish

To prepare a boundary around the rice-fish culture field, grow four to five rows of *Dhaincha (Sesbania aculeata)* along the boundary. After two months of sowing, when the plants become 1 m high, their fibrous roots develop and make a network around each plant. This will restrict the movement of fish from fields.



Dhaincha root network



Hanging trays

Using pesticides

Integrated pest management techniques in the rice crop can be adopted to save fish, as pesticides applied to the rice crop may harm the fish.

1. In case of heavy pest infestation, drain the water slowly so that the fish return to the refuge pond, then apply pesticide to the crop.
2. Wait for a day and irrigate the field again so that the fish start to move freely.

Another method used to save fish from pesticide poisoning is to drive the fish to one half of the field and apply pesticide to the other half. Repeat this procedure in the remaining half of the field the next day.

Beware!

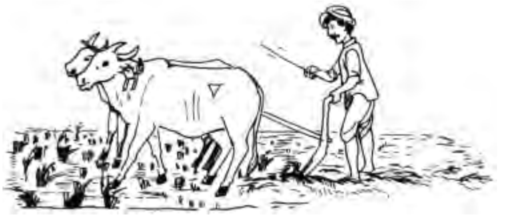
Pesticides harm fish. Avoid using pesticides in the ricefield when fish are raised.

In coastal areas, farmers can raise prawns in the saline water in ricefields.

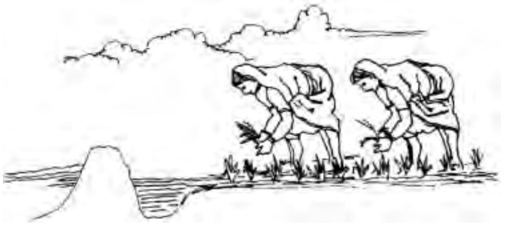
Drive fish to one half of the field before spraying pesticide.

Rice-fish culture activities

- Deepen sump pond (when field is fallow) to about 1 m. Raise and/or repair trenches and dikes. Plant fruits and vegetables on the dikes.



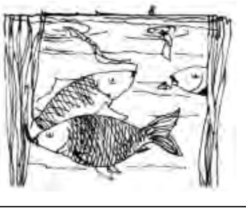
- Once water is available, prepare the field by cutting, raking and removing the weeds. All drain holes should be plugged to prevent fish from escaping. Add cow dung to the field.



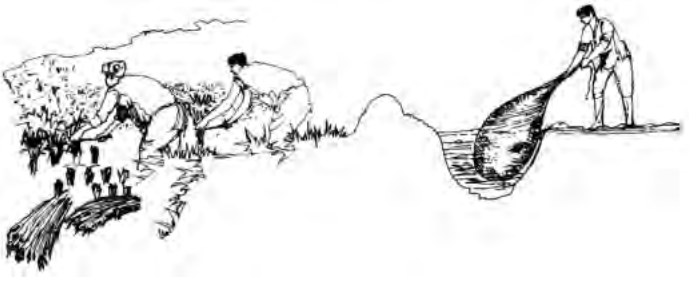
- Transplant rice seedlings. Weed the trenches to provide a feeding area for young fish.

  Fertilise the field with nitrogen, phosphorus and potassium as recommended.

- Stop all leaks in the field to prevent fish from escaping.



- Use integrated pest management.



- When the rice is nearly ready to be harvested, drain the sumps and harvest the fish. Leave smaller fish as stock for the next season.

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Prepared by:
Ram Singh

Crop Establishment in Rainfed Environments

Crop Establishment Practices in Rainfed Rice Cultivation

In eastern India, various practices are followed for growing rice under rainfed conditions to suit a particular soil or location, with variability in the water regime affecting the duration of the growing season. The growing practices for rainfed rice depend on the hydrology and ecosystem. Traditional practices of growing rice have been refined through research to ensure a higher sustained rice yield.

Practices of growing rainfed rice

Rice is generally established through direct seeding or by transplanting.

Direct sowing

Direct sowing is the practice of sowing seeds directly in the main field, eliminating the process of seedling raising and transplanting.

Direct sowing is the main crop establishment practice in all the upland sub-ecosystems: favourable upland with medium/long growing season; favourable upland with short growing season; unfavourable upland with long growing season; and unfavourable upland with short growing season.

Direct sowing in dry soil

The seeds are sown in dry soil either by broadcast or in lines in the furrows. In uplands, seeds are sown on lands prepared dry either before or with the onset of monsoon.

Rainfed lowland and deepwater ecosystem

Conditions	Method
Rainfed shallow, favourable	Direct sowing for summer rice; transplanting in other seasons
Rainfed shallow, drought-prone	Direct sowing and transplanting
Rainfed shallow, drought- and submergence-prone	Transplanting
Rainfed shallow, submergence-prone	Direct sowing and transplanting
Rainfed semi-deep, waterlogged	Direct sowing and transplanting
Deepwater and very deep water	Direct sowing

Sowing in lines ensures better and easy weed control, inter-culture and nutrient management.

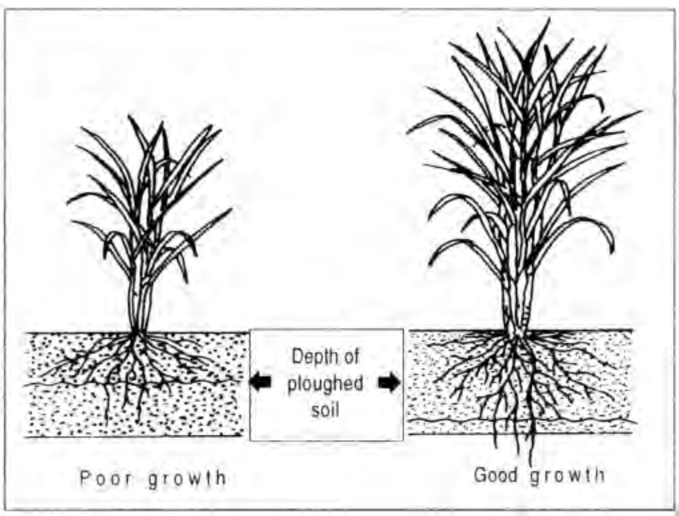
Advantages of direct sowing

- Lower labour requirement
- Eliminates seedling raising, uprooting and transplanting
- Lower water requirement for crop establishment
- Matures 7-10 days earlier than transplanted crop
- Sowing in dry soil and in dry season is possible

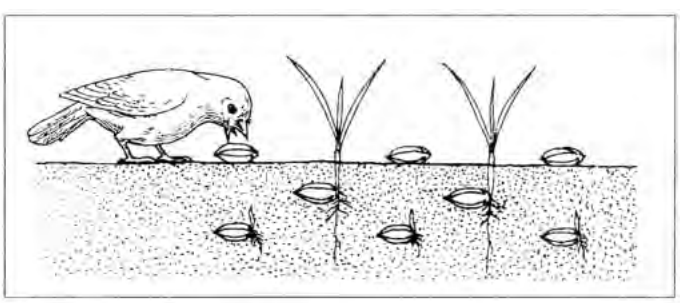
Disadvantages of direct sowing

- Poor establishment due to exposure of seeds
- High weed infestation
- Low tillering
- Tendency to lodge due to poor root development

The dry season rice is called *aus* in West Bengal, *ahu* in Assam and *beali* in Orissa.



Good soil tilth is essential for good growth



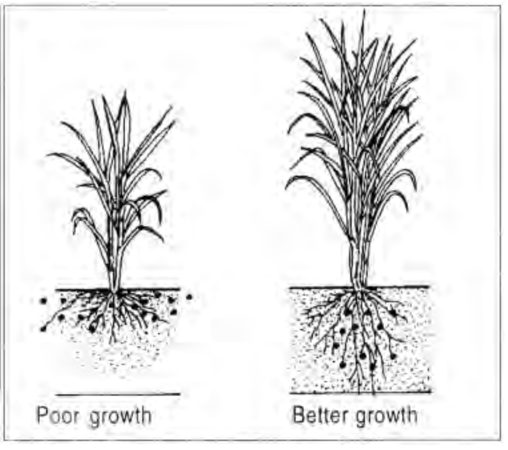
Sowing at proper depth leads to better germination and emergence

This method is also used in shifting cultivation in the northeastern hills either as a pure or as a mixed crop.

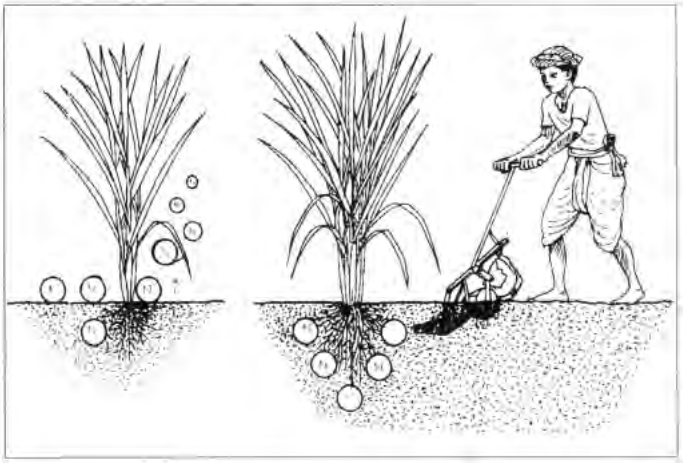
THE METHOD

1. Plough the land deeply after applying organic manures at least three weeks before sowing.
2. Complete six to eight ploughings to plough the soil into good tilth in heavy soil.
3. Apply a full dose of P_2O_5 just before the last ploughing.
4. Compact the soil by laddering or wooden planks to conserve moisture.
5. Treat the seeds by mixing Indofil M-45/captaf/foltaf at 2.5 g/kg of seed by agitating them for five minutes.
6. Sow the seeds behind the plough in furrows 15-20 cm apart and at 2-5 cm depth according to the soil moisture. The higher the moisture, the shallower is the seed placement. Cover the seeds by laddering.
7. Sow 80-100 kg of seeds per hectare to ensure a good plant stand.
8. Do not apply N and K_2O basally as they are not used by the crop and only encourage weed growth. They are also lost through leaching and runoff in high rainfall areas.
9. Remove the weeds before topdressing of fertilisers.
10. Topdress and incorporate 50% N and 50% K 15 to 20 days after emergence using a wheel hoe or a dryland weeder. Topdress the rest of the N and K at the panicle initiation stage.

11. For medium-duration varieties, apply N in three splits: 50% 20 days after seeding (DAS), 25% at late tillering and the rest at panicle initiation (PI).



Mix or incopporate fertilisers into the soil



Incorporate the topdressed N into the soil

Direct sowing in wet soil

Sprouted seeds are usually sown as a contingency measure on wetlands after flood occurs. When a flood occurs, seedlings are damaged. Therefore, direct seeding is the only option for such situations.

THE METHOD

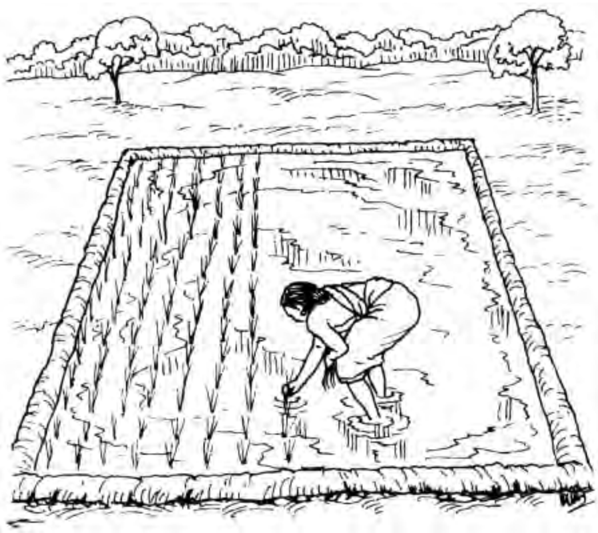
1. Plough/puddle and level the land properly.
2. Apply a full dose of P_2O_5 and K_2O, as basal.
3. Level the land by light laddering.
4. Allow the soil particles to settle before sowing if the soil is muddy.
5. Soak the seeds of short-duration varieties for 24 hours and incubate for 48 hours.
6. Sow the sprouted seeds in lines by an 8-row drum seeder at 60-70 kg/ha or by other means.
7. If line sowing is not possible, broadcast seeds at 60-80 kg/ha.
8. Complete weeding before topdressing of nitrogen.
9. Topdress 50% N 20 to 25 days after sowing and the rest at panicle initiation for short-duration varieties.
10. For medium-duration varieties, apply N in three splits (50% 20 DAS, 25% at late tillering and the rest at PI).
11. For topdressing of N, mix the fertiliser with farmyard manure (FYM) in a 1:10 ratio and incubate them for 48 hours. Broadcast in the field as incorporation into the soil is not possible. This practice helps reduce nitrogen losses through volatilisation.

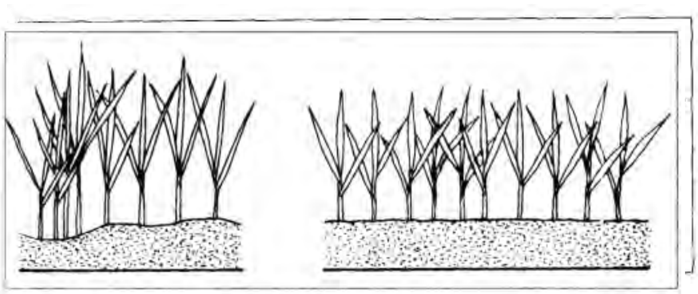
Advantages of transplanting

- Assures establishment of plant stand
- Lower seed rate
- Weeds are controlled due to went cultivation
- The crop gets more care in seeding stage

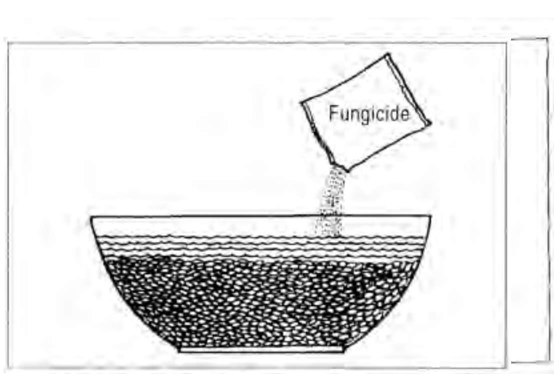
Disadvantages of transplanting

- Seeding raising, uprooting and transplanting require more time, labour and energy
- Crop takes longer time to mature





Make strip beds and level the land property for uniform growth



Soak seeds in fungicidal solution

Transplanting

Transplanting is the practice of raising the seedlings in a nursery and transplanting them into a separate puddled field. The crop is grown without disturbing thereafter.

Preparing the seedbed

Productivity of the rice crop depends on seedling health. To prepare the seedbed:

1. The area should be one-tenth of the area to be transplanted.
2. Complete one deep ploughing by mouldboard plough three weeks before sowing, followed by four to six cross ploughings and puddling.
3. Apply organic manure at 1 kg/ m^2 before the first ploughing to incorporate it into the soil.
4. Puddle and level the land properly. If necessary, make 1-2-m-wide strips with a 30-cm-wide drain channel between beds. Level each bed again.
5. If a rotavator is used for puddling, allow the soil to settle for 24 hours.
6. Soak the seeds for 24 hours and incubate them for 48 hours.
7. Soak the seeds directly in fungicidal solution of Indofil M-45/captaf/foltaf at 2.5 g/l of water or Bavistin at 1.0 g/l of water as a seed treatment.
8. Sow the sprouted seeds in the nursery at 50 to 60 g/m^2 depending on the test weight.
9. Observe the beds and maintain water in drains.

Uprooting

- Apply water or drain it out from the seedbeds to make uprooting easy.
- Pull out the seedlings by holding them at the base.
- Make small bundles for easy transportation.
- Maintain appropriate seedling age, which should be about three to four weeks and should not exceed 35 days for modern varieties.

Puddling

Puddling is the mechanical reduction in the apparent specific volume of soil. It eases transplanting and reduces water loss through percolation. Puddling can be done using a country plough/harrow, tractors and power tillers and rotavators followed by laddering.

Advantages of puddling

Reduces weed population

Eases transplanting and establishment

Improves nutrient use efficiency

Reduces percolation losses of water

Disadvantages of puddling

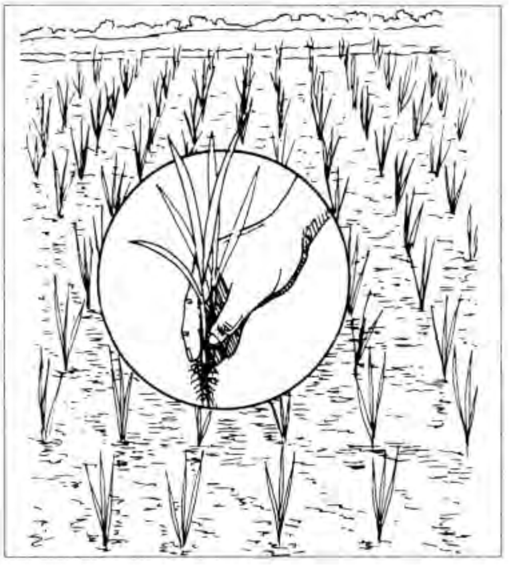
Temporarily destroys the granular structure of soil

Reduces yields of wheat, oilseeds and pulses during *rabi* if the crop follows transplanted rice

Makes the crop suffer from stress during abberant weather

Applying organic manure, followed by one deep tillage, reduces the weed population and varietal mixture and increases nutrient availability.

Add chemical fertilisers and incorporate them into the soil. Use 50% of the recommended N and 100%, of P and K before the final ploughing. Level the land for uniform water retention. Puddling and laddering for soil compaction help water retention.

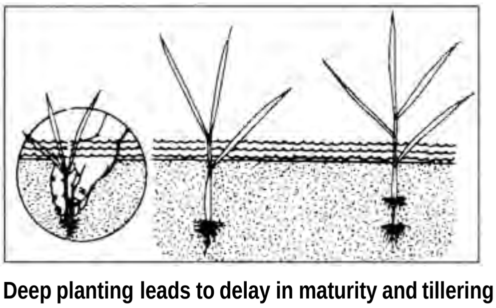


Transplant 2-3 seedlings per hill at proper depth

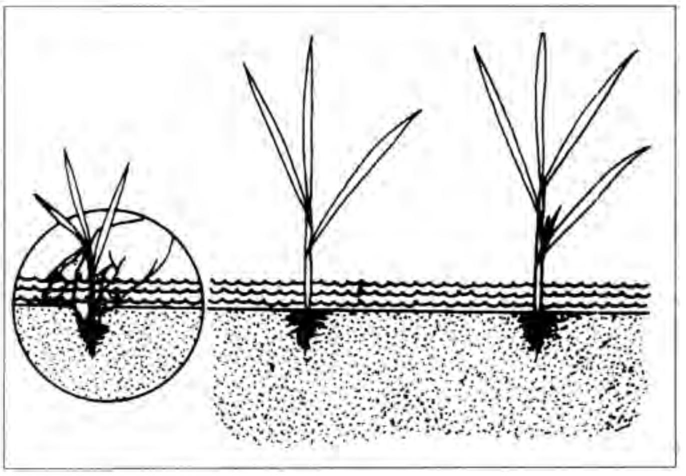
Transplanting

Transplanting methods depend on varieties used, hydrology and ecology.

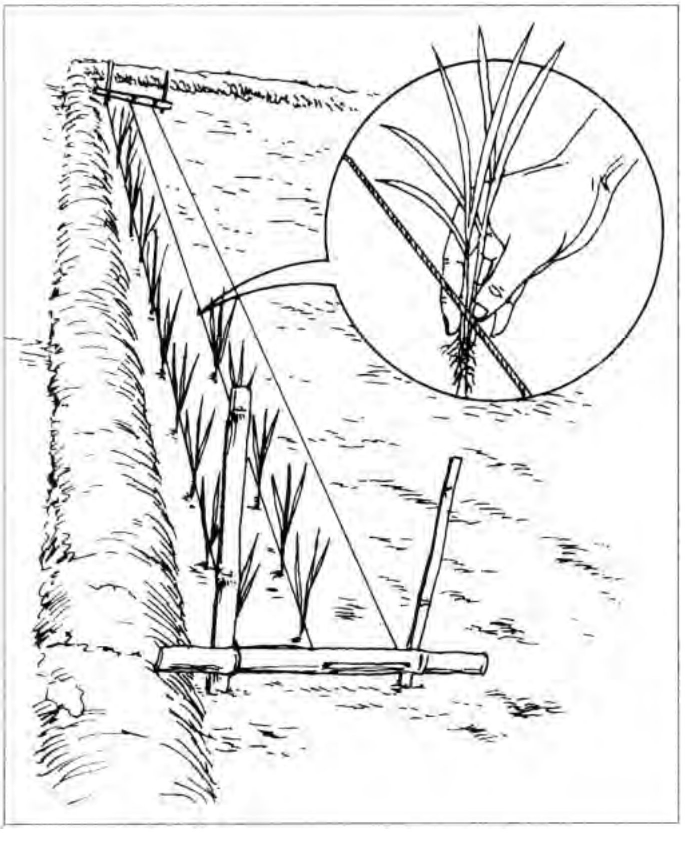
1. Transplant two to three seedlings/hill in normal planting and four to six seedlings in delayed planting. Spacing depends on varietal duration and season.
   - Transplant early duration varieties at 15 × 10 cm or 20 × 10 cm.



Deep planting leads to delay in maturity and tillering and causes staggered flowering



Transplant only 3-5 cm deep into the soil



Transplant in lines at proper depth and spacing

- Plant medium-duration varieties at 20 × 15 cm.
- Plant long-duration varieties at 20 × 20 cm. Closer spacing is needed in the dry season crop or in the post-flood rice with aged seedlings.

2. Transplant seedlings 3-5 cm deep. Deeper planting delays tillering and root regeneration, increases duration and induces flowering at different times.

3. Transplant in lines at proper spacing to maintain the correct level of panicles per m^2. This also eases subsequent operations. Random planting leads to an uneven growth of tillers and reduces panicles per m^2.

4. Replace the dead hills with new seedlings from the same nursery within one week.

5. Topdress 25% of the remaining N at both active tillering and panicle initiation stages. Incorporate the fertilisers into the soil by running paddy weeder between lines, if possible. Mix urea with FYM and incubate for 48 hours before topdressing in stagnant water.

Prepared by:
H. C. Bhattacharya, R. K. Singh and **V. P. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Comparative Analysis of Direct Sowing and Transplanting

Rice establishment in rainfed environments

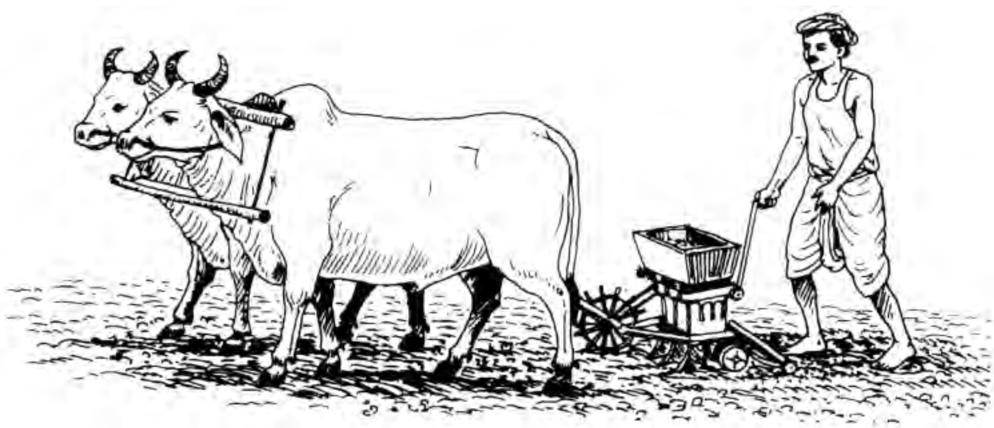
Rainfed upland and deep lowland rice are grown mainly by direct sowing and rainfed shallow and medium lowland rice by transplanting. Direct sowing reduces the labour cost for crop establishment but requires more seed than transplanting, 50 to 100 kg/ha depending on the method of sowing and the rice variety.

Direct sowing

Direct sowing with dry seeds (dry system) in well-prepared dry moist soil may be done as follows:

- Hand broadcasting and mixing with bullock-drawn country plough/cultivator/harrow, followed by planking.
- Seeding behind country plough followed by planking.
- Hill dropping by hand behind country plough followed by planking.
- Row seeding by bullock-drawn/ power tiller-drawn/tractor-drawn seed drill/seed cum ferti drill.

Hand broadcasting



Bullock-drawn three-row seed cum ferti drill

Seeding behind country plough

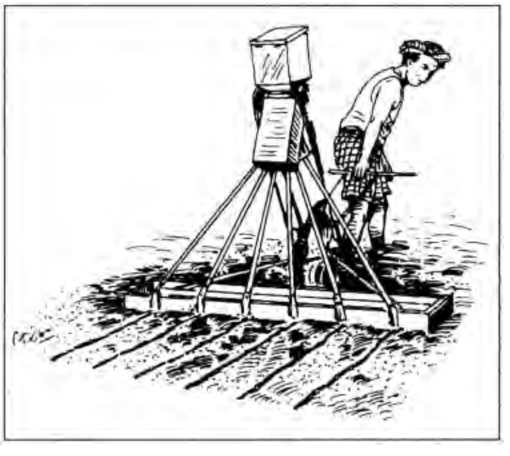
Reasons for farmers opting for direct sowing

- Insufficient water in rainfed upland and lowland situations during the time of planting.
- In deep lowland situations, this practice is adopted before the onset of monsoon for better crop establishment.
- Transplanting is more difficult to adopt because of the scarcity of labour.

Hand broadcasting of pre-germinated seeds

Direct seeding of pre-germinated seeds on puddled soil (wet system)

- Hand broadcasting on well-prepared puddled field.
- Row seeding with manual/ power tiller-drawn seeder under limited field situations having good drainage facilities.



Pre-germinated manual row seeder

Reasons for farmers using pre-germinated seed for direct seeding

- For better weed control
- To reduce water loss through percolation
- As a labour-saving device

Line hand transplanting

Transplanting

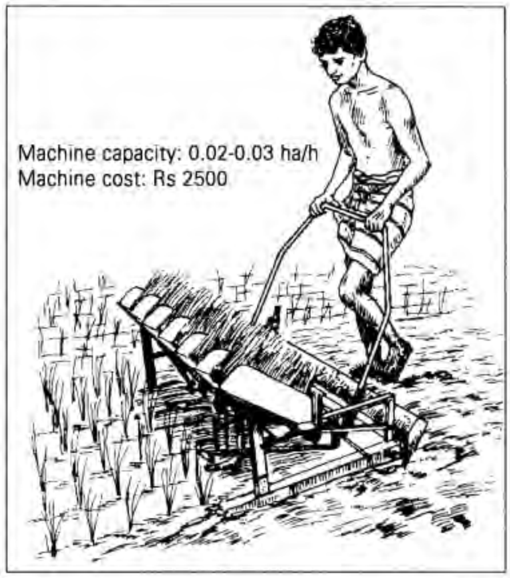
Pre-germinated seeds are sown in a nursery. Later, usually 20-30-day-old seedlings raised in the nursery are transplanted into the puddled field.

Hand transplanting

- Random
- Line

Machine transplanting

Manual and self-propelled rice transplanters may be used for rice transplanting. This is usually done with mat-type rice seedlings under limited field situations having suitable drainage facilities.



Manual machine transplanting

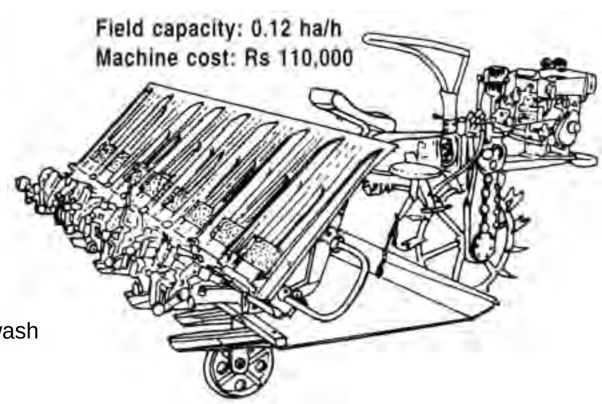
Mechanised rice transplanting

Benefits

- Reduced labour and drudgery
- Reduced operational cost
- Reduced weeding cost
- Increased yield

Constraints

- More labour required in nursery raising
- Additional labour required in root-wash nursery preparation
- Better skill and water management required in mat-type seedling vis-a-vis traditional nursery raising
- Sometimes standard of transplanting accuracy is poor
- Radical change in nursery raising
- High cost of machine



Self-propelled rice transplanter

Self-propelled rice transplanters may be introduced through custom hiring by cooperatives, government and semi-government organisations and private entrepreneurs.

NOTE

The break-even point (BEP) for the manual rice transplanter is 2 ha or 0.75 ha per year with 2.5 years as payback period (PBP). Similarly, for the machine rice transplanter, BEP is 40 ha or 10 ha per year with five years as the PBP at the present wage rate of Rs. 47 per day.

Table 1. Cost of operation and labour requirement in direct sowing and transplanting of rice

Particulars	Direct sowing						Transplanting		
	Dry system				Wet system				
	Seed drilling								
	Hand broadcasting (dry seeding + mixing)	Bullock drawn seed cum ferti drill	Power tiller-drawn seed cum ferti drill	Tractor seed cum ferti drill + planking x 1	Pre germinated seeds, hand broad-casting	Pre germinated seeds, manual rice seeder	Manual, random for hand trans-planting	Manual rice trans-planter[1]	Self-propelled rice trans-planter[2]
1. Cost of land preparation by tractor (Rs/ha)									
a. Dry system[3]	1458	1458	1458	1458					
b. Wet system[4]					1937	1937	1937	1937	1937
2. Cost of seeding/ planting including inputs and nursery raising (Rs/ha)	1259	887	922	920	663	735	3516	2222	2047
3. Cost of weeding (Rs/ha)									
a. Hand weeding	3613				2719		1940		
b. Weeder + intra-row hand weeding		3142	3142	3142		2448		1514	1514
4. Labour requirement (m-h/ha)									
a. Sowing/transplanting	10	20	10	5	12	21	472	244	171
b. Weeding	615	518	518	518	446	395	350	251	251
5. Cost saving (%) (Rs/ha)									
a. Seedbed preparation in dry system instead of wet system	479 (25)	479 (25)	479 (25)	47 (25)					
b. Sowing/planting vs. hand transplanting	2257 (64)	2629 (75)	2594 (74)	2596 (74)	2853 (81)	2781 (79)	–	1294 (37)	1469 (42)
c. Weeding vs. hand broadcasting or dry seeding	–	471 (13)	471 (13)	471 (13)	894 (25)	1165 (32)	1673 (46)	2099 (58)	2099 (58)
6. Labour saving (%) (m-h/ha)									
a. Sowing/planting vs. hand transplanting transplanting	462 (98)	452 (96)	462 (98)	467 (99)	460 (97)	451 (96)	–	228 (48)	301 (64)
b. Weeding vs. hand broadcasting or dry seeding	–	97 (16)	97 (16)	97 (16)	169 (27)	220 (36)	265 (43)	364 (59)	364 (59)
7. Grain yield (t/ha)	3.1	3.0	3.2	3.1	2.9	2.8	3.2	3.5	3.8

[1] *May be adopted under limited field situations having better drainage and water management with well-prepared levelled fields.*

[2] *Limitations for sowing with pre-germinated rice seeds in wetland puddled fields. It requires precise land levelling. The standing water must be drained before sowing and waterlogged conditions are adverse to plant emergence. Better water management is required at the initial stage of germination. For one week after sowing, the land should be kept free of standing water to prevent submergence of sprouted seeds and seedlings. However, soil should not be too dry to prevent emergence of seedlings.*

[3] *Dry system: Summer ploughing x 1 + Disc harrowing x 2 + Planking x 2.*

[4] *Wet system: Summer ploughing x 1 + Puddling by disc harrowing x 2 + Planking x 2.*

Direct sowing vs transplanting: a comparison

Direct sowing	Transplanting
■ May be adopted easily under rainfed upland, deep lowland and lowland dry situations.	■ Suitable only under shallow and semi-lowland situations.
■ Requires minimal water just sufficient for moistening at the initial stage. (Newly germinated seedlings will die within a few days if the soil surface dries out or if they are inundated.)	■ Requires a good amount of water at the time of transplanting but may resist short-duration drought and moderate rain.
■ Crop establishment involves less labour (8-12 man-hours/ha)	■ Is a labour-intensive operation (400-500 man-hours/ha)
■ More weed growth	■ Less weed growth.
■ Poor water control and more percolation losses.	■ Better water control and reduced percolation losses due to puddling of field.
■ In the absence of weed control, yield loss is about 40-50% in direct seeding on dry soil and 20-25% on puddled soil.	■ In the absence of weed control, yield loss is about 10-15%.
■ Root anchorage is poor and lodging is more serious.	■ Root anchorage is better and lodging is not so serious.
■ With proper weed management, gives moderate yield even under upland low-rainfall situation.	■ Cannot be used in a similar situation without supplemental irrigation facility.
■ Timely seeding may give a good yield with proper weed and water management.	■ Delayed transplanting due to late rains and labour shortage will result in drastic reduction in yield.
■ Land is used for a longer period, thus reducing turnaround time.	■ Land is used for a shorter period, thus increasing turnaround time.

Labour requirement and energy inputs

- Manual hand transplanting requires about 400-500 man-hours/ha, including nursery raising and uprooting. This is about 47 and 39 times more than the labour required in dry hand broadcasting and wetland hand broadcasting, including seedbed preparation.
- Workloads per person are higher with the wetland seeder (34.32 kilo joules/min) and hand wetland broadcasting (15.30 kilo joules/min) than in transplanting (12.97 kilo joules/min).
- The human energy required in weeding is much lower in transplanted rice (350 man-hours/ha) than in hand-broadcast rice (615 man-hours/ha in dry and 446 man-hours/ha in wet).
- Weeding in machine-transplanted rice using weeders is still less (251 man-hours/ha) than in other sowing methods.

Effect on grain yield

A higher grain yield is possible in transplanted rice than in broadcast rice under the same rainfed lowland situations with proper water management techniques.

Remember. . .

Under upland and deep rainfed lowland situations, with proper weed management and timely seeding, suitable varieties of xoadcast rice give better fields than transplanted rice, wen under low-rainfall conditions.

Prepared by:
M.R. Varma

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Beushening System in Bihar, India

Beushening is a traditional rice cultivation system, common throughout the rainfed regions of eastern India. In this method, farmers grow rice crops in risk-prone areas having highly variable climates and a poor resource base.

Beushening practice

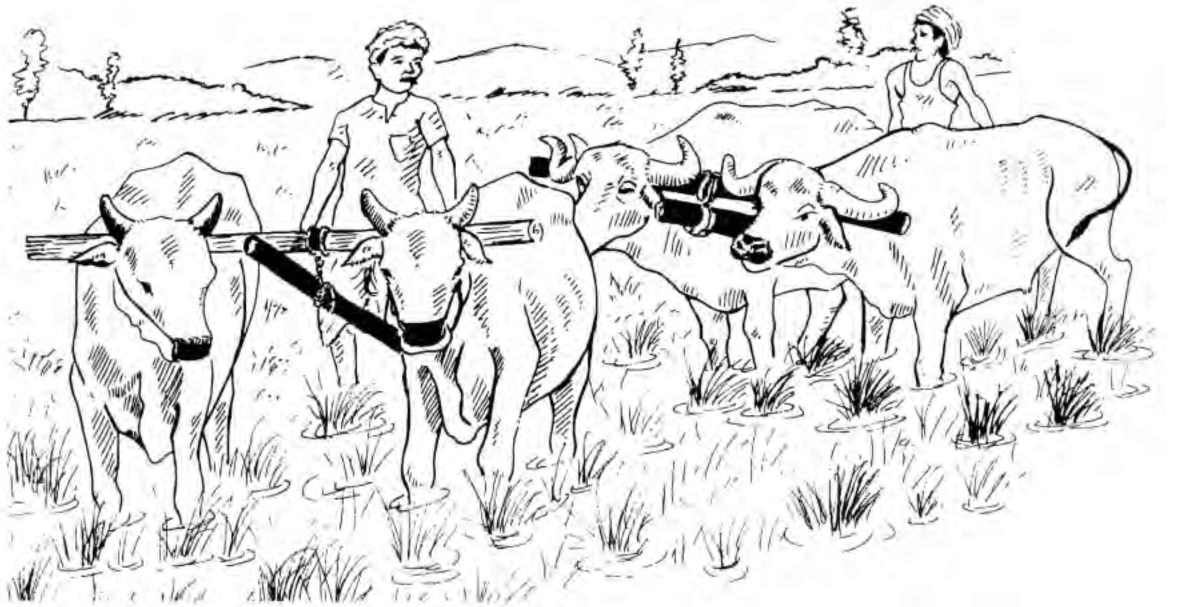
Beushening is locally known as *baug* or *bidauni.* It involves two broad series of field operations:

- direct seeding of mostly traditional tall rice cultivars using higher seed rates than those used for direct seeding without beushening; or
- wet ploughing and laddering of the field, generally 25-35 days after germination of the rice, when about 15 cm of rainwater is accumulated in the crop field. In some cases, seedling redistribution is also done after this operation.

Beushening . . .

facilitates stable rice yields under low levels of inputs and uncertain climatic conditions through effective weed control, stimulated root growth and optimum plant stand with enhanced tillering. Its disadvantage, though, is the uneven plant stand without gap filling.

Rice cultivars mostly used in beushening are of local origin, with maturity duration of 150-170 days and medium tillering capacity. improved varieties are rarely used for beushening.



Beushening: wet ploughing and laddering of fields with old seedlings and water.

The beushening process

- The fields to be beushened are ploughed immediately after the winter or summer rain and two to three times thereafter during summer to control weeds, insects and rodents. Ploughing is done by an animal-drawn wooden plough, without inverting the soil.
- If weeds are observed after the first monsoon rain, additional ploughings are done to suppress them.
- Rice seeds are then broadcast in the dry soil and mixed by harrowing in the last week of May.

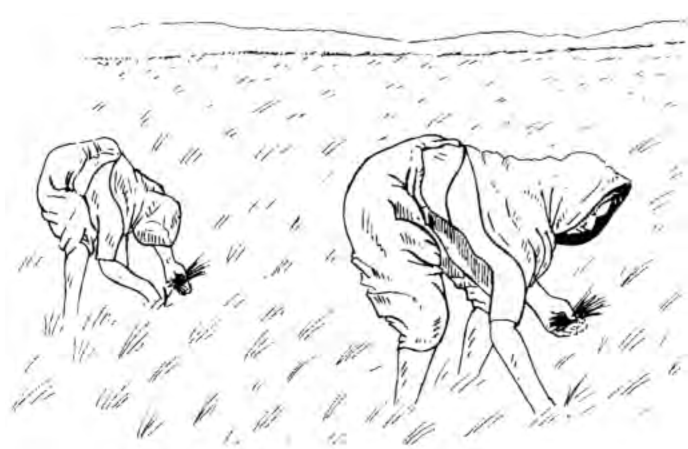
  Farmers had experienced that sowing in May resulted in higher grain and straw yields because the crop matured before the occurrence of late season drought in early to mid-October.
- Wet ploughing is done 25-35 days after germination, but only after having 15-20 cm of standing water in the rice field.
- Farmers let their cattle graze rice seedlings one week before ploughing to de-top seedlings to improve tillering and maintain optimum plant population. They also use the crop foliage as fodder which otherwise would be lost during ploughing and laddering.
- Rice fields are ploughed, followed by one or two ladderings with 15-20 kg of load (usual plough load) on the ladder, to only break the “soil slice” and loosen it without damaging rice plants.
- Farmers observe weed conditions in fields for two to three days after laddering. If weeds were not well incorporated into the soil, farmers repeat ladderings.
- Two to three ladderings are generally sufficient to damage and incorporate the weeds, especially *Echinochloa colona (jhimpa or jharua),* which was difficult to distinguish from the rice plant.
- Seedling redistribution is done to fill up blank patches and thin out the dense patches caused by repeated laddering.

Farmers’ reasons for beushening

Labour requirement

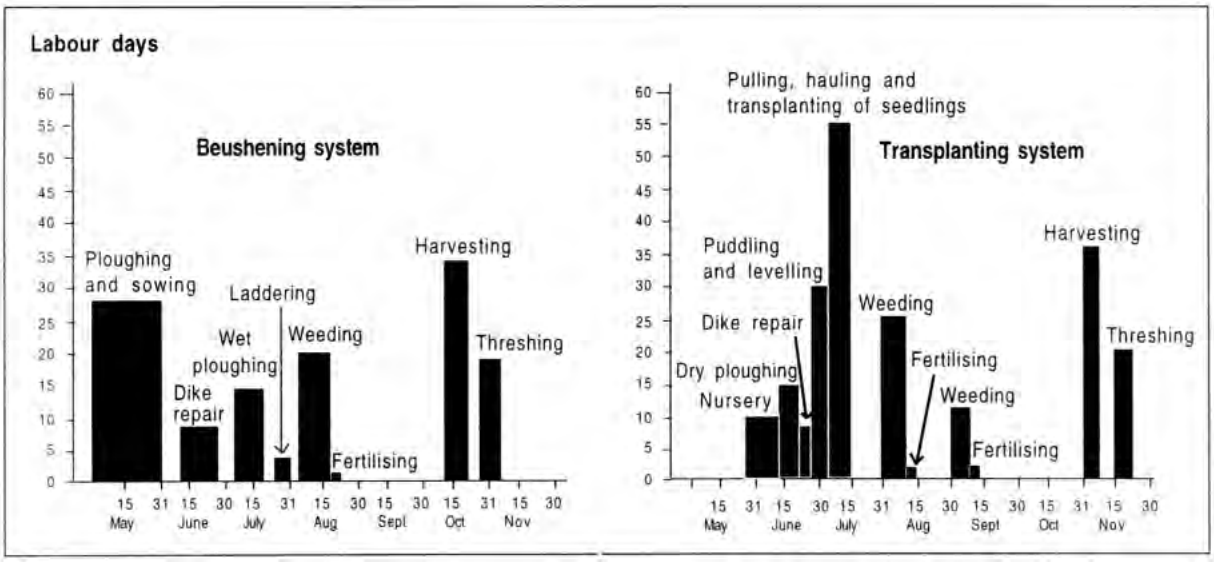
Labour saving in beushening is mainly in nursery growing, land preparation, transplanting and weeding operations. As the operations in beushening, especially land preparation, wet ploughing and hand-weeding, are done over a longer period of time, the labour demand for these operations could be spread over time.

The beushening system of rice cultivation requires less labour and spreads labour demand over a longer period of time. A total of 130 person-days/ha are required in the various operations of beushening versus 209 person-days/ha in the transplanting system. The beushening system also uses less animal power (42 days/ha) than the transplanting system (50 days/ha).



Beushening requires less labour

Distribution of labour input use in beushening and transplanting systems of rainfed rice cultivation in Hazaribagh District of Bihar, India



Low fertiliser requirement

Farmers in beushening rice farming use traditional tall cultivars which require minimum fertiliser and do not respond economically to higher doses. According to farmers, high-yielding varieties (HYVs) require high purchased inputs and are not suited for beushening. Farmers also avoid HYVs for transplanting because of their inability to invest in more fertilisers.

Beushening does not require a nursery

Owing to a shortage of water and the problem of stray animals during summer months, it is difficult to raise seedlings in a nursery. This also saves farmers substantial labour cost.

Puddling is not required

Farmers have to wait for enough water to accumulate for puddling, which, even in normal years of rainfall, is possible only in mid- to late July. Therefore, by transplanting, crop establishment is not only delayed but also suffers from drought in mid-October, near flowering time. Beushened fields, on the other hand, which already contain a crop as a result of sowing in May, could hold water like a puddled field.

Less pest problems

As the fields to be beushened are repeatedly ploughed during summer, these fields reduce rodent and weed problems, because summer ploughing destroys rodent burrows and uproots weeds, which are dried up in the summer heat. The remaining weeds are buried in the mud during wet ploughing and laddering, done 25-35 days after germination.

Less cash inputs required

Besides not having nurseries and puddling operations, beushening also requires no additional expenses for fertilisers. Moreover, because labour requirements are spread over a longer period of time, most operations in beushening are done by family labour. In then transplanting system, hired labour is needed as most of the operations up to transplanting have to be done within about a month. Beushening is therefore a cost-saving strategy.

Beushening is an appropriate alternative in drought- and submergence-prone areas

Transplanted or direct-seeded rice cultivation in drought- and submergence-prone areas is not economically feasible because of erratic rainfall and undulating topography. Depending on the rainfall, the crop is likely to suffer from drought or floods or both, sometimes even in the same season.

The timeliness of transplanting is crucial because, with progressive delays in transplanting, the seedlings become older. This results in a lower number of tillers and the crop faces a greater risk of water shortage and low-temperature injury at the reproductive stage in mid-November and early December.

Stable yields

For the above reasons, farmers harvest more stable yields of beushened rice than transplanted or direct-seeded rice. Transplanting is simply not possible in years with low rainfall at the beginning of the season, whereas a beushened crop is possible.

Ease and timely establishment of non-rice crops

In clay soils, several years of puddling for transplanting reduced rice yields and created difficulty in establishing a subsequent non-rice crop because of soil compaction. As transplanted rice was harvested two to three weeks later than beushened rice, subsequent non-rice crops in transplanted fields also suffered from soil moisture depletion even ai early stages of growth. These problems are not encountered in beushened fields.

Varieties suitable for rice culture

For Tarkha and Garha land	Tarkha land	Garha land
Kalamdani, Lalkadhan and Dudhkandar	Mahkari	Dhushari
	Kaitka	Haskalma
	Site (if <30 cm water in field)	Site (if >30 cm water in field)

Fertilisation practices for beushening and transplanting

Farmers generally use inorganic: fertilisers only in transplanted rice. In Barkagaon block, for example, inorganic fertilisers are used in beushened rice, but with lower application rates. All the traditional cultivars, even with half rates of fertilisers, yield on a par in the beushening system compared with the transplanting system.

Effect of fertilisation (kg/ha) on grain yield of rice (t/ha) in transplanting and beushening systems of cultivation, Hazaribagh, Bihar, India

	Transplanting			Beushening		
Rice cultivar	**N**	**P_2O_5**	**Yield**	**N**	**P_2O_5**	**Yield**
Chandragrahi	36.0	12.2	2.0	0.0	0.0	1.6
Mainathor	23.8	12.6	1.9	12.5	0.0	2.0
Mainathor	65.6	31.4	4.0	47.5	25.1	3.6
Dhushari	65.6	71.9	4.0	47.5	25.1	4.0
Kaitka	29.4	18.8	3.0	5.6	6.3	3.2
Sita (improved)	60.0	25.1	5.0	47.5	25.1	3.2
Mean*	46.7	28.7	3.3	26.7	13.6	2.9
CV for yield (%)	–	–	–	–	16.7	–

* *Mean yield of transplanting and beushening is not significantly different at 0.05 level by DMRT.*

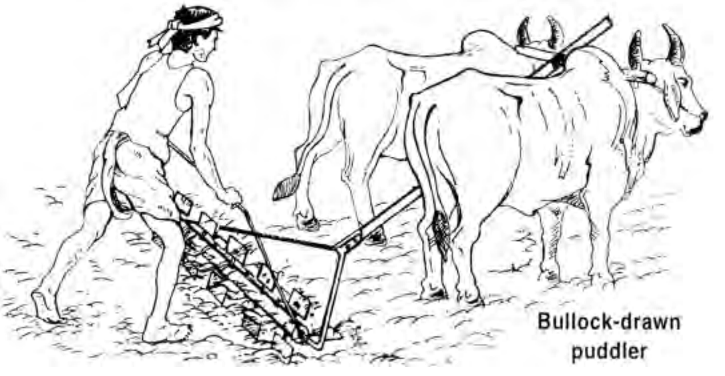
Presented by:
V.P. Singh, R.K. Singh and C.V. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Tillage Practices and Implements for Rainfed Rice Cultivation

Tillage is a mechanical manipulation of the soil to provide a favourable environment for good germination of seed and crop growth, to control weeds and to improve the physical, chemical and biological conditions of the soil. For rainfed rice cultivation according to seeding/ planting methods, two major systems are followed for land preparation under different ecosystems:

- dryland tillage for dry seeding; and
- wetland tillage (puddling) for wet seeding and transplanting.



Dryland tillage

After one deep ploughing, undertake two to four secondary tillage operations (ploughing using country ploughing/cultivator/disc harrow plus planking) for land preparation using draft animals/power tiller/ tractor.

To achieve best results from tillage

- Till no more than necessary.
- Till only when the soil moisture is within the favourable limit.
- Vary the depth of ploughing.

Wetland tillage

Wetland tillage is undertaken in most parts of eastern India, usually with the onset of the rains or under irrigation. One deep ploughing or two ploughings are carried out in the dry soil followed by puddling and levelling during the rains or when irrigation water is provided. For puddling in general, two cross ploughings/disc harrowings and planking/laddering are done for land preparation using bullock or tractor power.

Use cage wheel/steel-lugged wheel with tractor and power tiller for wetland tillage:

- It helps in puddling and avoids sinking of tractor/power tiller in wetland.
- Cage wheel reduces slippage of tractor/ power tiller and thereby saves about 20-25% in fuel consumption.
- It improves traction capability of tractor/ power tiller.

In weed-infested fields and heavy soils, puddling followed by planking is repeated after two to three days and then wet seeding/transplanting is done. Puddling using a power tiller/tractor rotavator may be done effectively with just two rotopuddlings, followed by levelling.

Tillage systems

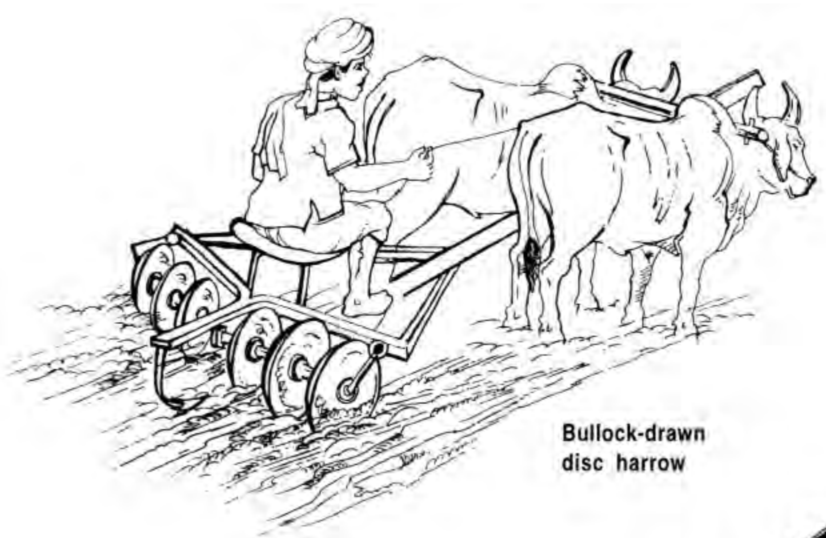
In rice-based cropping systems, different crops are grown in different ecosystems as per their suitability. For better production, the following tillage systems, apart from the conventional system, can be used.

Tillage system	Suitability
Minimum tillage system This system helps reduce time, labour and machine operations. One or two tillage operations for field preparation can be done.	In light and medium soils having lesser weed infestation for timely seeding/planting of next crop.
Till-plant system Field preparation and seeding are done simultaneously.	For timely seeding of wheat or other crops just after harvesting in light and medium soils having adequate moisture for early emergence of plants.
Ridge and furrow tillage system Making ridges and furrows across the slope, preferably along the contour, and seeding on ridges using ridge or lister planter.	In low-rainfall areas/season to conserve moisture and grow better crop.
Rotary strip tillage system A narrow strip of land along the row is tilled and the areas between the rows are left undisturbed. Strip tilling, seeding and application of nutrients are done simultaneously in a single operation. (PAU Ludhiana strip drill.)	In light and medium soils having adequate moisture for timely seeding of next crop.
Zero tillage system Crop is directly seeded after harvesting of rice using tractor-drawn zero till seed cum ferti drill (Pantnagar zero till seed cum ferti drill.)	For timely seeding of chickpea (gram), wheat and lentil crops after rice harvesting, especially in moist soils requiring more time to become suitable for tillage operations.

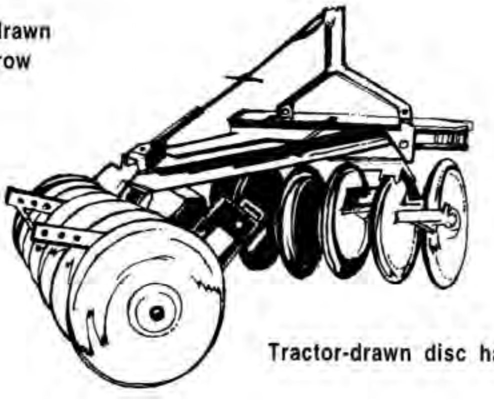
Zero tillage system, chickpea after rice

Tillage implements

	Implements	
Function	**Conventional**	**Improved**
Bullock-operated		
Deep ploughing	Country plough	Mouldboard plough
Ploughing	Country plough	3-tyne cultivator
Puddling	Country plough	Disc harrow/puddler
Levelling	Bamboo laded wooden planker	Harrow patela/ wooden planker
Tractor-operated		
Deep ploughing	Cultivator	Mouldboard/disc plough
Ploughing	Cultivator	Disc harrow
Puddling	Cultivator	Paddy disc harrow/ rotavator
Levelling	Wooden planker	Wooden planker
Power tiller-operated		
Deep ploughing	Rotavator	Mouldboard plough
Ploughing	Rotavator	Cultivator/rotavator
Puddling	Rotavator with steel-lugged wheel	Rotavator with steel-lugged wheel
Levelling	Wooden planker	Wooden planker



Bullock-drawn disc harrow



Tractor-drawn disc harrow

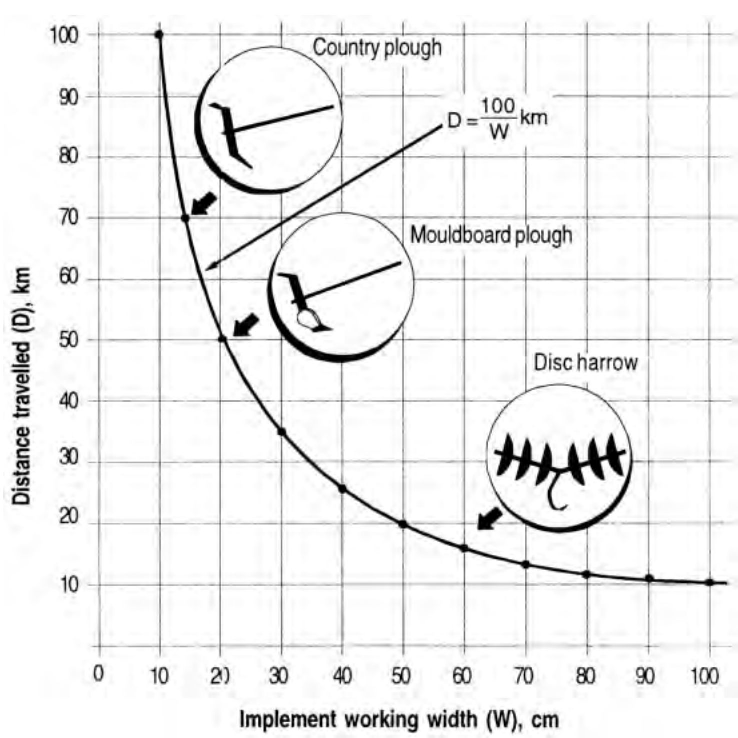
Why use improved tillage implements?

- Saving in time and energy
- Reduction in drudgery
- Better field preparation
- More coverage per unit time
- Low cost in land preparation
- Better weed control
- Better crop growth and yield
- More economic return
- Increase in productivity

Do you know that..

A farmer needs to travel 65-100 km to plough 1 ha of land with a country plough vis-à-vis only 15-18 km with a bullock-drawn six-disc single-acting disc harrow.

Effect of implement working width on distance travelled to cover 1 ha



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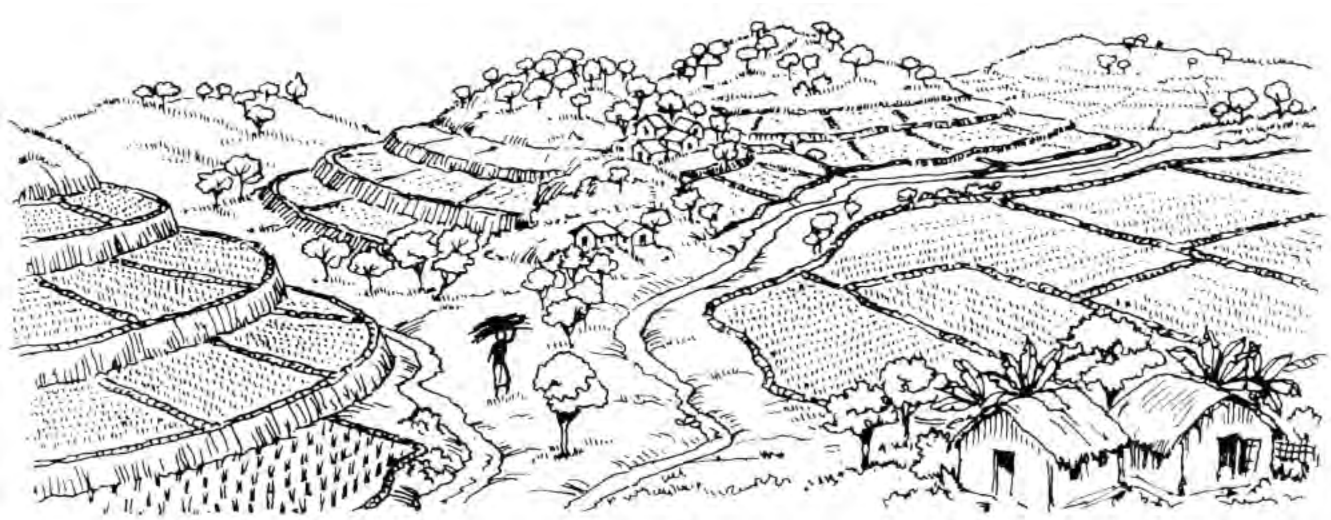
Prepared by:
M. R. Varma

Rainfed Rice Varietal Development and Improvement: Breeding Strategies, Methods and Outputs

Improving the Yields of Traditional Varieties to Conserve Biodiversity



Northeast India has remained geographically isolated, undisturbed and little explored, which, combined with unique environmental situations and topographical variations, made room for the wide genetic variability of rice. The selections made through trial and error by various ethnic groups practising different forms of agriculture in different altitudes and agro-climatic situations have contributed to the diversity of the rice crop. The total number of landraces in this region was estimated to be 8,000. Of these, 6,630 accessions called the Assam Rice Collection (ARC) were explored earlier.

The traditional rice cultivars of northeast India have many valuable genes possessing resistance to various biotic and abiotic stresses, and unique quality and plant architecture.

Remember. . .

When farmers increase the yield of traditional varieties, using simple methods, they will have a bigger incentive to continue to raise these traditional varieties, thereby saving them for future generations. Moreover, these valuable materials will continue to evolve to adapt to the changing environment.

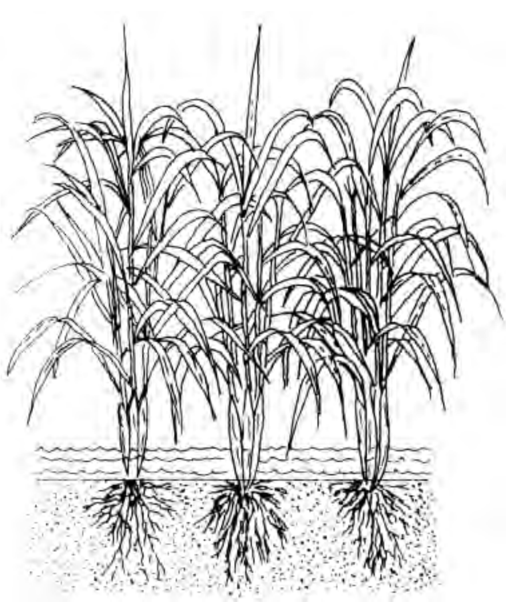
With the advent of modern varieties and improved rice production technology, several of these traditional varieties have been driven towards extinction. Immediate steps need to be taken to save them. One way to do this is to help farmers increase the production of these varieties through simple management techniques.

Why do farmers still prefer the traditional varieties?

- Yield stability and high quality (milling, cooking, taste and nutritional quality)
- High level of adaptability
- Resistance to biotic and abiotic stresses
- Satisfying special needs of different ethnic groups
- Relevance to cultural rituals
- Poor infrastructure to support the cultivation of modern varieties
- Less external input requirement
- Prolonged viability and desired dormancy

Types of rice culture in northeast India

■ *Ahu* (Mar-Jun)	Coarse-grained, photoperiod-insensitive varieties
■ *Sali* (June-Dec)	
• *Sali*	Coarse-grained varieties
• *Lahi*	Slender-grained varieties
• *Joha*	Fine-grained aromatic varieties
• *Bora*	Glutinous varieties
• *Chakowa*	Semi-glutinous soft varieties
• *Asra*	Semi-deepwater varieties
• *Jhum*	Shifting cultivation with coarse-grained, weakly cold-tolerant varieties
■ *Bao* (Mar-Dec)	Coarse-grained, photoperiod-sensitive deepwater varieties
■ *Boro* (Nov-May)	Both coarse- and fine-grained varieties flowering by April



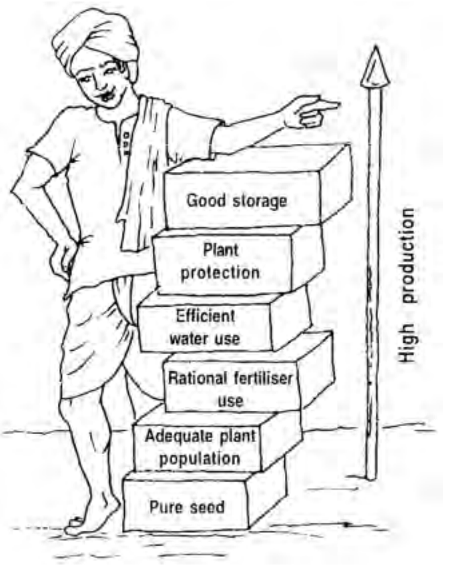
Traditional rice

Special qualities present in traditional varieties

Qualities	Example
Pest and disease resistance	Balam, Kolongibao
Drought tolerance	Maibi, Fapori
Flood tolerance	Negheri bao, Amona bao
Cold tolerance in vegetative stage	Ngoba, Tepi boro
Weakly cold-tolerant at high elevation	Maibi, Ngoba
Presence of aroma	Maniki Madhuri joha
Superfine grain	Kunkuni joha, Badshabhog
Stickyness (more amylopectin)	Ghew bora, Gandhi bora
Soft kernel	Garu chakowa
More bran	Rangadoria
Nutrilious bold grain	Boga bordhan
Puffing quality	Kalamdani, Ampakhi
Parching quality	Malbhog
Suitability for delayed planting	Andrew sali, Solpona

Threats to the erosion of traditional varieties are due to

- poor yields primarily because of lodging;
- fast spread of modern varieties; and
- poor crop management.



Yield of traditional varieties can be raised substantially by simple management practices

Need for in situ conservation of traditional varieties

- More suited to adverse environments
- Some varieties have nutritional attributes
- Selection and utilisation as donors in the development of modern varieties
- Income generation based on rice products requiring special qualities found only in traditional varieties

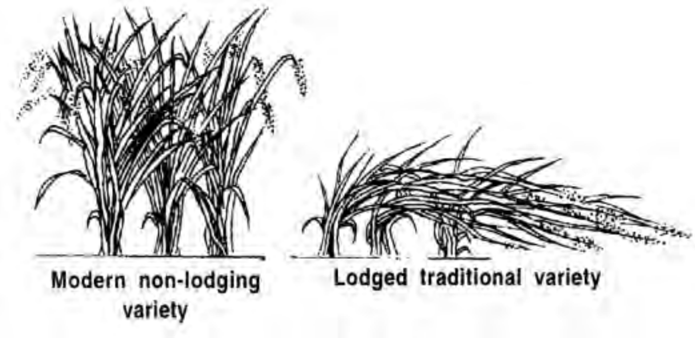
Do you know that . . .
Lodging is the single most important reason for poor yield in traditional varieties.

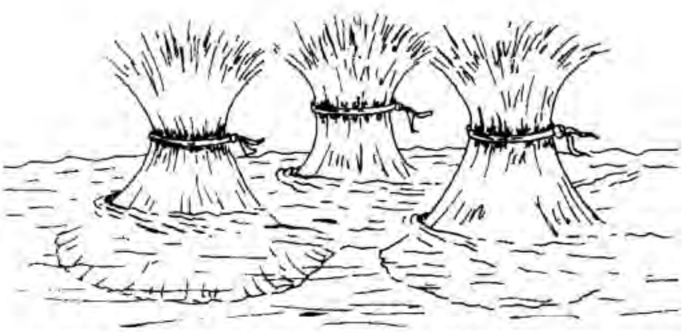
Possible methods for conservation

- Proper survey, exploration and evaluation of genetic materials
- Exploitation of or maximising potential yields through proper crop management
- Yield improvement with suitable management practices with prevention of lodging can help *in situ* conservation of traditional varieties.
- Establishing gene sanctuaries
- Encouraging farmers to grow at least 10-25% of these varieties
- Marketing of traditional varieties
- Mini-kits of seeds aimed at reintroduction of lost germplasm

Improving yields of traditional varieties

- Improvement of on-farm soil and water management and integrated nutrient management
- Application of 40 g SSP and 20 g MOP/12.5-sq-m seedbed
- Application of 10 kg/ha each of P_2O_5 and K_2O in the main field
- Transplanting at 25 × 25 cm spacing
- Topdressing nitrogen (20 kg N/ha) in two splits at tillering and at panicle initiation
- Transplanting at a higher soil depth (2.5 to 5.0 cm)




Resting seedlings for 5-7 days in clean running water

About 10-15% of grains are lost by shattering and another 10-15% are lost during storage. Prevention of these losses can increase yield by 20-30%.

Prevention of lodging

- No direct seeding but transplanting only
- Using over-aged seedlings (35-45 days)
- Deep and late planting (August)
- Delay in nitrogen application (topdressing)
- Wider spacing (25 × 25 cm)
- Application of adequate potassium
- Pruning leaves at maximum tillering in bacterial leaf blight-free areas
- Resting of seedlings after uprooting in clean running water for five to seven days before transplanting to regenerate the broken roots

Post-harvest technology

- Harvesting the crop at physiological maturity (30 days after 50% flowering)
- Making small bundles and keeping them for drying
- Storing bundles in panicles in upside position on the threshing floor (before threshing in wet season)
- After threshing, drying under the sun, stirring every half hour to prevent grain cracking
- Reduction of moisture content up to 12% for storage

Prepared by:
N.K. Sarma, H.C. Bhattacharya and **Julian Gonsalves**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Farmers' Participatory Plant Breeding

Many improved varieties are not popular due to their lack of stability under unfavourable conditions. On the other hand, local varieties are known to have desirable characters of stability for grain yield even under variable factors.

Breeders may, therefore, have failed in their efforts to respond to some of the problems in rainfed ecosystems, leading to slow and restricted adoption of new varieties. This may be because of certain factors in the approaches of conventional or institutional plant breeding programs.

The question of why modern varieties are so poorly adapted to rainfed risk-prone ecosystems can be viewed from two angles: accessibility and adoptability.

Accessibility

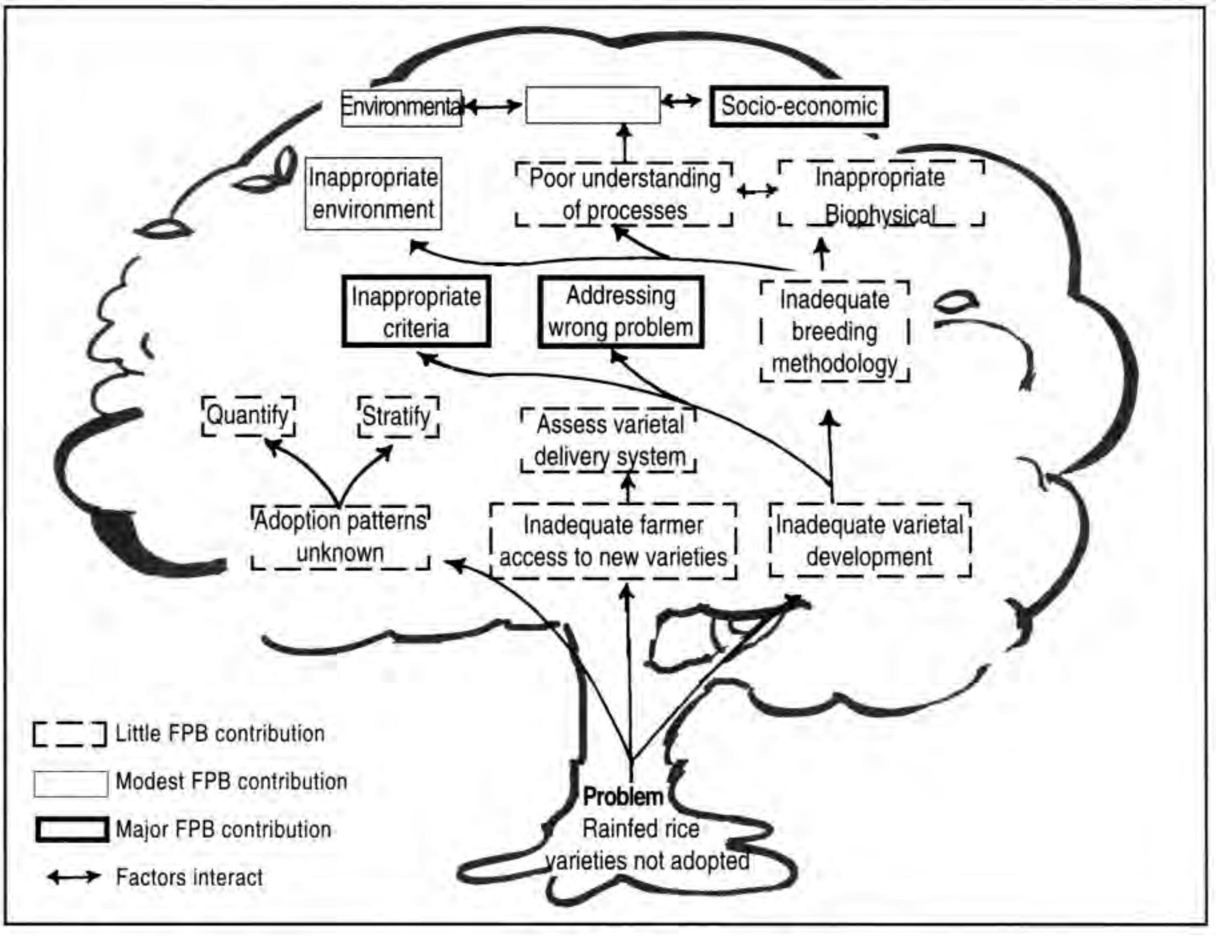
Although improved varieties are considered good, the poor delivery process in centralised systems prevents farmers from having easy access to them. In some cases, farmers have adopted new varieties, e.g., *Mahsuri,* before they are officially released. This shows that, if a variety is good, farmers will get hold of it, not necessarily by official channels.

For this, a more systematic study is required to confirm what changes at institutional and policy levels are needed to improve farmer access to good seed materials (Figure 1).

Conventional/institutional plant breeding

- Problem conceived and strategy formulated by breeders
- Universal concept of breeding objectives:
  - High yield
  - Improved resistance
  - Improved quality
- Selection and testing under controlled conditions
- Released for cultivation by farmers
- Most suited for favourable environments while adaptability is low under uncertain rainfed heterogeneous environments.

Figure 1: Rainfed rice adoption problem tree: possible intervention points for farmer participatory breeding (FPB)



Search for alternative: socio-economic concerns
■ Rate of growth in favourable environments declining. ■ Large potentials of rainfed ecosystems untapped. ■ Dwindling on-farm conservation of germplasm: farmers losing interest. ■ Farmers' knowledge on genetic diversity, their perceptions of plant type and traits not used. ■ Farm produce mostly being consumed, local (society) preferences, taste, quality, by-products utilisation matter more in choice of varieties.

Adoptability

Lack of adoptability, on the other hand, directly or indirectly implies that improved varieties are inferior or have no comparative advantages relative to traditional varieties. The causes for this may be:

- Inappropriate and/or poorly defined selection criteria;
- breeding methods not relevant to selection criteria; and
- breeding not conducted in an environment representative of the target, site, etc.

In this case, decentralisation and increasing participation of farmers in plant breeding processes could substantially improve their efficiency.

There are just a limited number of varieties that cannot be relied upon to address a range of farmers' concerns. Farmers respond to these concerns and needs by growing a range of varieties in a rainfed ecosystem. Varietal improvement programs that are geared towards generating a broad range of options are liekly to be more successful in these environments. Some varieties are also valued for their characters other than high yield. An important challenge for farm scientists is to predict which traits will continue to be valued by farmers as production systems undergo changes and become more closely integrated with markets.

Farmers' participatory plant breeding (FPB)

Definition

FPB is used in the widest context, ranging from decentralised breeding controlled by plant breeders to various degrees of farmers' involvement in the breeding process. Thus, FPB is a decentralised way of assessing and selecting breeding lines with farmers' participation in the specific environment where they will be cultivated.

Rationale of FPB

- Conceptually and practically, FPB suits complex farming systems and meets diverse farmers' preferences and a great diversity of local growing environments. Farmers must, however, be involved in identifying needs and setting objectives.
- FPB can address the requirements for specific adaptations to a complex combination of environmental factors.
- FPB can make full use of farmers' knowledge and take into account constraints to the environment and to farmers' time, money and consumption preferences.
- FPB promotes wider use of genetic diversity and encourages rapid adoption of improved materials.

Types of FPB

Participatory varietal selection (PVS)

PVS is the selection of fixed lines by farmers in their target environments using their own selection criteria. Providing seed choice is the central theme of PVS with an assumption that farmers do not have access to such diversity.

Some features of a successful PVS are:

- identification of farmers' needs in a cultivar;
- search for suitable materials;
- experimentation on acceptability in farmers' fields; and
- wider dissemination of farmer-preferred cultivars.

Current status of FPB

- Widespread consensus on desirability to involve farmers in agricultural technology development and dissemination.
- Institutionalisation of farmer participatory research is inadequate.
- Divergent views among breeders on:
  - Need for farmer involvement
  - Stage of breeding
  - Degree of involvement
  - Roles and responsibilities of farmers
  - Farmers' rights
  - Need for modification in breeding objectives, strategies, varietal release and seed production procedures

Participatory plant breeding (PPB)

PPB in which farmers select cultivars from segregating material under a target environment is a logical extension of PVS. PPB needs to be used when:

- the possibilities of PVS have been exhausted; or
- when the search process in PVS fails to identify any suitable cultivars for testing before germplasm enhancement is done; and
- before crosses are made, the research program should have a clear breeding agenda based on farmers' needs and preferences.

Women's involvement in plant breeding

There is a greater understanding of women's involvement as decision-makers and storehouses of valuable traditional knowledge. It is therefore important to determine gender knowledge gaps in the selection of rice varieties to be grown in different rice ecosystems.

Major steps in PPB and the roles of farmers and breeders in the breeding process

Steps in FPB	Nature of participation	Farmer	Breeder
Goal setting	Consultative	Opinions and views considered	Identify cooperating farmers through survey and consultations
Generating new variability			Key role
Selection and evaluation	Collaborative participation	Site selection Selection within and between populations Post-hatvest and sensory evaluation Trade-off for multitraits vs yield	Screening incoming germplasm Screening disease/pest resistance Selection - early generations Training - heritability
Variety release and distribution	Collaborative	Informal seed supply system	Prepare proposal for release and monitoring of spread

Selection of sites and farmers

Site

- Representative of the target area
- Diverse range of agroclimatic conditions
- Market integration

Farmers

- Primarily traditional rice farmers
- Landowners rather than tenants
- Some degree of literacy
- Involvement of women

Eastern India FPB project

Active participation of users in the process of technology development is vital to achieve results that will benefit the poor. Scientists from the international agricultural research centers (IARCs), national agricultural research systems (NARS) and NGOs therefore got together and started consultations regarding such issues. This led to the launching of a "system-wide initiative" on participatory plant breeding, involving several Consultative Group on International Agricultural Research (CGIAR) centers, NARS and NGOs.

Eastern India truly represents rainfed rice ecosystems and the International Rice Research Institute (IRRI) thus decided to work with four different research institutions, each representing unique rainfed rice sub-ecosystems of eastern India.

Agenda for Eastern India FPB

Socio-economic issues

- Germplasm development and the delivery process through indigenous and formal systems in the target region.
- Documentation and stratification of bio-physical and socio-economic environments for FPB approaches.
- Identification and characterisation of genetic materials for testing.

Methodological issues

- Determine appropriate experimental design, develop necessary biometrical tools and data collection, analysis and interpretation.
- Determine effect of decentralisation separately from that of farmers' participation in breeding efficiency.
- Define and test protocols for farmers' participation (stage and degree of involvement) and skills for selection.

Institutional/policy issues

- Avenue for professionalisation of FPB by adopting innovative curriculum in university programs.
- Policy support for FPB, decentralised seed certification and multiplication strategies, property rights and research management.

Objectives of eastern India FPB project

- A plant breeding component to develop and evaluate a methodology for participatory improvement of rice for heterogeneous environments and to produce breeding materials suiting farmers' needs.
- A social science component to analyse production systems and highlight farmers' selection criteria. These elements are then integrated with field results to understand the bases for farmers' varietal decisions.

Impact assessment

- Effect of FPB on changes in biodiversity.
- Assessment of adoption pattern (rate, diffusion, costs/benefits).

Project status and results

The project has run for two cropping seasons. The preliminary results show that:

- There was, by and large, a good agreement among farmers and breeders in choice of varieties.
- The agreement was, however, less in more diverse environments.
- Though farmers and breeders agreed in on-farm varietal ranking, their on-station ranking did not match.
- The yield ranking did not match with the overall ranking of varieties by breeders and more so by farmers. This shows that the rankers, especially the farmers, considered other traits equally or more important than yield alone in selection.

Farmers' preferences of varieties differed greatly in raw and parboiled rice. The results show that all the test varieties are not suitable for either raw or parboiled rice. The preference of the farmers based on cooking characters was not correlated with the actual yield of the varieties.

Conclusions

- On-station research alone will not fully serve farmers in uncertain rainfed heterogeneous environments. However, some doubt whether farmers' participatory approaches, e.g., participatory breeding, are the best alternatives.
- The IRRI-Eastern India FPB project aims more at testing some of the hypotheses testing whether FPB increased efficiency, rather than pursuing it as an alternative to formal breeding. The results will determine the future of FPB.
- FPB can complement mainstream plant breeding.
- FPB can fulfill equity, efficiency and sustainability objectives.
- Methodology development efforts are needed to make FPB more effective.
- FPB will become legitimate only if research policy and institutional support are forthcoming.

Prepared by:
R. K. Singh, K. Prasad, R.K. Sahu, J.K. Roy, A.T. Roy, S. Singh, R. Thakur and **N.K. Sarma**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Identification of Donors for Rice Breeding

The total rice area in India is 42.3 million ha, of which about 63.3% (26.8 million ha) is under rainfed cultivation. Rice area in eastern India, comprising the states of Assam, Bihar, Orissa, West Bengal, eastern Madhya Pradesh, and eastern Uttar Pradesh, is 26.8 million ha (i.e., 63.3% of the total rice area). About 21.3 million ha (79.5%) of this area is rainfed, of which 4.3 million ha is rainfed uplands, 12.9 million ha is rainfed lowlands and 4.1 million ha is under deepwater situations. Rice productivity in these lands is low. Yield potential of locally adapted, low-yielding, stress-tolerant varieties is improved genetically by hybridisation and selection. These cultivars are the storehouse of useful genes, and are used as donors in breeding programs.

Rice yields in eastern India

Rainfed uplands	0.6-1.5 t/ha
Rainfed lowlands	0.9-2.4 t/ha
Irrigated lands	3.2 t/ha
Eastern India (average)	1.43 t/ha
National average	1.91 t/ha

Rainfed ecosystems and plant types

Uplands

FAVOURABLE UPLANDS

- High rainfall zone, bunded, fertile soil
- Plant type needed: semi-dwarf/ semi-tall

UNFAVOURABLE UPLANDS

- Low rainfall zone, without bunds, poor soil
- Plant type needed: semi-tall

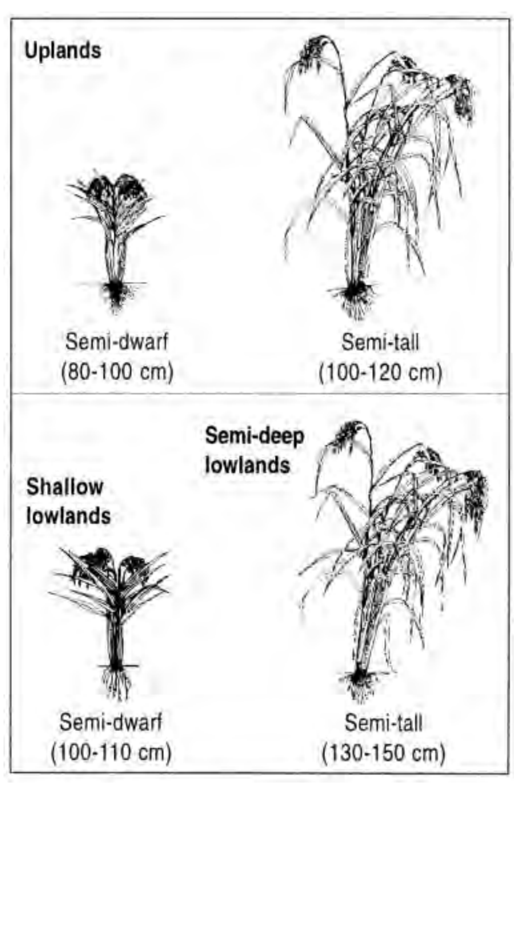
Lowlands

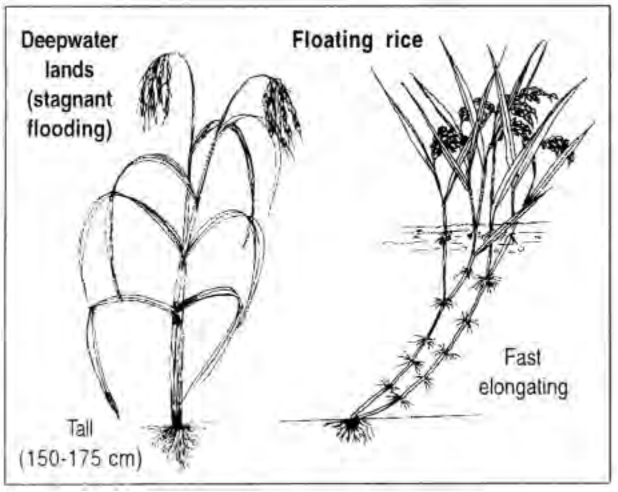
FAVOURABLE LOWLANDS

- Shallow with 0-30 cm water depth
- Plant type needed: semi-dwarf/ intermediate dwarf

UNFAVOURABLE LOWLANDS

- Semi-deep situation (flash-flood) (water depth is 30-50 cm)
- Plant type needed: semi-tall





Production constraints in rainfed upland

- Drought at vegetative and reproductive stages.
- Weed growth.
- Soil problems – light texture, low water-holding capacity, deficiency of nitrogen (N), phosphorus (P), zinc (Zn), iron (Fe), calcium (Ca), magnesium (Mg) and manganese (Mn); aluminium (Al) toxicity.
- Major pests – gundhi bug and termites.
- Major diseases – blast and brown spot.
- Non-availability of high-yielding varieties suitable for different regions.

Deepwater area

Stagnant flooding (water depth 50-100 cm) and very deep water (water depth >100 cm) (floating rice area).

Rainfed uplands

Varietal needs

- Extra-earliness (70-80 days) for drought-prone uplands.
- Earliness (about 100 days) for favourable uplands.
- Early vigour to arrest weed growth.
- Semi-tall stature (100-120 cm) for unfavourable uplands.
- Semi-dwarf habit (80-100 cm) for favourable uplands.
- Drought tolerance at vegetative and reproductive stages.
- Deep root system.
- Long and heavy panicles.
- Seed dormancy (15 days).
- Tolerance to blast and gundhi bug.
- Efficient in soil with low P content.

Suitable donors

For the diverse and heterogeneous rainfed uplands, locally adapted, stress-tolerant varieties serve as better donors than varieties adapted to wider environments.

Table 1. Characteristics of important donors used in breeding high-yielding upland Varieties

Characteristics	Aus	Indica[1]	Japonica[1]
Drought tolerance	CR 143-2-2, Salampikit, Brown gora	Lalnakanda 41, Annada, RR 18-3	IRAT 112, OS 6
Drought recovery	Brown gora, Black gora, Kalakeri	Annada, Bala, C 22	
Earliness	N 22, Brown gora, Karhani	Sattari, Heera, CR 289-1208	RAT 112
Vegetative vigour	Brown gora, Kalakeri, VHC 1253	Kalyani-2, Neela, RR 2-6	–
Weed competition	Brown gora, VHC 1253, Sathi 34-36	RR 2-6, Kalyani-2	–
High grain density	N22, Panke	RR 158-327	–
High grain weight	Sathi 34-36		Khao Khae, Khaolo 33
Deeproot	Kalakeri, Black gora	Vandana	Moroberekan
Tolerance to blast	RR174-1	RR 166-645, Rasi	Moroberekan, OS 6
Tolerance to brown spot	CH 45	RR 35-4-1, RR 36, RR 36-141, Kalinga III, Neela	–
Tolerance to stink bug	Black gora	Sneha, RR 50-3, RR 165-1160	–
Tolerance to adverse soil	Dular	Rasi, Vandana	–
Good grain quality	RR 6-1	Laloo 14, Gaurav, Saket-4	Azucena
High yield potential	–	IR36, IR50, Annada	
Wide compatibility	N 22, Dular		–

[1] *Donors in Indica and Japonica groups are high-yielding.*

Rainfed lowlands

Varietal needs for shallow lowlands

- Semi-dwarf habit (100-110 cm) for favourable lowlands.
- Stiff straw (non-lodging habit).
- Duration / photosensitivity (region-specific).
- Thermo-insensitivity.
- Submergence tolerance.
- Long and heavy panicles.
- Seed dormancy.
- Iron toxicity tolerance.
- Tolerance to major pests (gall midge and stem borers) and diseases (bacterial blight, sheath blight and tungro).
- Suitability for late planting.
- Efficiency under low fertility.
- Good grain quality.

Varietal needs for semi-deep lowlands (flash/intermittent flooding situations)

- Semi-tall habit (130-150 cm).
- Drought tolerance at initial growth stage.
- Deep root system.
- Sturdy stem.
- Tolerance to at least 7-10 days of complete submergence.
- Fast regeneration ability.
- Resistance to stem borers and nematodes.

Suitable donors for shallow and semi-deep lowlands

Highly diverse and heterogeneous environmental conditions occur in rainfed lowlands. There is a need for genetic materials that suit different day-lengths and temperatures at flowering time in different regions of eastern India for use in varietal improvement programs.

Donors for three photoperiod-sensitive groups of varieties for rainfed lowlands in eastern India

Flowering time	Location	Donor
Group I		
October 2nd week	Raipur (Madhya Pradesh)	Safri 17
Group II		
October 3rd week	Titabar (Assam)	Manoharsali
	Patna, Pusa (Bihar)	Rajshree
	Masodha (Uttar Pradesh)	Madhukar
Group III		
October 4th week	Cuttack (Orissa)	Savitri
November 1st week	Ranital (Orissa)	CR 1014
	Chinsurah (West Bengal)	Sabita

Varieties/donors with specific traits for rainfed lowlands

Trait	Donors
Drought tolerance at vegetative stage	Janki, CN 506-147-2-1, Rajshree
Submergence tolerance	
Early vegetative stage	FR 13A, FR 438, CN 540, Sabita
Late vegetative stage	Khajara, Dhusara, Nali, Baunsa Gaja, Lunifarm
Resistance to stagnant flooding	Tilakkachari, Panidhan, Patnai-23, Suresh, Biraj
Semi-tall habit	Bako(Javanica)
Photosensitivity	Sabita, Madhukar, Gayatri
Iron toxicity	Samalie, Mahsuri
Phosphorus deficiency	Patnai-23, IR55008
Alkalinity	Jalmagna, Madhukar
Good grain quality	CR 1014, KDML 105, Mahsuri

Production constraints in semi-deep lowlands

Poor crop establishment due to early drought and/or early submergence.

Non-availability of genotype with flood/submergence tolerance at early and late vegetative stages.

Suppressed tillering due to prolonged waterlogging.

Crop damage due to cycles of flash floods at different stages of crop growth.

Iron toxicity.

Stem borer infestation at heading stage.

Popular varieties grown in rainfed lowlands and used as donors

Variety	State	land type	Variety	State	Land type
Safri 17	Madhya Pradesh	Shallow (drought-prone)	Dhusara	Orissa	Semi-deep
Chepti Gurmatia	Madhya Pradesh	Shallow (drought-prone)	Janki	Bihar	Semi-deep
Rani Kajar	Madhya Pradesh	Shallow (drought-prone)	Jalapriya	Uttar Pradesh	Semi-deep
Bako 1	Bihar	Shallow	Manoharsali	Assam	Semi-deep
Chakia 59	Uttar Pradesh	Shallow	Tilakkachari	West Bengal	Semi-deep
Mahsuri	Assam	Shallow	T 1242	Orissa	Semi-deep
Madhukar	Uttar Pradesh	Shallow	Suresh	West Bengal	Semi-deep
Pankaj	Assam	Shallow	Patnai-23	West Bengal, Orissa	Semi-deep (coastal)
T 141	Orissa	Shallow	Jalmagna	Uttar Pradesh	Deep
BAM 6	Orissa	Semi-deep	FR 13A	Orissa	Flood-prone
Biraj	West Bengal	Semi-deep	FR 43B	Orissa	Flood-prone
CR 1014	Orissa	Semi-deep	Khajara	Orissa	Flood-prone

Production constrainrs in deepwater lands

- Extreme floods and drought.
- Low plant population.
- Lack of adequate adaptability and stability in newly developed varieties.
- Non-availability of quality seed.
- Inadequate crop and resource management practices.
- Predominance of monoculture farming in deepwater lands.
- Weed management problems especially during pre-flood crop.
- Loss of yield due to yellow stem borer and ufra (caused by stem nematode).

Two lowland varieties, FR 13A and FR 43B, from Orissa are the best donors for submergence tolerance. FR 13A has a high degree of submergence tolerance at the early vegetative stage (with least elongation habit), but is susceptible to submergence when floods recur in the late vegetative stage. The landraces Dhusara and Begunia Khajara tolerate cycles of flooding/ submergence at both early and late vegetative stages.

Suitable deepwater rice varieties identified and used as donors

Character	Donors
Elongation ability	Baisbish, Jalmagna, Negharibao, LMN 111, TCA 177, NDGR 402, Padmapani, *Oryza rufipogon*
Submergence tolerance	FR 13A, FR 138, BKNFR 76106-16-0-1, IR31432-6-2-2-3, IR31406-33-1, IR28884-26-3-505-1-1, Madhukar, Kurkaruppan, Goda, Heenati, Maguribao
Drought tolerance	RD 19, Patnai-23, CR 1009, NC 1626, Baisbish, BIET 821, Gurmatia
Photoperiod sensitivity	CNW 539, CN 505-5-32-9, Janki, TCA 48, Jalrnagna, BIET 821, Safri 17
Seed dormancy	CN 499-160-13-6, NC 92, FR 13A
Long panicle	OR 143-7, BIET 807, TCA 4, FRG 7, Kolimooch 64
Ufra resistance	Rayada 16-06, Rayada 16-09, Rayada B3, Bazail 65, Ufra 4, Ufra 12, Ufra 14, Ufra 15, Ufra 16, *O. rufipogon*
Kneeing ability	Negharibao, Dalbao, Amonabao, Padmapani

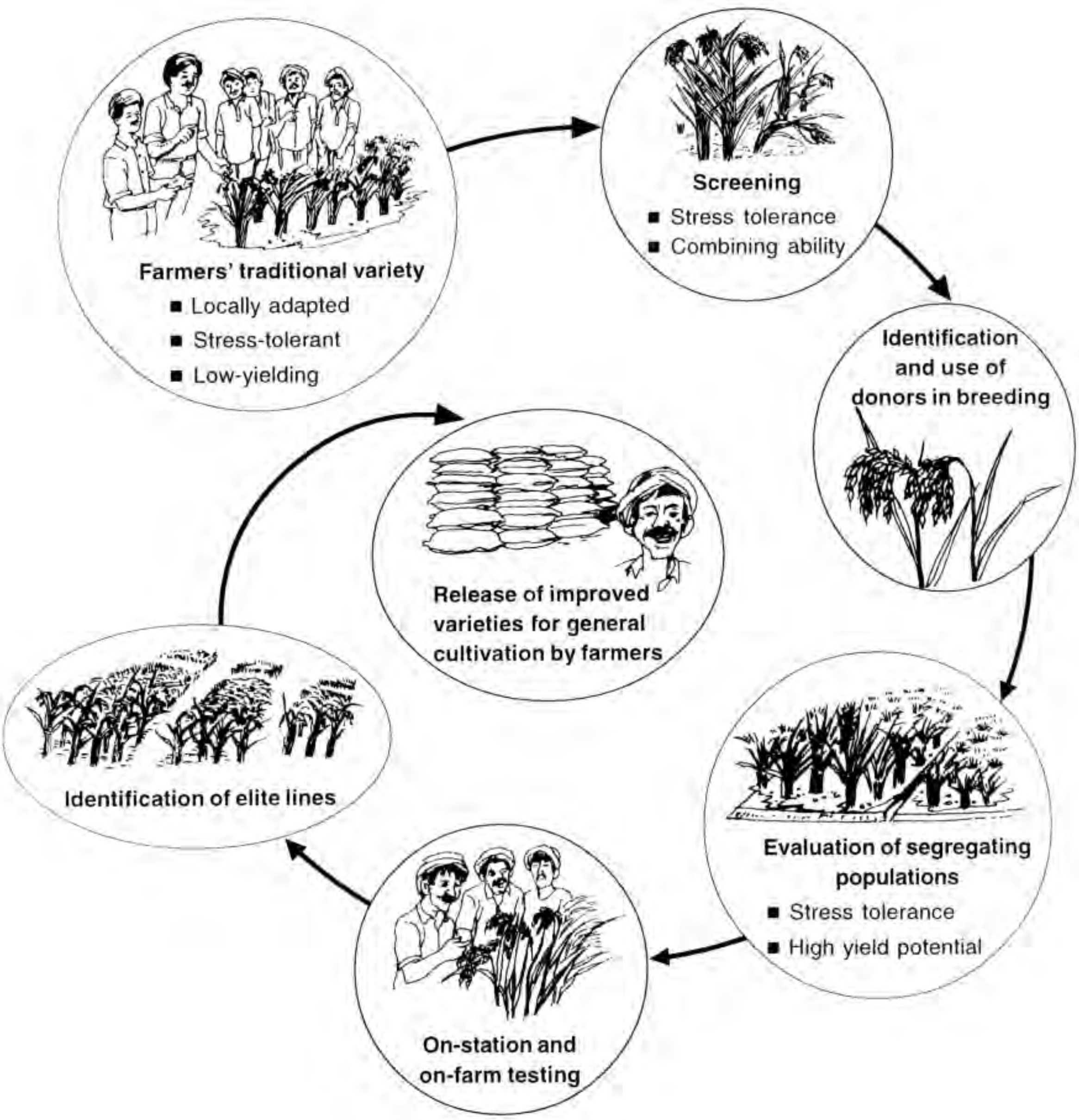
Deepwater area

Varietal needs

- Drought tolerance at early crop establishment stage.
- Need-based elongation ability.
- Tall habit (150-175 cm).
- Nodal tillering to compensate for poor plant population.
- Kneeing ability.
- Photoperiod sensitivity (flowering between last week of October and early November).
- Non-shattering behaviour.
- Seed dormancy.
- Tolerance to yellow stem borer.
- Resistance to ufra.

Importance of donor varieties to farmers

Farmers can improve their economic status through better agriculture. Improved seed is the easiest and cheapest technology for enhancing yields. To improve yields, factors/stresses that reduce yields should be identified, and donors having desirable traits should be identified. The required characters must be transferred to a high-yielding variety by breeding. Farmers can then use the genetically improved local variety for high yield and increased income.



Prepared by:
R.K. Singh, J.K. Roy, K. Prasad, S. Mallik, R.K. Sahu, N.K. Sarma and **J.L. Dwivedi**

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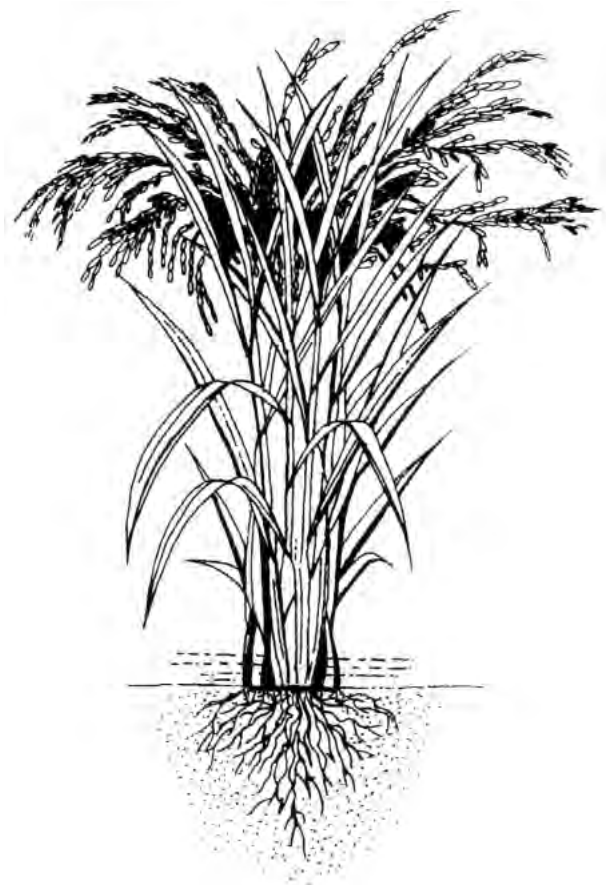
Varietal Development: Evaluation and Screening Procedures

India has made tremendous progress in agriculture by developing high-yielding varieties (HYVs) of rice.

- It is estimated that farmers in India grow 80,000 local varieties of rice with a yield potential below 1 t/ha.
- From local landraces, about 500 improved varieties have been developed through pure-line selection with improved yield potential of 1-2 t/ha.
- India has released 512 HYVs so far, with yields of 4-14 t/ha.



Semi-dwarf variety

Evaluation process

After crosses are made, it takes seven to eight years to stabilise them through selection. Then, the field evaluation process starts. Rigorous testing during variety development ensures selection of the right type of cultivars. The new selections become entries for further evaluation and must have characteristics that last long and a defined level of adaptability to different production conditions.

Evaluation and screening involve testing newly developed cultivars for:

- yield potential vis-à-vis the best existing varieties, used as checks;

Do you know that?

- developing a new variety of rice requires a lot of research and even more patience.
- It takes seven to eight generations to stabilise the cultivar through breeding: four years for early/medium varieties (two crops/year) and eight years for late varieties (one crop/year)
- A national testing program takes two to four years
- The total time frame for release = six to 12 years

- resistance to different biotic (pests and diseases) and abiotic (unfavourable agro-climatic conditions) stresses;
- adaptability to varying agro-ecological conditions, including soil types;
- quality parameters; and
- response to nutritional and other agronomic management practices.

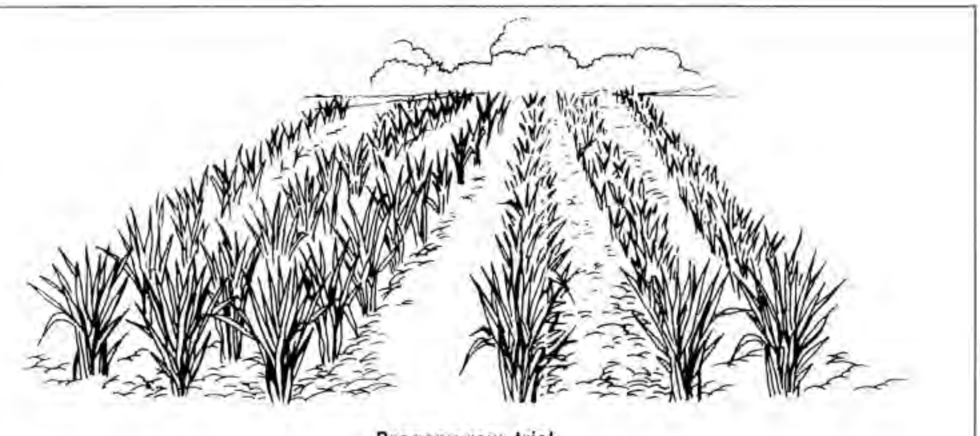
Varietal evaluation and screening must facilitate the identification of varieties with minimum time and cost.

Levels of testing for variety development

Station trials (ST)

The process of variety evaluation starts when the breeder identifies desirable genotypes having the requisite features and genetic makeup to meet set objectives.

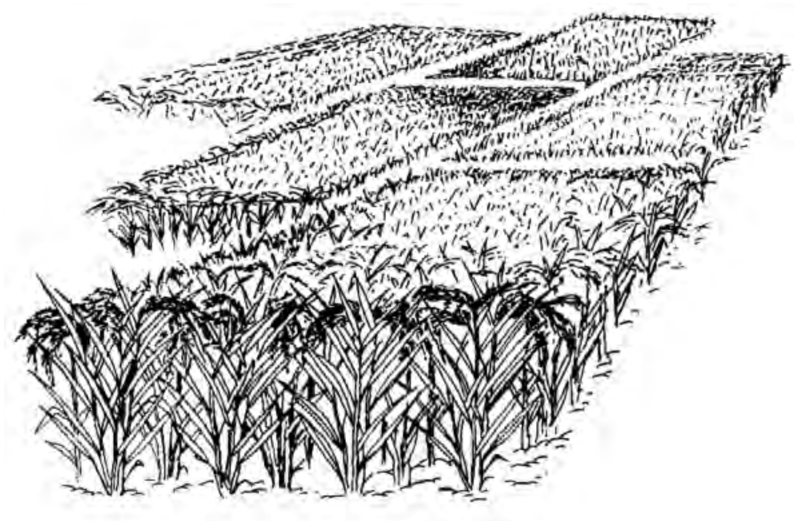
- The observation trial (OT), or progeny-row trial, is the first step in the evaluation process where test entries are compared with one another and with checks in unreplicated single rows. Checks are generally the best locally adapted varieties. At this stage, emphasis is given to plant type, uniformity in height and maturity duration.



Progeny-row trial

- Laid out in a lattice or randomised block design with two to three replications, the small-scale trial (SST) or preliminary evaluation trial is the first replicated yield trial. Observations on uniformity in plant height, maturity duration, plant type and yield per plot are undertaken here.
- Entries selected from SST are entered into large-scale trials (LST) conducted by breeders, preferably at two to three locations, in their own area of operation. These are actually the performance trials; therefore, yield per plot and disease and pest reactions of the test entries are also recorded.

The other option for breeders is to test the entries for two years at their own station to identify two to three lines to be included in multi-location trials.



Yield trial

Required characteristics of entries for MLT

- Superior performance for yield in ST
- Desirable agronomic/quality traits
- High degree of phenotypic uniformity and genotypic stability
- Known pedigrees/parentages

Multi-location trials (MLT)

Cooperating breeders conduct multi-location trials (also known as national trials). The entries for these trials come from cooperating breeders of the crop network and are grouped according to different ecosystems and crop duration, i.e., early, medium and late maturity groups.

The trials are laid out at several locations, representative of different agro-climatic zones, identified by the crop coordinator in consultation with cooperating institutions.

These trials provide the entries received from breeders of different parts of the country the opportunity to express their potential in varying sets of environments. They also enable breeders to identify suitable varieties and their adaptability characteristics.

Types of multi-location trials

Performance trials

- INITIAL EVALUATION TRIALS (IET)
  Based on their performance in station trials, entries are selected by breeders for IET. The number of entries is generally quite large, but, inclusive of checks, should not exceed 49.

- INITIAL VARIETY TRIALS (IVT)
  Entries with better performance in yield and/or disease and pest reactions in IET are promoted to this stage. Besides yield, data on disease and pest reactions, etc., of the entries under natural conditions are recorded.

- ADVANCED VARIETY TRIALS (AVT)
  Based on their performance in the IVT, promising entries are promoted for testing to AVT. This being the final yield evaluation trial, entries are tested for at least two seasons in replicated trials.

- ADDITIONAL DATA TRIAL (ADT)
  For collecting information on agronomy, resistance to biotic stresses and quality.

Associated multi-discipline trials

Besides testing of varieties in a regular channel from station trials through IVT and AVT for their yield performance, entries are also subjected to some other tests described below:

- **Agronomic Trials**
  The entries from IVT that are recommended for testing in AVT should also be tested in agronomic trials. These are normally planned to precisely develop appropriate agronomic practices.

- **Screening for Resistance**
  The set of entries which go in for yield trials in IVT is also exposed to artificial inoculum of important diseases and pests. It may not be necessary to have a replicated trial for testing against diseases and pests. But one must use susceptible infector rows after every four to five lines of test entries. This is for inducing maximum disease/pest inoculum for better screening of resistance/ tolerance.

- **Quality Analysis**
  Samples of the entries identified for final testing in AVT are also analysed for certain important quality characters. A few cooperating centers under the program have facilities to do this work, and the data are made available to the breeder/coordinator for incorporating in the report to be finally used for variety identification/release.

On-farm trials (OFT)

Only those varieties identified by the crop workshop and having the chance to be released are used in on-farm trials. Data from OFT, particularly from adaptive trials, are required to support data for release of varieties.

On-farm trial

Adaptive trials

Adaptive trials are conducted by state departments of agriculture on their own farms on an area of 0.2 ha. Identified entries are compared with control varieties grown side-by-side in an equal area.

Mini-kits

Mini-kits are small 2-5-kg seed bags, which are distributed to farmers and monitored by the Directorate of: Rice Development (Patna). The purpose of mini-kits is to popularise the new cultivars among farmers and to get feedback.

Demonstrations

Sometimes, breeders, with the assistance of the state departments of agriculture, organise demonstrations in farmers' fields to convince them of the potentials and advantages of new varieties.

Monitoring of trials

On-site monitoring of trials is an important aspect of the varietal evaluation and release process. The monitoring is done by a team of scientists:

- project director/project coordinator/zonal coordinator as chairman;
- senior breeder as member;
- senior agronomist as member; and
- senior pathologist/entomologist as member.

Variety release and notification

Once the candidate variety passes through various tests and trials, as described above, it is proposed for formal release.

Release process

Identification

Varietal identification takes place during the annual group meeting of all the respective All India Coordinated Crop Research Projects (AICRP). Concerned breeders submit proposals supported by data from three years of testing, reactions to diseases and pests and data on quality parameters. The Variety Identification Committee (VIC), consisting of senior scientists from cooperators and other organisations, examines the proposals and identifies superior genotype(s) for one or more zones depending upon adaptability during the tests in different zones. The breeder is then asked to submit the formal release proposal.

Release

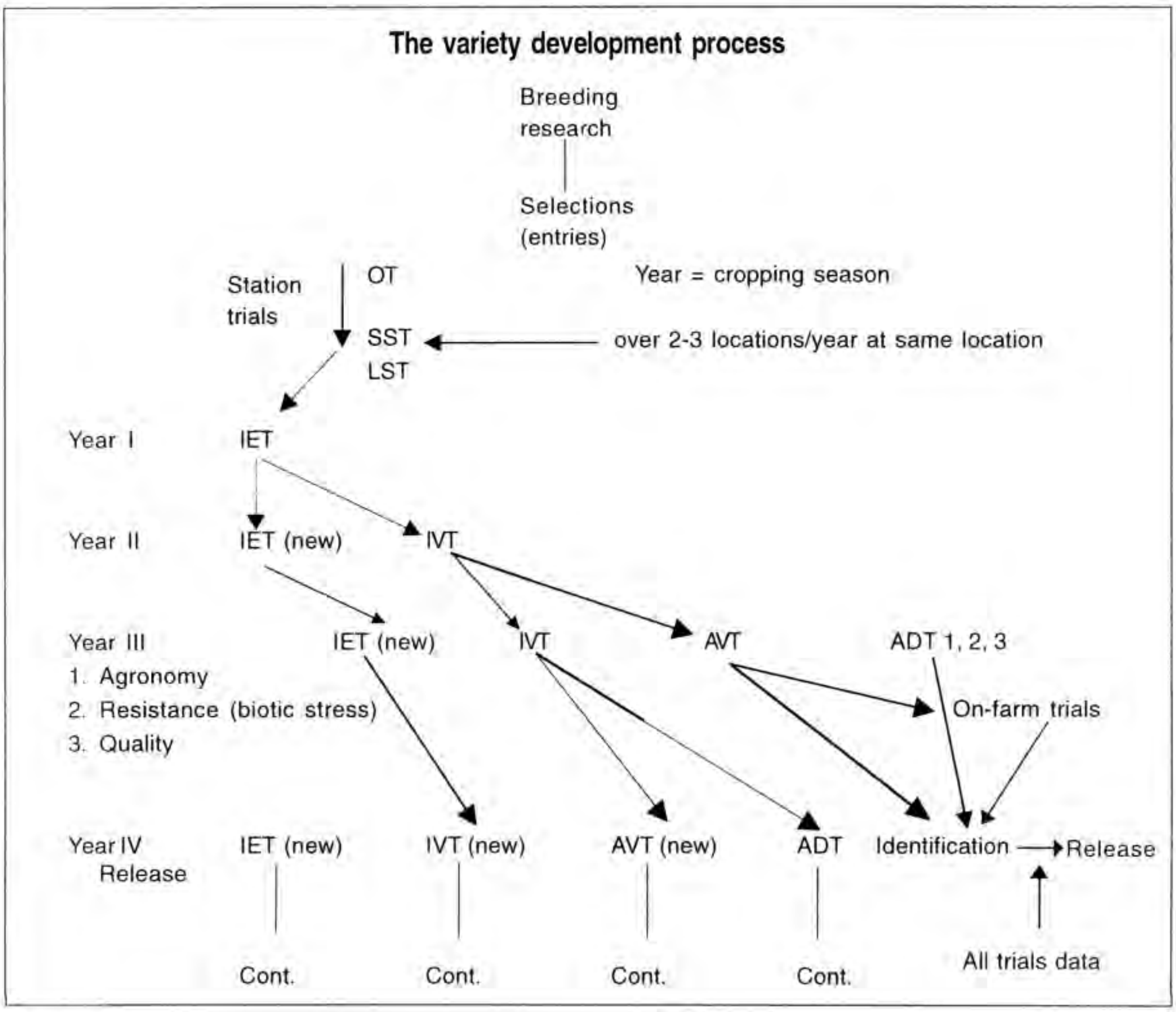
The variety is released and notified by a committee called the Central Variety Release and Notification Committee (CVRC). The CVRC accepts only those release proposals for varieties that have already been identified by the workshop. A certificate from the coordinator, along with recommendations of the VIC, is attached to the proposal. State Variety Release Committees (SVRC) are also empowered to release varieties for their respective states.

Notification

Multiplication of certified seeds of a variety released by CVRC or SVRC and sale to growers for production are only allowed when the variety is finally notified by the CVRC. Notification through the official gazette is necessary to regulate the quality of certified seed of any kind of variety to be sold for agricultural purposes.

The CVRC also has the power to de-notify a variety. De-notification is considered essential when a variety becomes highly susceptible to certain diseases and pests or deteriorates and/or when better options become available for its replacement.

The whole process of variety development begins with hybridisation and selection and ends with release and notificatcon. The flow of material from one stage to another is summarised in the figure below.



Prepared by:
R.K. Singh, J.K. Roy, R.K. Sahu, N.K. Sarma and **K. Prasad**

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Traditional Varieties vs. Modern Varieties: Potentials and Risks

What are traditional varieties?

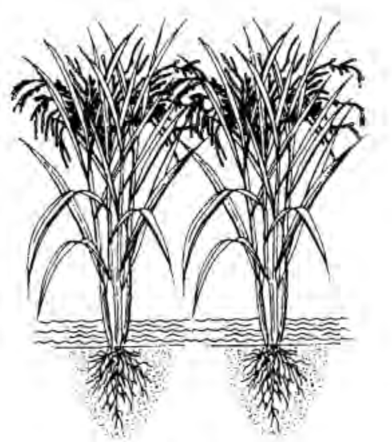
Traditional varieties are those that have been cultivated regionally by farmers for centuries. These are grown to suit specific needs and purposes.

Efforts have been made to improve traditional cultivars. Donors with specific characteristics have also been identified from traditional varieties.

Traditional variety

What are modern varieties?

Modern varieties are varieties developed as genetically superior to traditional varieties in yield and that have intermediate plant type, better response to fertiliser and a yield potential of more than 4 t/ha on average. These varieties are also commonly referred to as high-yielding varieties (HYVs). Most modern varieties have been developed through hybridisation.



Modern variety

Hybridisation and pedigree methods

Hybridisation is the crossing of two or more genetically unlike parents with the desired characteristics. An F_1 seed is planted to produce the F_2 seed in bulk. The F_2 seed is space-planted singly and selected individually (single plant selection).

In the pedigree method, seeds from individual F_2 plants are sown in single-row plots to form the F_3 generation. The seeds from the best plants of the superior F_3 rows are harvested individually tu form F_4 lines. This process is continued until the lines become uniform (F_5 to F_7). The superior lines are then bulk-harvested for testing in larger plots.

Trends in varietal improvement

In the past, varietal development has focused mainly on increasing yield. Lately, the focus has widened to include resistance to major pests and diseases. Now, quality is also being emphasised.

Over the past 35 years, more than 512 high-yielding varieties have been released in India. About 67 of these are on the national seed chain but only one-third of these 67 have been widely adopted and popularised.

Bulk breeding

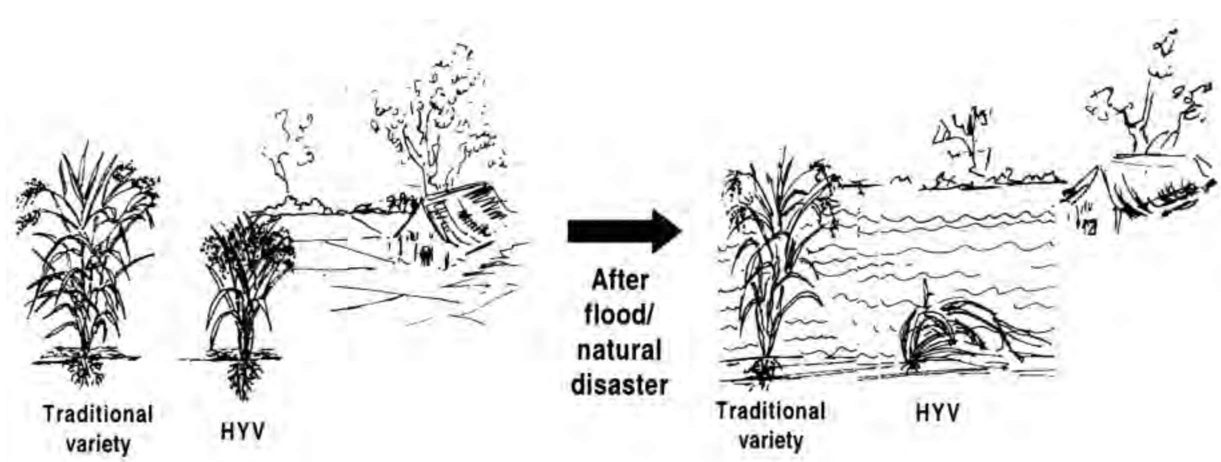
Bulk breeding is an alternative to the pedigree method in which each generation (beginning with F_2) is harvested in bulk until homogeneity is attained (F_5 to F_7). Natural selection, which favours plants that produce more seeds in the final bulk generation, is allowed to take its course. The best plants are selected and their seeds are sown in pedigree rows or observation plots. Uniform lines are entered for yield trials.

The facts . . .

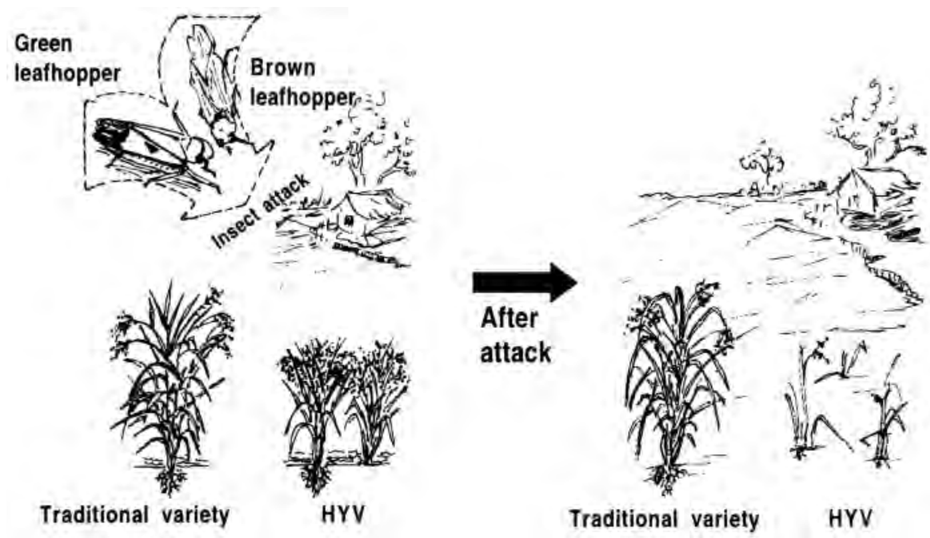
- 63.3% of the total rice area in the country is in eastern India.
- A recent sampling done with farmers in some cluster villages of Orissa showed that 30 indigenous varieties and 11 high-yielding varieties are being used. More than 70% of the farmers are growing two to five traditional cultivars while 20% are growing six to eight traditional varieties.
- In another case study done on upland rice in Hazaribagh, it was found that 93% of the farmers have no access to modern varieties. This indicates that varietal improvement 'is still slow in rainfed environments.

Potentials and risks

There is no question that modern varieties have greater yield potential than traditional varieties. However, they are also more prone to risk in situations involving stress or epidemics. Traditional cultivars, on the other hand, possess the inherent capacity to withstand stress and adverse environments. These varieties may have low to moderate yields under adverse conditions, whereas modern varieties may fail completely.



Most modern varieties have been developed through hybridisation involving the single dwarfing gene source De geo woo gen (DGWG). This single dwarfing gene source increases the plant's vulnerability to pests and diseases, such as devastation by the brown planthopper in Kerala in the late 1970s and bacterial blight in Punjab in 1980. The current trend to use a single wild abortive (WA) cytoplasmic male sterile source to develop hybrid rice may lead to similar epidemics.

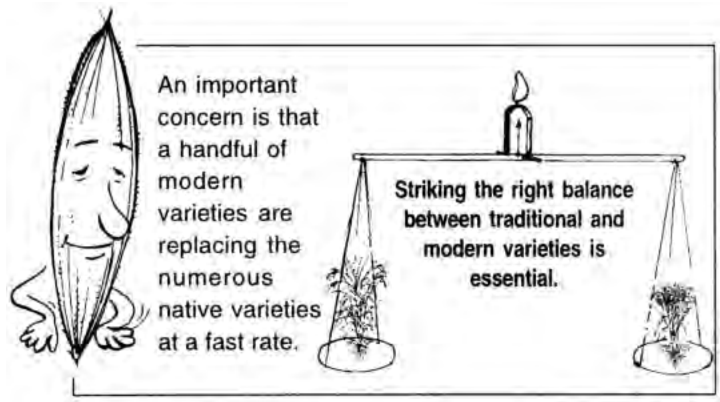


Strategies to meet projected rice demand in India

- Total rice production in India has to increase from the present 82 million tons to 95 million tons per annum by 2002-2003.
- To achieve this target, in addition to the seeds of modern varieties, higher amounts of chemical fertilisers and insecticides/fungicides will have to be used. But these inputs can pose environmental and human health hazards and need to be constantly monitored.

- The increase of 13 million tons of rice production has to be achieved within the next five years. This is possible only through the extensive use of new HYVs and improved production technologies.
- Eastern India has a total rice area of 26.8 million ha amounting to 63.3% of the rice area of the country. A modest yield increase of half a ton per ha will contribute about 13 million tons of extra rice, thus meeting the demand.

- Some small increases can also be achieved by increasing. the productivity of prospective traditional cultivars (an increase of 10-15%, is readily achievable).



Characteristics of traditional and modern varieties: a comparison

Parameters/characteristics	Traditional varieties	Modern varieties
Yield	1 to 2 t/ha	4 to 10 t/ha
Fertiliser responsiveness	Low	High
Height	Mostly tall (>100 cm)	Mostly semi-dwarf (80 to 100 cm)
Photosensitivity	Late-duration cultivars possess photosensitivity	Mostly photo-insensitive
Dormancy	Moderate to high	Mostly absent
Stability over years	Highly stable	Less stable
Adaptability	Adaptability to local environments only	Wider adaptability
Inputs	Suitable for low-input technology	Responsive to high-input technology
Resistance to abiotic stresses such as drought and flood	Moderate to high	Low
Resistance to biotic stresses such as diseases and pests	Moderate to high	Low
Type of resistance, if any	Horizontal resistance (moderate level of resistance against different biotypes)	Vertical resistance (specific resistance to specific biotype)
Eating qualities (taste, expansion, softness,etc.)	Highly acceptable	Moderate to poor acceptability
Aroma and special characteristics	Present in many	Rare

Prepared by:
R. K. Sahu, R. K. Singh, K. Prasad, J. K. Roy and **N. K. Sarma**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

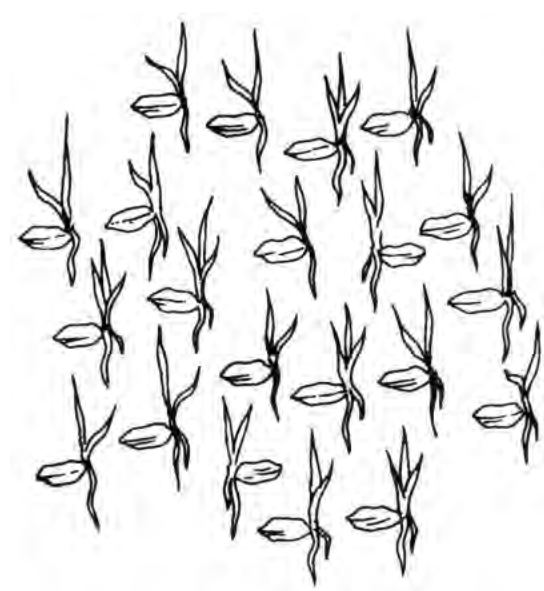
Rice Seed Management

Rice Seed Supply in Eastern India

Seed acts as a catalyst in agricultural production. The pace of progress in food production will therefore largely depend on the progress of the seed program in the country. The miracle seeds of improved varieties have played a key role in the agricultural transformation in India.

High-quality seed

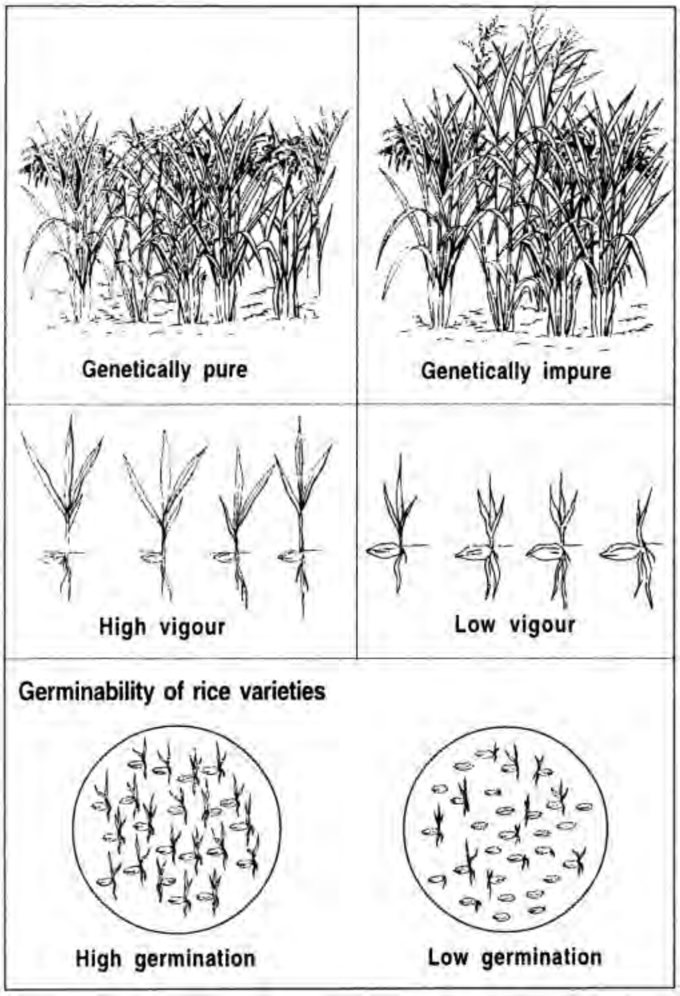
The use of high-quality seeds increases productivity by 10-25%. During 1970-80, food grain production increased by 155% and productivity by 96%. During this period, the distribution of high-quality seed was the highest and increased by 384%. The maximum increase in productivity and total production was observed during the following decade (1980-90). This can be attributed to the increased distribution of high-quality seed, which increased from 0.25 million t in 1980 to 0.57 million t in 1990.



The distribution of high-quality seed has also helped in increasing the area under high-yielding varieties (HYVs). The maximum increase in distribution of high-quality seed recorded between 1980-81 and 1990-91 was highly associated with the increase in area under HYVs in 1988-89. In subsequent years, the distribution of high-quality seed increased steadily and a similar trend was also observed in the expansion of area under HYVs. By 1994-95, the HYV program had maximum impact on rice, with 74.6% of rice area under HYVs.

Area under high-yielding varieties of rice in India

Year	Area (%)
1966-67	2.6
1988-89	60.9
1989-90	62.1
1990-91	64.2
1991-92	65.7
1992-93	65.9
1993-94	68.8
1994-95	74.6



Characteristics of high-quality seed

- High genetic purity (true-to-type) (>80%)
- High physical purity
- Free from pests and diseases
- Free from weed seeds
- High germinability
- High vigour
- Safe moisture content (1-12%)
- Uniform size
- High density

Status of rice seeds

In self-pollinated crops such as rice, seed replacement of 25% each year is recommended so that seed is replaced every three to four years. However, the current seed replacement rate of rice in India is about 15%.

Requirement and availability of rice seed in eastern India during 1998-99[1]

State	Area (million ha)	Seed rate (kg/ha)	Total seed required ('000 t)	Seed demand by state government[1] ('000 t)	Seed availability/ supplied[1] ('000 t)	SRR[2] (%)
Uttar Pradesh	5.58	50	270	25	25	8.96
Madhya Pradesh	5.17	50	259	13	11	4.82
Bihar	5.03	50	252	25	25	9.92
West Bengal	5.95	50	298	25	24	8.39
Orissa	4.53	60	272	37	45	13.60
Assam	2.50	50	125	2	2	1.60
Sikkim	0.02	50	1	–	–	
All India	42.90	45	1931	230	300	11.91

[1] ***Source:*** *Department of Agriculture and Corporation, Government of India (personal communication)*
[2] *SRR = seed replacement rate, i.e., seed supply as % of total seed required*

Status of breeder seed

The Indian Council of Agricultural Research (ICAR) has created an impressive infrastructure for production of breeder seed of different crops in collaboration with the state agricultural universities (SAUs). The ICAR also allows breeder seed production by the National Seeds Corporation (NSC), State Farms Corporation of India, state seed corporations, and non-governmental organisations in specific cases. Breeder seed is produced as per the indent submitted by the Ministry of Agriculture, Government of India, based on the demand from both the public and private sectors. Generally, the production of breeder seed is more than the indent.

Breeder seed production (BSP) and seed technology research (STR) centers in eastern India

Center	Component
NDUAT (Faizabad)	BSP/STR
BHU (Varanas)	BSP
AAU (Jorhat)	BSP
BAU (Ranchi)	BSP
RAU (Dholi)	BSP/STR
OUAT (Bhubaneshwar)	BSP/STR
IGKVV (Raipur)	BSP

Seed programs in India

The National Seeds Corporation (NSC) was established in 1963 and the Uttar Pradesh Seeds and Tarai Development Corporation in 1969, followed by other state seed corporations and seed certification agencies. These developments triggered the growth of the private seed industry. The Seed Act was passed in 1966 and implemented in 1968. The National Seed Project, NSP-I, was launched in 1977 with the assistance of the World Bank at an estimated cost of US$ 52.7 million followed by NSP-II in 1978 with an outlay of US$ 34.9 million. The seed program received further help with the launching of the All India Coordinated Research Project on Seed, called the National Seed Project (NSP) (Crops), in 1979 by the ICAR. The Council further strengthened the seed research programs by launching the special project on “Promotion of Research and Development Efforts on Hybrids in Selected Crops” in 1989. NSP-III (WB), implemented in 1989, supported not only the public sector seed industry and ICAR, but also the private seed industry.

The National Seed Project (Crops)

Mandate

- To conduct, coordinate and monitor research on different aspects of seed science and technology.

Rice breeder seed *(t)* produced during 1997-98

State	Government of India		State		Total	
	Indent	Production	Indent	Production	Indent	Production
Uttar Pradesh	13.9	54.4	26.0	68.6	39.9	111.1
Madhya Pradesh	5.9	5.63	2.4	46.0	29.7	51.6
Bihar	NA[1]	NA	2.0	6.0	2.0	9.0
West Bengal[2]	1.0	1.5	2.0	1.9	3.0	3.4
Orissa	14.0	2.9	26.8	122.1	140.8	135.0
Assam	0.0	NA	6.6	7.4	6.7	7.0
Sikkirn	<0.1	NA	NA	NA	<0.1	NA
All India	64.0	110.5	327.8	416.1	391.9	529.6

[1] *NA = Data not available*

[2] ***Source:*** *N.K. Saha and S.D. Chatterjee (personal communication)*

- To produce an adequate quantity of nucleus and breeder seed of high quality as per the national requirement.
- To generate basic information on seed certification standards including seed health.
- To disseminate information and impart training on seed production, processing, storage and packaging; and quality control and seed health.
- To promote linkages with crop improvement projects, seed industry, seed certification agencies, and seed trade.
- To establish national and international linkages for strengthening seed research.

Infrastructure

The NSP (Crops) is being implemented at 36 SAUs and ICAR centers for breeder seed production of varieties or parental lines of hybrids of various crops. In addition, 21 centers are conducting seed technology research.

Activities

- Produce breeder seed as per the national or seed industry requirements.
- Give feedback on developments in seed technology including seed production, storage, seed health and upgrades in seed quality through seed processing.
- Assist in training of trainers and farmers on various aspects of seed.

Tips to farmers for seed production

- Selection of the rice field or portion thereof depending on the seed requirement of the following year.
- Proper agronomic management.
- Proper roguing and weeding.
- Seed health care and plant protection measures.
- Proper care during harvesting, threshing, and winnowing to avoid seed mixtures (e.g., weeds).
- Proper cleaning, drying, packaging, and storage.
- Seed testing for germinability before planting.
- Seed treatment.

Seed cleaning

Roguing

Plant protection

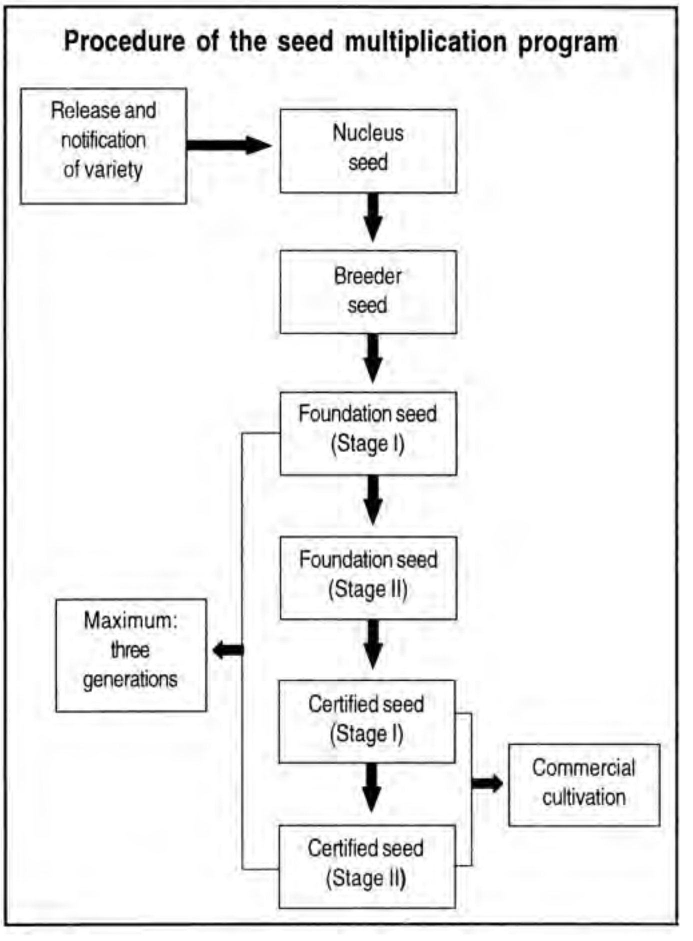
Seed treatment

Seed testing

Seed generation system in India

A three-generation seed multiplication system is followed in India.

The flow chart illustrates the procedure of the seed multiplication program.



Procedure of the seed multiplication program

Seed industry in India

- National Seeds Corporation
- State Farms Corporation of India
- State seed corporations – 13
- State seed certification agencies –19
- Notified seed testing laboratories –63
- Private seed companies

Future strategies

- To make available the required quantity of high-quality seed.
- Create awareness among farmers:
  - To use high-quality seed and change/replace the seed at least every three to four years.
  - About various steps/ precautions to be taken for on-farm production of seed with desired quality after initial purchase.

Private seed industry

There are about 500 big and small private seed companies. Of these, 24 have their own research and development programs. The industry mainly deals with high-value, low-volume seed, i.e., hybrids and vegetable crops.

Prepared by:
R.K. Chowdhury and **R. K. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Rainfed Rice Seed Production Systems: Towards a Bigger Role for Farmers

Though globally India ranks first in area under rice cultivation, it ranks seventh in productivity. More than 50% of paddy cultivation is under rainfed conditions. The state of Uttar Pradesh (UP) is one of the largest contributors (14%) to the national rice stock. Approximately 30% of the paddy area (i.e., 1.9 million ha) in UP is cultivated under rainfed conditions and the total seed requirement for this area is estimated at around 0.66 million qts. The seed replacement rate of all the rice varieties in the state is around 12.5%. However, for rainfed conditions, it is less than 8%. The situation in other states of eastern India is worse.

Seed requirement

Seed is the most important component contributing to increased crop production and productivity. Seeds should be of high genetic character, healthy, free from any disease and pest infestation, pure (without contamination) with good germination and appropriate for local conditions (e.g., resist stress conditions of the area).

The use of unidentified and unknown grain as seed may not ensure the required levels of production as it may not suit local conditions. The crop grown from such seed may not use inputs efficiently, and it may not withstand stress conditions. It may also be susceptible to various pests and diseases.

The farmer's own paddy produce may not always be as good as the newly procured certified seed. The farmer's rice crop may become contaminated and degenerate with time and agroclimatic situations. It is therefore better to change seeds at least every third year, and use appropriate high-yielding varieties.

Classification

For the production of genetically pure and high-quality seed, four classes of seed are defined.

Nucleus seed: This is the original seed in a very small quantity available to the plant breeder and it is used for breeder seed production.

Breeder seed: This seed is directly produced and controlled by originating institutions, and its quality is very closely monitored. A committee consisting of representatives of the National Seed Corporation, ICAR, Seed Certification Agency and the breeder takes care to ensure the purity of this class of seed.

Foundation seed: This is the direct multiplication of breeder seed and is produced under strict supervision of technical experts. This seed has a high degree of genetic purity.

Certified seed: This is a progeny of the foundation seed. This seed maintains sufficient genetic purity of the variety and other standards of seed, which is certified by an appropriate certification agency.

National seed multiplication program

The key players in the seed multiplication program in India include the Indian Council of Agricultural Research (ICAR), the state agricultural universities and the central and state governments and their organizations.

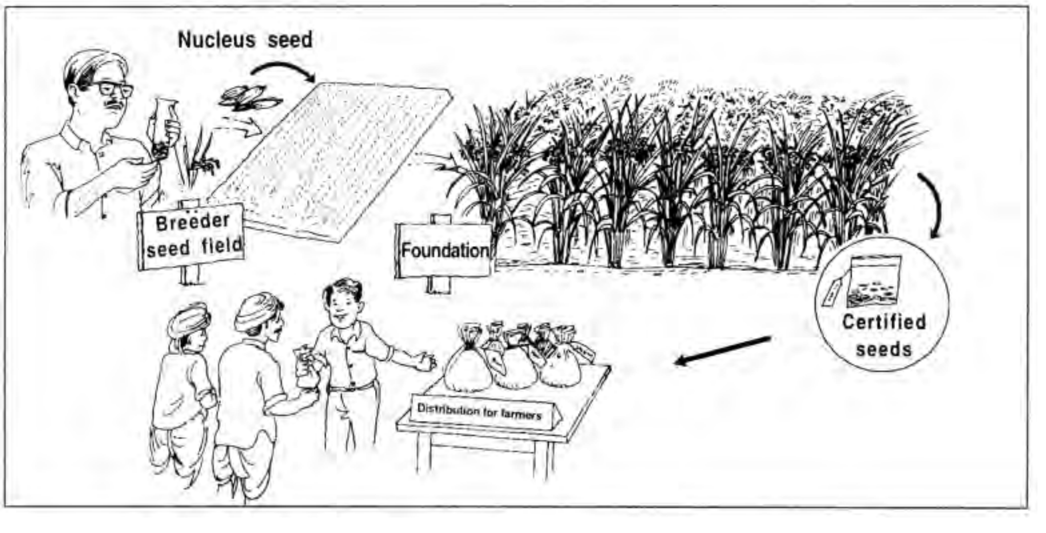
Almost every state has a seed certification agency that certifies and authenticates foundation and certified seeds grown by various agencies. The important agencies engaged in seed multiplication activities in India are the National Seed Corporation, State Farms Corporation, 13 state seed corporations and more than 200 private seed companies. The contribution of the cooperative sector to the seed multiplication program is negligible.

There are 19 state seed certification agencies and 96 seed testing laboratories in the country which are responsible for certifying the purity of various approved varieties. This system of seed multiplication takes care of breeder seed, foundation seed and certified seed.

Seed multiplication program in Uttar Pradesh: towards a bigger role for farmers

In Uttar Pradesh, the seed multiplication program of various crops and varieties including paddy is being taken care of by the following institutions:

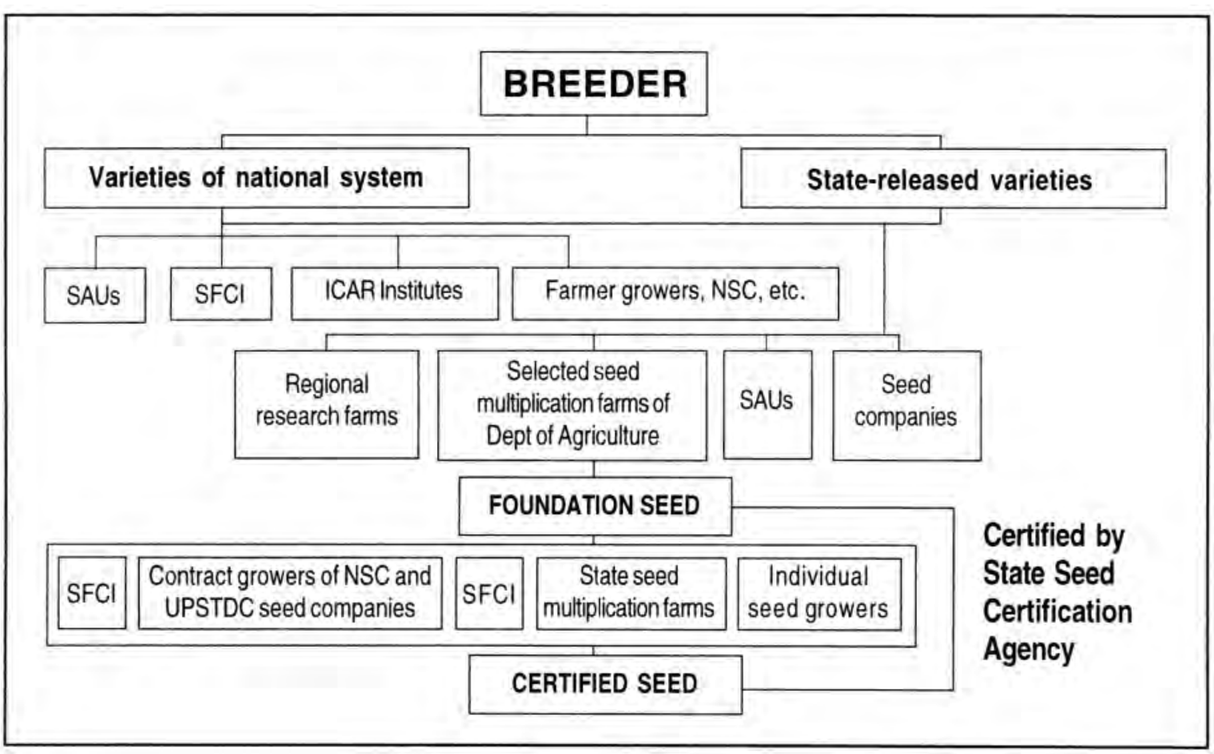
- three state agricultural universities (SAU)
- 180 seed multiplication farms of the Agricultural Department, spread over an area of 8148 ha (government system)
- the Uttar Pradesh State Tarai and Seed Development Corporation - UPSTDC (state seed corporation)
- the private seed-growing companies and individual farmer entrepreneurs
- the farms of State Farms Corporation situated in Uttar Pradesh (SFCI)
- National Seed Corporation (NSC) through the registered growers



The breeder seed multiplication and supply of centrally released and notified varieties is coordinated by the seed unit of the Ministry of Agriculture (MOA) and ICAR institutes. The breeder and foundation seeds of state-released varieties are maintained and multiplied under university supervision at the three state agricultural universities and the Banaras Hindu University (agricultural institute, Varanasi). These units also multiply centrally released varieties. Foundation seeds are also multiplied on the regional research farms and selected farms of the department of agriculture and at the farms of SFCT and selected contract growers of NSC and UPSTDC.

UP Tarai and the Seed Development Corporation and various other institutions under the corporate sector get the certified seeds produced through the registered growers who are the contract farmers of the company and the company ensures proper marketing of the seed. These registered growers enter into a memorandum of understanding (MOU) with the concerned corporations or institutions and get the seeds certified through the Seed Certification Agency. The parent material in all such cases (expected to be of very high purity) is arranged by the respective corporations/ institutions.

The registered seed growers or the contract farmers are expected to be skilled and possess well-leveled high-quality fertile land with appropriate irrigation facilities.



The entire multiplication chain needs a period of five years of advance planning to ensure an optimum quantity of certified seed. A detailed action plan is prepared for this time requirement. The department of agriculture, UP, has formulated a plan for seed multiplication for the next 15 years.

Constraints

Major constraints to seed multiplication include:

- The varietal development of paddy for rainfed conditions is too slow and very weak.
- Availability of high-yielding varieties and new improved varieties of rice for rainfed conditions is very poor.
- Multiplication of degenerated varieties occurs because new ones are not available.
- Multiplication of deepwater and very deep water varieties is not usually taken up on a large scale.
- The farmers in rainfed areas own comparatively small holdings and are considered resource-poor. Often, they cannot even afford to hold on to their own seed stock and they rely on seed materials from other less reliable sources; therefore, they can ill-afford to take risks of storing their produce to be used as seed which is required after a long time gap.

Traditional method of rice seed production

Farmers in the rainfed environment have their own traditional system of seed selection, storage and other management aspects. These systems, however, vary across the region.

Seed distribution

The seed produced by the UPSTDC, State Farms Corporations, SFCI, NSCI, etc., is distributed through the following chain.

- the state department-owned seed stores
- the cooperative societies
- the UP State Agro-Industrial Corporation
- the outlets of the private companies and private trade

The seed produced on the farms of the state government is distributed through departmental stores. This seed is also certified, graded and processed for other institutions.

Most of the paddy seed multiplied is basically for irrigated conditions. Incidentally, a majority of the varieties recommended for irrigated conditions are also cultivated in uplands as well as shallow rainfed lowlands. The seed multiplication for deep and very deep water situations is negligible and is largely confined to the SAUs.

Example of traditional method of rice seed production

Before harvesting the crop, farmers pick selected healthy panicles from the field, bundle them and keep them near the cooking place. This protects the seed from insect pest infestation as well as from humidity. Since the grains are unthreshed, they are not attacked by the grain pest. By following this process repeatedly, they try to maintain the genetic purity as well as take advantage of the healthy seed which is best-acclimatised to local conditions.

The new approach to a seed multiplication program: the UP perspective

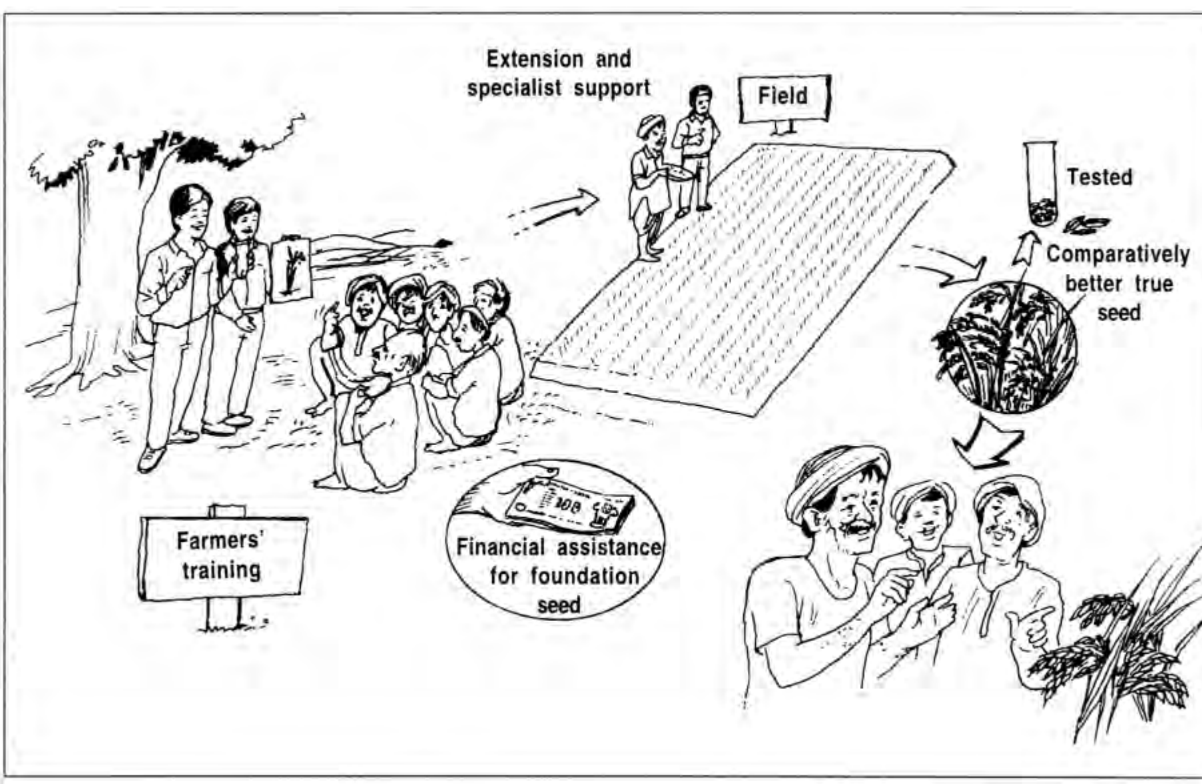
The state government has drafted a seed policy to ensure extensive seed multiplication of high-yielding and newly developed varieties in optimum quantity so as to attain an SRR of 15%) by the end of the five-year plan and 20% by 2020.

Some major thrusts of the program are:

- The research system for varietal development for rainfed and various stress conditions is to be strengthened.
- A larger investment in infrastructure development for supporting the research system is to be ensured.
- The seed multiplication process is to be accelerated.
- A system of high-quality seed production by farmers for local needs would be put into operation.
- The infrastructure support and skill development of farmers for seed multiplication would be intensified.

In the process, a program of quality seed production on a massive scale has been laid out. Salient features of the program are:

- A few farmers from each village would be selected for multiplication of the seed of the appropriate variety, most suited to local conditions, and to be grown on an appropriate, manageable area.
- These farmers would be trained on the technique of seed multiplication and an improved package of practices.



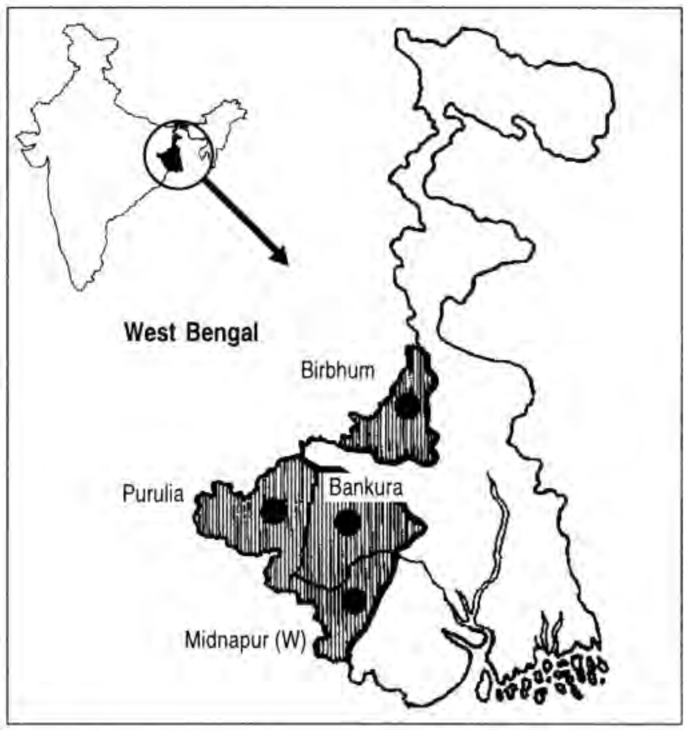
- The village extension workers and the specialist would guide the seed producer-farmer during frequent visits to the field and at any time of need (to ensure healthy and pure crop production).
- These farmers would be provided the required foundation seed at a subsidised rate of 50% of the cost of seed (at present Rs. 500 per quintal). This would serve as an incentive to farmers to grow rice for seed.
- The seed multiplied in this manner would certainly be better than the unidentified and old seed available to farmers. The seed may be sold or exchanged locally. Although this seed may not be certified, it is expected to be better than the local unidentified seed. It could also help increase farmers' income as they can engage in farm-level seed sales.

Prepared by:
D.C. Gupta

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Influence of High-Quality Seeds on Rainfed Upland Rice Yield

West Bengal grows 0.6 million ha of rice in rainfed uplands. With the introduction of improved-quality seed, as in the mid-l970s, much change in rice yield has been noticed. To highlight the role of improved-quality high-yielding variety (HYV) seeds in enhancing rice production in this ecosystem, a project was carried out during 1992-1995. The districts of Bankura, Purulia, Birbhum and Midnapur (West) were included in the study.



Characteristics of the environment

- The bulk area is distributed in red and lateritic tracts.
- The ricefieids are broadly divided into bunded and unbunded types of topography ranging from 2% to 4% slope to flat, terraced or unterraced land forms.
- Because of the topography and high internal drainage arising from light texture of the soil, the fields do not impound rainwater.
- The rice crop in this region is generally directly sown in unbunded fields and transplanted in bunded fields.
- The rainfall varies from 1200 mm to 1300 mm.
- Monsoon generally starts from the second to third week of June and ends by mid-September.
- About 80% of the total rainfall occurs during these months. But due to undulating topography and poor soil depth, 50% of the rain flows away as runoff. As a consequence, the moisture balance of the soil normally lasts for about 70-75 days, thereby extending rice cultivation in this ecosystem.
- Rice is sown just after the onset of monsoon.

Constraints to rice production in red and lateritic soils

Because of environment, farmers usually cultivate local seed varieties with low-cost traditional methods. The yields of these varieties are very poor.

The specific constraints are as follows:

- Intermittent soil moisture stress due to erratic distribution of rainfall and poor moisture-holding capacity of the soil
- Heavy weed infestation
- Loss of applied nitrogen due to runoff and deep percolation
- Nutrient stress in the soil (nutrient deficiencies, toxicities and adverse soil pH)
- Uneven germination due to quick disappearance of soil moisture, leading to poor crop stand and poor soil fertility, resulting in poor crop growth and low panicle density and grain number per panicle
- Farmers' apathy to adopting modern technology due to economic backwardness and lack of knowledge

Impact of high-quality seeds

Technologies for boosting production in this ecosystem are available. Among these, replacement of farmers' seeds with improved ones is the least costly. Adoption of improved seed was therefore considered as an important impact point in the pilot project.

About 53 direct-seeded demonstrations in an unbunded situation and 110 transplanted demonstrations in a bunded situation were laid out in the four districts. The control in both types of demonstrations was the farmers' local seed. The demonstration fields, including the control, were under the same management.

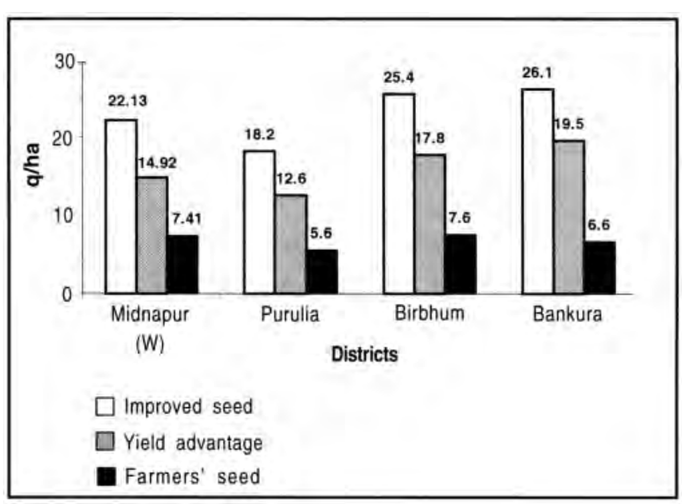
- Use of high-quality seeds alone can ensure yield advantage of 5.6-7.6 q/ha in bunded transplanted fields on red and lateritic soils.

Improved varieties used in the demonstrations

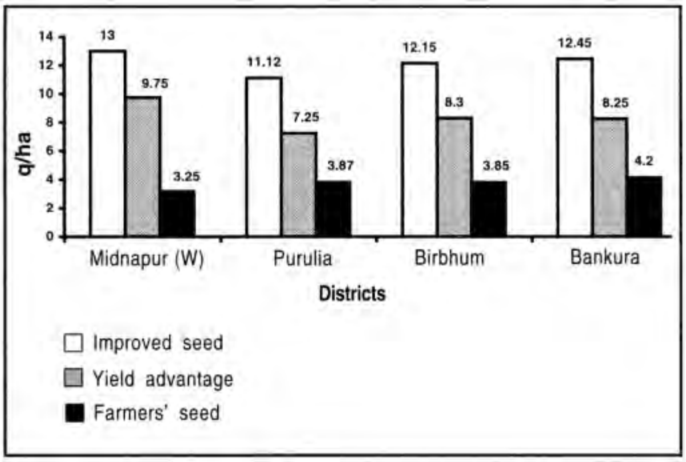
Bunded fields
- Bhupen
- Annada
- IET – 12029

Unbunded fields
- Heera
- BG – 367-4-1
- BG – 367-7-1

Yield of transplanted rice as influenced by high-quality improved seed in field demonstrations during 1992-95 in rainfed uplands of four West Bengal districts



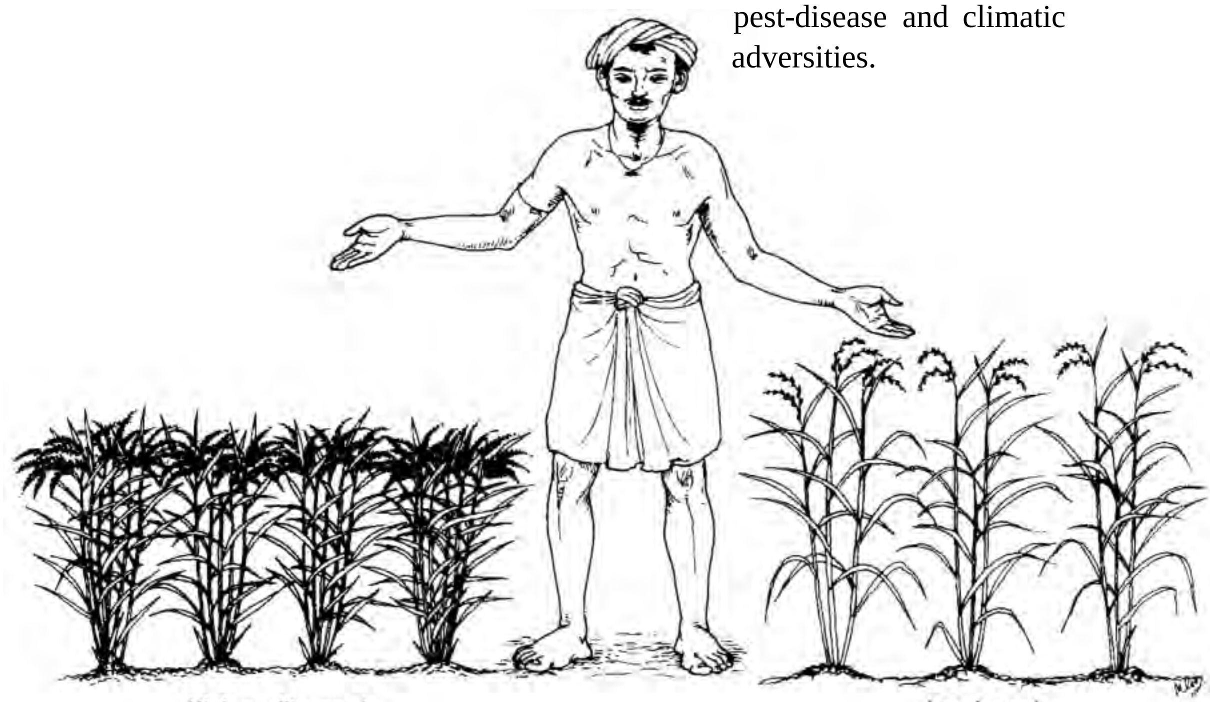
Yield of direct-seeded rice as influenced by high-quality improved seed in field demonstrations during 1992-95 in rainfed uplands of four West Bengal districts



- The yield advantage through the use of high-quality seeds in direct-seeded unbunded fields ranged from 3.25 q/ha to 4.20 q/ha in various districts.

Characteristics of high-quality seeds

- improved germination, vigorous early growth;
- capacity to suppress weeds, leading to adequate plant population and growth;
- efficient uptake and use of nutrients and water from soil through well-developed rooting system; and
- higher tolerance to prevailing pest-disease and climatic adversities.



Subijam sukshetre jayate sampadyate
(Good seeds in good soil yield abundantly)
Manu Smriti

Prepared by:
S.D. Chatterjee

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

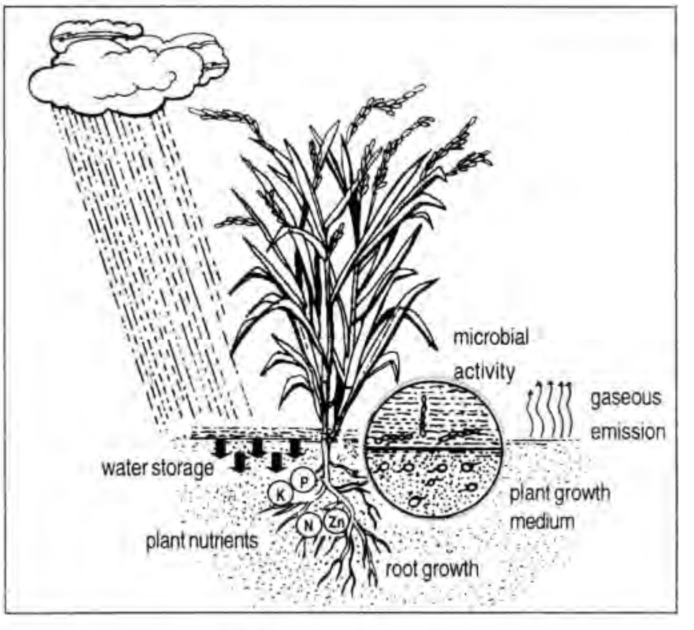
Soil and Nutrient Management

Soil Quality and Land Suitability Classes for Different Rainfed Rice Ecosystems

Soil is a natural non-renewable resource and medium for plant growth.

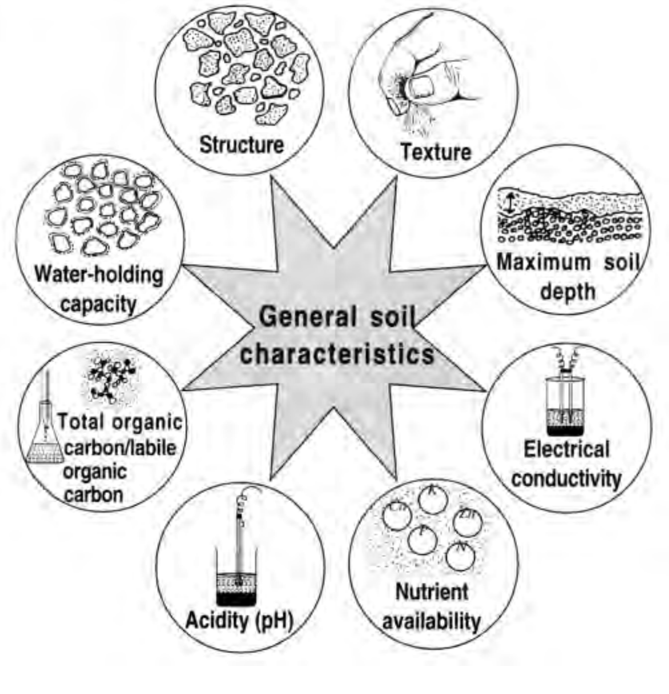
Functions of the soil

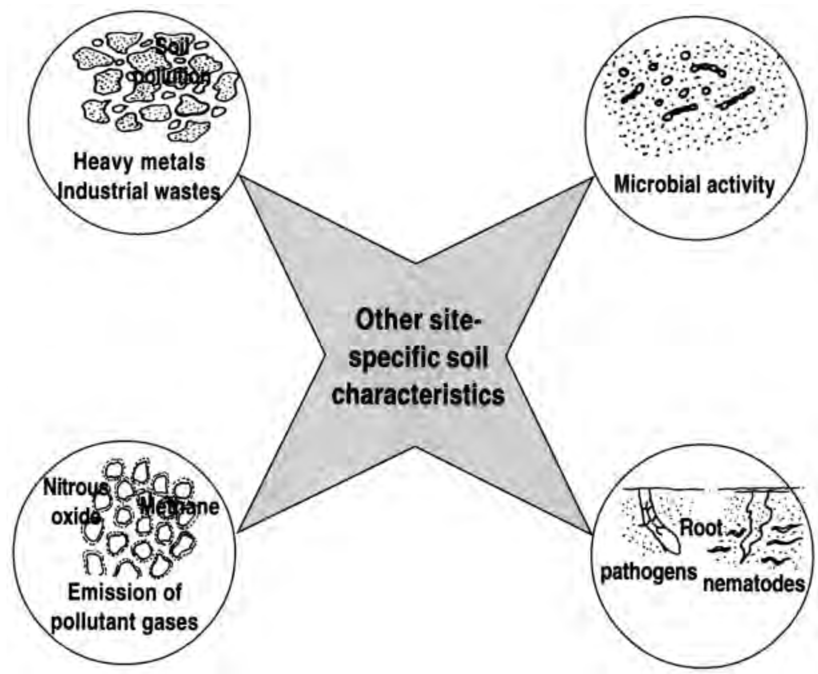
- Provides physical conditions for root growth and water storage.
- Source of essential plant nutrients.
- Harbors microbes affecting nutrient cycling.
- Acts as an environmental filter to control the quality of both ground and runoff water.
- Source of gaseous emission to the atmosphere.
- Has the capacity to sustain biological productivity.
- Can maintain environmental quality.
- Supports life forms dependent on it.



Soil characteristics

Improper management of soil resource leads to degradation of the soil, resulting in poor productivity. Soil quality assessment is, therefore, an important factor for sustainable use of soil resources.





Land suitability classes

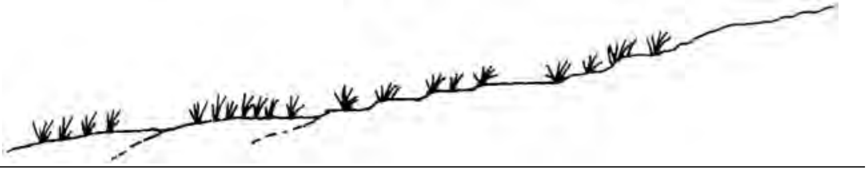
Based on the different soil characteristics, land suitability classes for different rainfed rice ecosystems have been identified and shown in the following tables.

Soil characteristics common to all rainfed rice ecosystems

Characteristics/ factors	CLASSES				
	Suitable	Moderately suitable	Marginally suitable	Unsuitable but potentially suitable	Potentially unsuitable
Depth of impermeable layer (cm)	>90	>50	>20	>20	<20
Rockiness (%)	0	<2	<10	<10	>10
Surface stones (m apart)	>100	>30	>10	>1.5	any
Electrical conductivity (dSm^{-1} in saturation extract)	<2	<4	<6	<6	>6
Exchangeable sodium (%)	40	<30	<40	<40	>40
Calcium carbonate (%)	<6	<15	<25	<25	>25
Base saturation (%)	>50	>35	45		
PH	5.5-7.5	5.2-5.5 or 7.5-8.2	4.2 or >8.2		
Apparent cation exchange capacity [cmol (p+) kg^{-1} soil]	>16	>0 (negative charge)	>0 (negative or positive charge)		
Organic carbon (%) in surface soil					
■ Low-activity clay	>1.5	>0.8	<0.8		
■ Calcareous soil	>0.8	<0.8			

Land suitability classes for different rainfed rice ecosystems

Rainfed unbunded rice (upland)



Soil characteristics/ factors	CLASSES Suitable	Moderately suitable	Marginally suitable	Unsuitable but potentially suitable	Potentially unsuitable
Slope (%)					
■ Mechanical	<4	<8	<16	<25	>25
■ Primitive	<8	<16	<30	<30	>30
Flooding	None	None	None to slight	None to slight	Any
Natural drainage					
■ Fine texture	Good	Moderate or better	Imperfect or better	Poor or better	Very poor or better
■ Coarse texture	Imperfect	Imperfect or moderate	Good, moderate or imperfect	Poor or better	Very poor or better
Surface texture/ structure	Clay to loam	Clay to loamy fine sand	Clay to coarse sandy	Clay to coarse sandy	Clay massive to coarse sandy
Surface coarse fragments (%)	<15	<35	<55	<55	>55
Sub-surface texture	Clay with weak structure to sandy clay loam	Clay to loamy fine sand	Clay to fine sand	Clay to fine sand	Clay massive to coarse sandy
Sub-surface coarse fragments (%)	<35	<55	<55	<55	>55

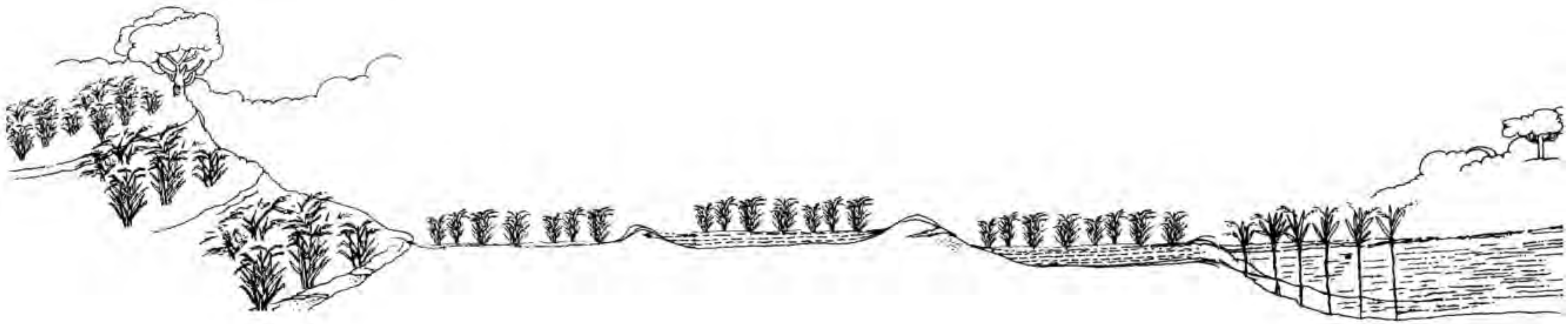
Rainfed bunded rice (lowland)

Soil characteristics/ factors	CLASSES Suitable	Moderately suitable	Marginally suitable	Unsuitable but potentially suitable	Potentially unsuitable
Slope (%)	0-4	4-8	8-12	12-25	>25
Flooding	No flooding to 10-20 cm for 3-4 months	No flooding to 10-20 cm for >4 months	No flooding to 20-40 cm for >4 months	No flooding to 40-80 cm for >4 months	No flooding to >80 cm for >4 months
Natural drainage	Imperfect	Poor to moderate	Poor to good	Poor to good	Very poor to good
Surface texture/ structure	Clay massive to silty clay	Clay massive to silt	Clay massive to sandy clay	Clay massive to sandy clay	Clay massive to coarse sandy
Surface coarse fragments (%)	None	<15	<35	<35	>35
Sub-surface texture	Clay massive to silt	Clay massive to sandy clay	Clay massive to loamy fine Sand	Clay massive to loamy fine sand	Clay massive to coarse sand
Sub-surface coarse fragments (%)	None	<15	<35	<35	>35

Deepwater rice

Soil characteristics/ factors	CLASSES Suitable	Moderately suitable	Marginally suitable	Unsuitable but potentially suitable	Potentially unsuitable
Slope (%)	No	<2	<4	<6	>6
Flooding	<10 cm to 10-20 cm for 3-4 months	10-20 cm for 3-4 months or >4 months	10-20 cm for 3-4 months to 40-80 cm for 2-3 months	10-20 cm for 3-4 months to 40-80 cm for 2-3 months	10-20 cm for 3-4 months to no flood,
Natural drainage	Poor	Very poor to imperfect	Very poor to moderate	Very poor to moderate	Very poor to good
Surface texture/structure	Clay massive to silty clay	Clay massive to sandy clay loam	Clay massive to fine sand	Clay massive to file sand	Clay massive to fine sand
Surface coarse fragments(%)	<15	<35	<55	<55	>55
Sub-surface texture	Clay massive to loamy fine sand	Clay massive to coarse sand			
Sub-surface coarse fragments(%)	<35	<55	>55		

Soil Limitation and possible solutions under different rainfed rice ecosystem



	UPLAND Drought-prone	LOWLAND Drought-prone	LOWLAND Favourable	LOWLAND Drought/submergence-prone	DEEPWATER/TIDAL WETLANDS Waterlogged
Limitations	■ Soil erosion ■ Waterstress ■ Soil acidity/alkalinity ■ Low organic carbon ■ N, P, S, Ca, Mg deficiency	■ Waterstress ■ surface stones ■ coarse fragments on surface ■ N, P, ZN, Fe, B deficiency High calcium carbonate	■ N, P, ZN difficiency ■ High calcium carbonate	■ Poor drainage ■ Flooding/drought at early stage of crop ■ Secondary salinisation ■ N, P, ZN deficiency ■ Fe toxicity	■ Waterlogging/flood ■ High salinity ■ N, P, K, Ca, Mg deficiency ■ Fe toxicity
Solution	■ Nutrient loss ■ Al toxicity ■ Suitable soil and water conservation measures ■ Drought-resistantvarieties ■ Use of chemical amendmens ■ Additionof organic matter ■ Addition of required amount of fertilizer by correct method	■ Suitablesoilmoisture conservation measure ■ Drought-resistant varieties ■ Innovativemethod of puddling and transplanting ■ Addition of required fertilizes/amendments by correct method	■ Additionod required fertilizer and amendments by correct method	■ Surface drainage ■ Bunding ■ Addition of required fertilizer by coorect method and suitable nutrient management practices ■ Varieties tolerant to iron toxicity	■ Bunding ■ Varieties tolerant to salinity and waterlogging ■ Addition of required fertilzer by correctmethod ■ Varietiestolerant to Fe toxicity

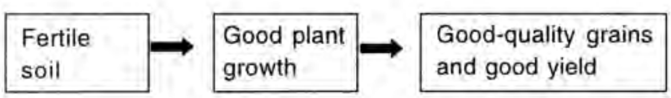
Symbols: N-Nitrogen; P-Phosphorus; K-Potassium; Ca-Calcium; Mg-Magnesium; S-Sulfur; Fe-Iron; Zn-Zinc; B-Boron; Al-Aluminum

Prepared by:
P. C. Srivastava

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Dealing with Decline in Soil Fertility and Land Productivity

Soil is the storehouse of all plant nutrients. Roots absorb nutrients from the soil for plant growth and nourishment. A fertile soil supports healthy crop growth and produces good yield and good-quality grains by supplying major nutrients and micronutrients in a balanced proportion to the crop. Decline in soil fertility seriously hampers crop growth and reduces yield drastically. It makes plants more susceptible to diseases and pest attack and also decreases the productivity of the land.



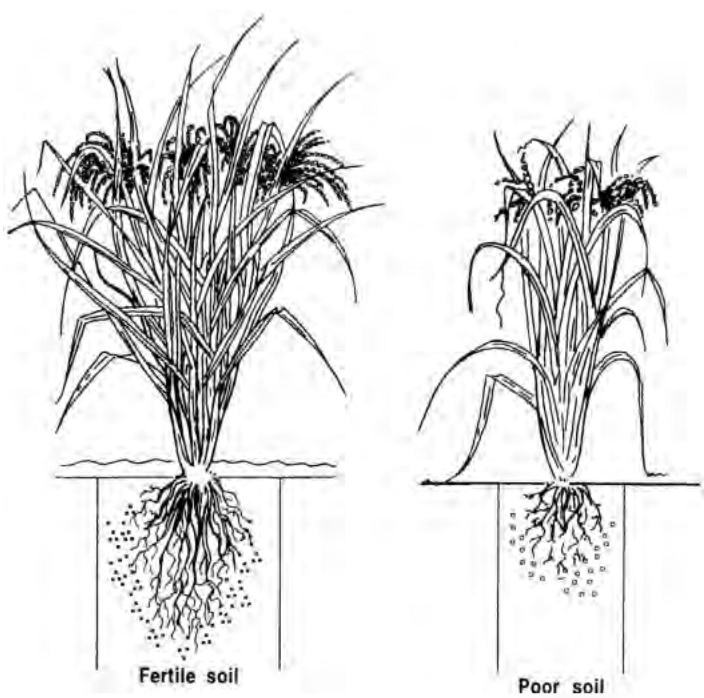
Soil is a natural resource. If sustained, it can eradicate hunger from the world. Therefore, all efforts should be made to keep it productive and sustainable.

Fertile soil

- Has adequate supply of plant nutrients.
- Has no soil problems.
- Has adequate rooting depth and water-holding capacity.
- Has high/normal organic matter content.
- Has medium to fine soil texture.

Poor soil

- Has inadequate supply of plant nutrients.
- Has soil-related problems.
- Has shallow depth and poor water-holding capacity.
- Has low organic matter.
- Has coarse texture.



Why do soil fertility and land productivity decline?

Soil fertility and land productivity decline due to:

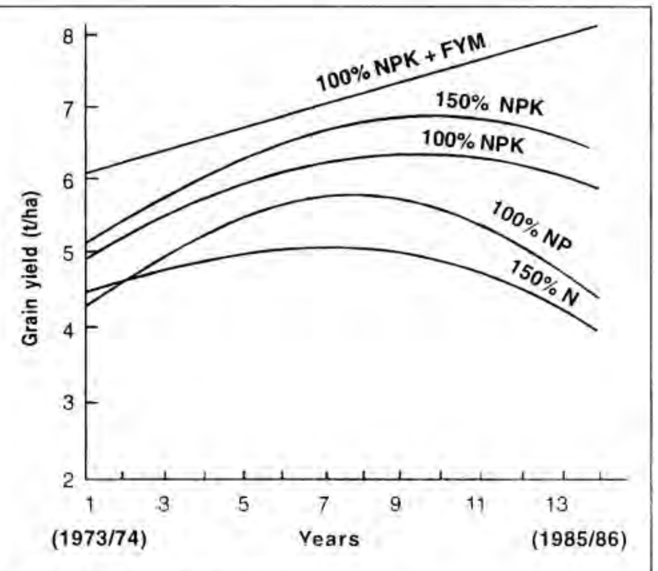
- Continuous cropping without replenishing the nutrients through external sources.
- Imbalance in application of plant nutrients to the soil.
- Indiscriminate use of fertilisers and inappropriate methods of cultivation.
- Lack of or inadequate application of organic manure to the soil.
- Improper land, soil and water management practices.
- Use of inappropriate cropping patterns.
- Erosion of fertile surface soils.
- Improper tillage practices.
- Improper crop management practices.
- Waterlogging and/or occurrence of drought.

Improving soil fertility and land productivity

Integrated use of organic and inorganic fertilisers

Apply as much organic manure as available [up to 10 t/ha of compost or farmyard manure (FYM)] annually and mix it thoroughly with the soil at least two to three weeks before sowing/planting. In addition, use chemical fertilisers during crop growth. Continuous application of organic manure and inorganic fertiliser together builds up soil fertility and increases the yield of subsequent crops.

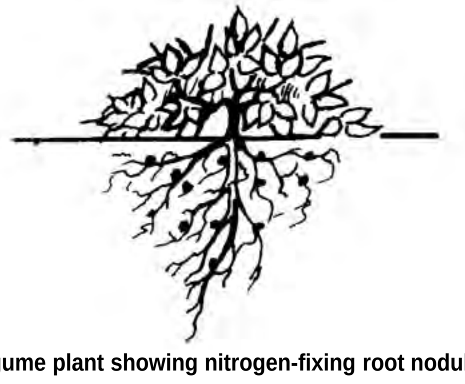
Yield trend of rice (kharif + rabi) in laterite soil in Bhubaneshwar, Orissa



Source: Nambiar, K. K. M. (1994)

Green manuring

Grow green manure crops [*dhaincha* (*Sesbania aculeata*)] *in situ.* Grow green-leaf manure trees such as *Gliricidia* spp. or other leguminous crops on field bunds and incorporate the foliage into the soil. Green manuring improves nitrogen (N)-use efficiency of fertiliser N as well as conservation and utilisation of soil



Legume plant showing nitrogen-fixing root nodules

moisture. *In situ* green manuring is better than growing the green manure crop elsewhere and incorporating it into the soil in another field.

Application of nutrients based on soil test values

Almost all the districts in eastern India have soil-testing laboratories. Before sowing operations, test the soil for its available nutrient content. Apply an adequate amount of the required nutrients.

Application of appropriate type of fertiliser

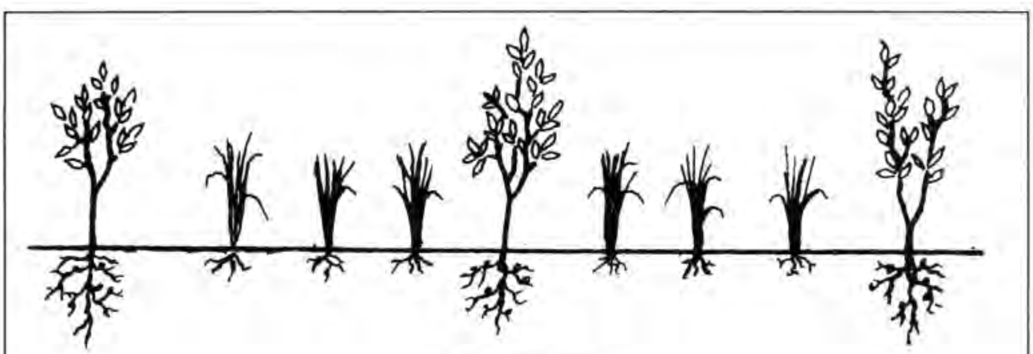
Do not apply ammonium fertilisers to soils having high pH, as it encourages volatilisation loss of ammonia from the soil. Instead, urea will serve as a, better source of N.

Placement of fertilisers

Apply fertilisers in the furrows along the seed at the time of seeding in direct-seeded rice and incorporate it before transplanting in the transplanted crop.

Inclusion of legumes in rice-cropping systems

Include a legume/pulse crop (e.g., mungbean) after wet season rice depending upon the availability of soil moisture. This improves soil fertility due to the presence of useful bacteria (i.e., *Rhizobium* sp., N_2-fixing bacteria) in the root nodules of the pulse crop. In upland soil, include a pulse crop as a sequential crop (e.g., rice-pigeonpea-rice) or as an intercrop (e.g., rice + pigeonpea). Incorporate the crop residues of the pulse crop into the soil to enhance the N content. Rice + pigeonpea is one of the best rice-based cropping systems. The combination of rice, a shallow-rooted crop, and pigeonpea, a deep-rooted crop, helps maximise utilisation of soil moisture and nutrients.



Rice + pigeonpea

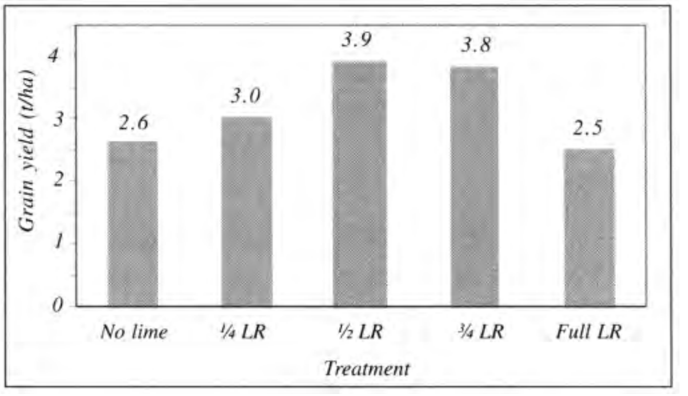
Phosphorus (P) application

Phosphorus deficiency is common in rainfed upland soils. In P-deficient soils, mix P fertiliser [single superphosphate (SSP)] with compost or FYM in a 1:2 ratio. Incubate the mixture for 72 h and place it in the seed furrows to improve P availability.

Alleviate soil acidity

Soil acidity and sometimes aluminum (Al) toxicity occur in rainfed uplands. To overcome these problems, apply half of the lime requirement (LR) recommended to the soil, two to three weeks before sowing/transplanting in alternate years. Deep plowing up to 15 cm depth helps in thorough mixing of lime in the soil and also inactivates Al.

Yield trend with different levels of lime application (with recommended dose of NPK) in farmers' fields in trials conducted by CRRI, Cuttack

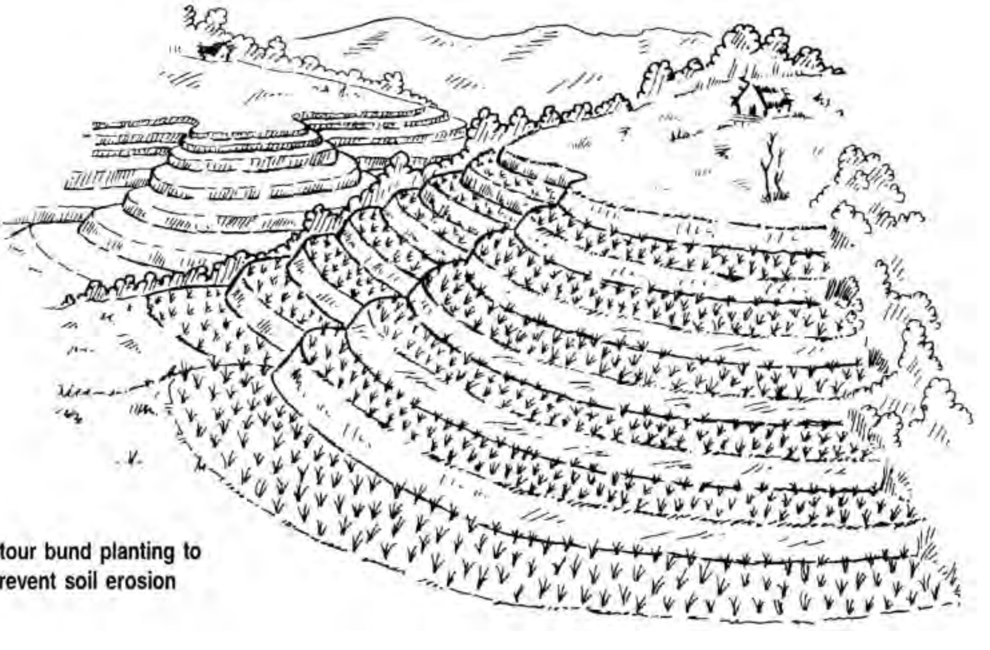


Zinc application

With intensive rice cultivation, soil fertility is declining and Zn deficiency has been widely reported. In Zn-deficient soils, apply 20-25 kg zinc sulphate ($ZnSO_4$) or 5 kg Zn-EDTA/ha before seeding or transplanting. Alternatively, dip the roots of rice seedlings in 0.5% $ZnSO_4$ or zinc oxide (ZnO) solution overnight before planting. Do not mix Zn with phosphatic fertiliser.

Land management practices

- The land should be levelled properly before sowing/planting rice to avoid soil erosion and runoff.
- In sloping uplands, soil and water conservation methods such as contour bunding, contour cultivation and planting and deep tillage should be adopted.



Contour bund planting to prevent soil erosion

- Summer ploughing should be done to conserve water and soil after early showers of monsoon, which subsequently helps in proper land preparation. This also facilitates leaching of soluble salts from saline soils and improves soil productivity. If rainfed lowlands have been summer ploughed, further ploughing to loosen the soil during the rainy season may not be necessary for transplanting rice.

Measures for arresting decline in soil fertility

- Organic manuring/recycling.
- Balanced nutrient application as per soil test.
- Correction of soil-related problems.
- Inclusion of legumes in rice-based cropping systems.
- Proper soil and water management.
- Adoption of integrated nutrient management technology.

Rainwater harvesting and recycling

- Rainwater harvesting and recycling are useful for life-saving irrigation during drought. A pond in 1/20 or 5% of rice area is appropriate to store enough water for providing irrigation. Construction of a pond in the middle of a sloping land can improve the productivity of the land. At the lower side of the pond, rice grows well due to seepage of water while crops at the upper side could be irrigated as and when needed, utilising the pond water.
- In lowlands, the drainage. system should be improved to avoid prolonged waterlogging. In shallow lowlands, management of levelling with increasing bund height should be followed to store more rainwater to mitigate drought, especially at later growth stages.

Case study

Soil and water conservation

A study was conducted in farmers' fields in Hazaribagh under upland conditions. Trenches (0.5 m x 0.5 m) dug at 10-m intervals in a sloping land increased the productivity of the land by 25-50% due to conservation of soil and moisture which supported good plant growth.

Prepared by:
S.K. Mohanty, V.P. Singh and R.K. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Balanced Fertilisation for Improving Soil Fertility and Increasing Yield

Balanced fertilisation

Crops need varying quantities of nutrients for their proper growth and productivity. The variation occurs within crops based on the total biomass production. These nutrients may be from either natural or artificial sources. Since rainfed farming depends on rainfall at different growth stages, there is always a factor of risk in such a type of farming.

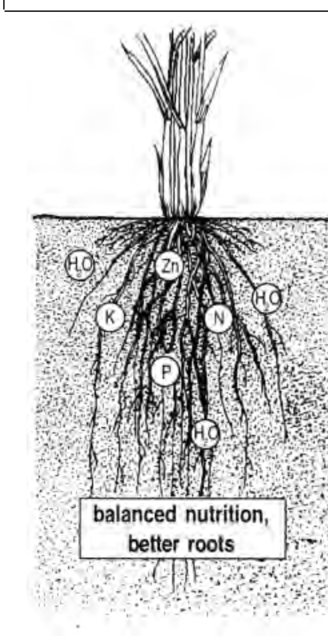
Farmers do not want to spend scarce resources on fertilisers and generally apply only nitrogenous fertilisers. However, the application of phosphorus and potassium provides drought resistance to the plants.

- The first important rule of thumb of input-responsive agronomy is balanced nutrition based on a soil test.
- Balanced nutrition enhances better root development.
- Better root development enhances the exploitation of water and nutrients from deeper soil depths.

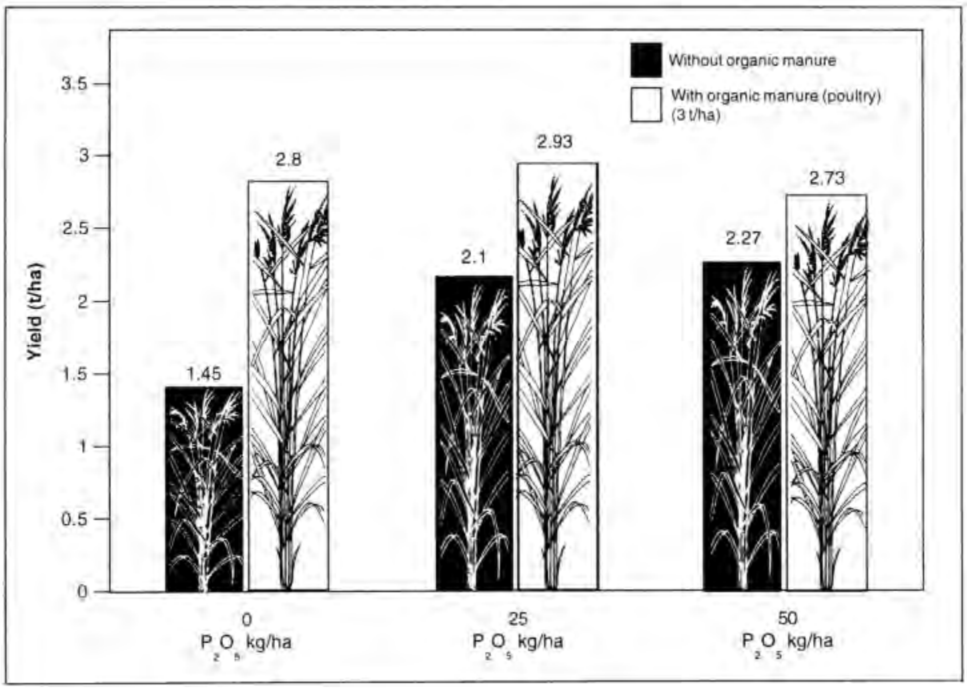
Application of phosphorus (P_2O_5) and organic manure increases the grain yield of upland rice, for example, by about 50% in the case of P_2O_5 and double in the case of manure. The results shown in the graph below are based on a nitrogen dose of 120 kg/ha, while the doses of phosphorus (P_2O_5) for this trial were 0, 25 and 50 kg/ha.

General overview

- Overexploitation and pressure on soil and water, along with imbalanced fertiliser use, deplete native nutrient reserves.
- According to a national study, it is estimated that about 10 m tons more of nitrogen, potassium and phosphorus are removed by crops in addition to the external supply.
- The rainfed farming system involves a high risk factor, resulting in extensive overexploitation of soil nutrients.
- To increase productivity under rainfed conditions, balanced fertilisation, along with use of organic manure, is a must.



Comparison of grain yield at different doses of P_2O_5 and organic manure



Integrated nutrient management

Integrated nutrient management means the supply of plant nutrients through the mixing of organic manure, biofertiliser and chemical fertilisers. The role of integrated nutrient management is very important, particularly in rainfed rice ecosystems.

- Input costs will be less due to the use of in-house organic materials like cattle dung, feed waste, crop waste, etc.
- It improves fertiliser use efficiency.
- It improves the moisture retention capacity of soil.
- It increases yield and net returns.
- Application of organic wastes also maintains a clean environment.

On the other hand, application of organic manure increases the water-holding capacity of the soil. For example, a study showed that at 2% and 7% organic matter levels,. available water supply was 0.25% and 0.26%, respectively, in heavy-texture soil. This means that the higher the organic matter application, the higher the available water content of the soil.

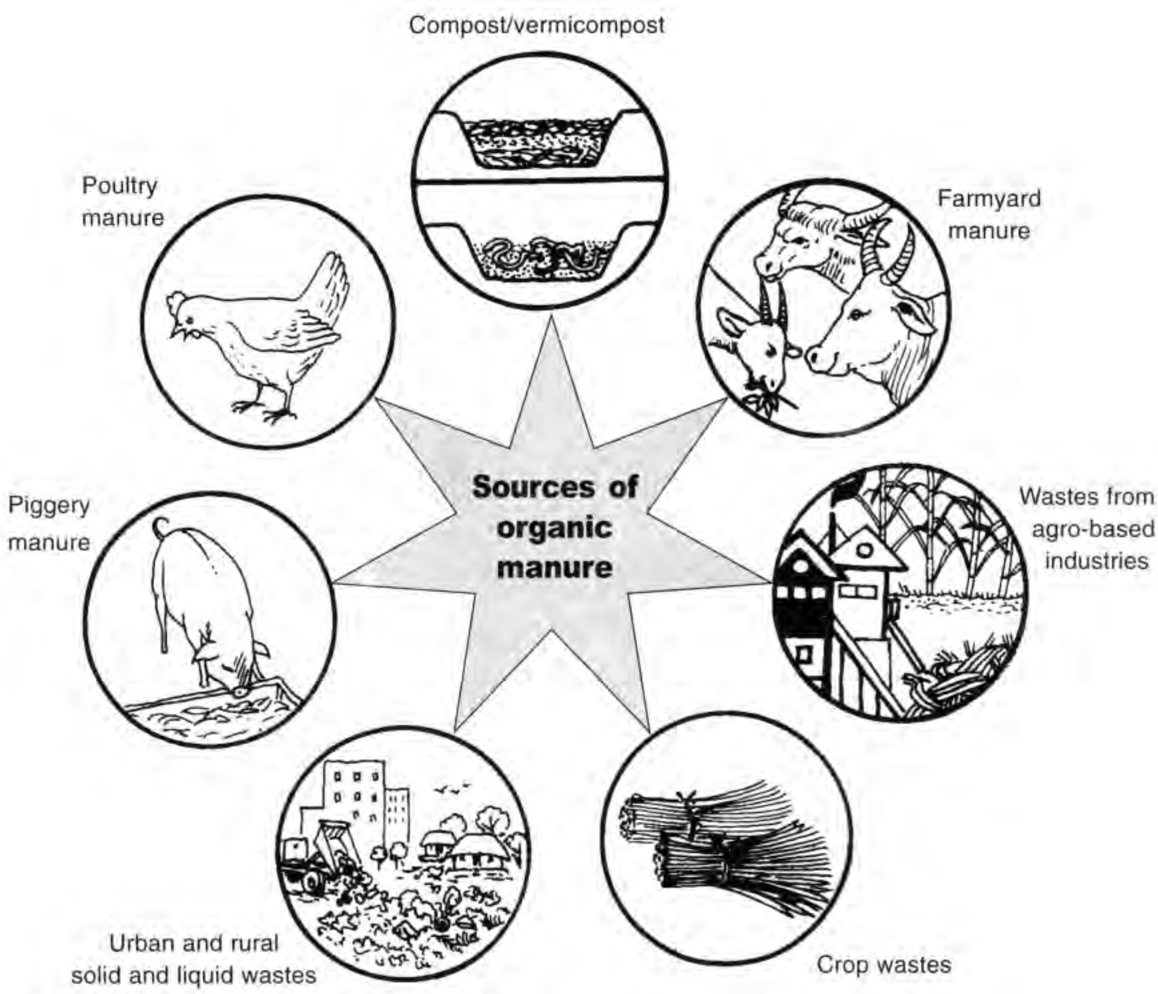
Under field conditions, a small application of organic manure normally increases the water content of the soil. In this way, water becomes available to rice plants for a longer duration. In drought conditions, the manured plants will also take longer before wilting.

Sources of organic manure

Any biological wastes that are used to fertilise the crop can be called organic manure, such as farmyard manure, compost, sludge, etc. A proper carbon to nitrogen ratio (C:N) is essential to ensure a supply of nutrients to plants; otherwise, immobilisation of plant nutrients may occur.

Nutrient removal

All crops absorb a definite quantity of plant nutrients from the soil. The removal of nutrients is entirely based on the yields of that crop. While the absorption of potassium varies from site to site, nitrogen and phosphorus (P_2O_5) uptake is almost constant and varies according to genotypes, quantity used and biomass.



Price for a ton of rice

A ton of rice, when harvested, removes small quantities of micronutrients and:

- 11-15 kg nitrogen;
- 3-5 kg phosphorus; and
- 11-15 kg potassium.

Fertiliser use efficiency

The portion of fertiliser removed by plants from applied quantities refers to fertiliser use efficiency (FUE). FUE is a very important issue with respect to the feasibility of fertilisation. The net return per unit of nutrient is always higher at its lower dose. It is advised, however, that the economic return be considered as an important criterion while recommending any dose to the farming community.

Nutrient removal by rice crop under various treatments

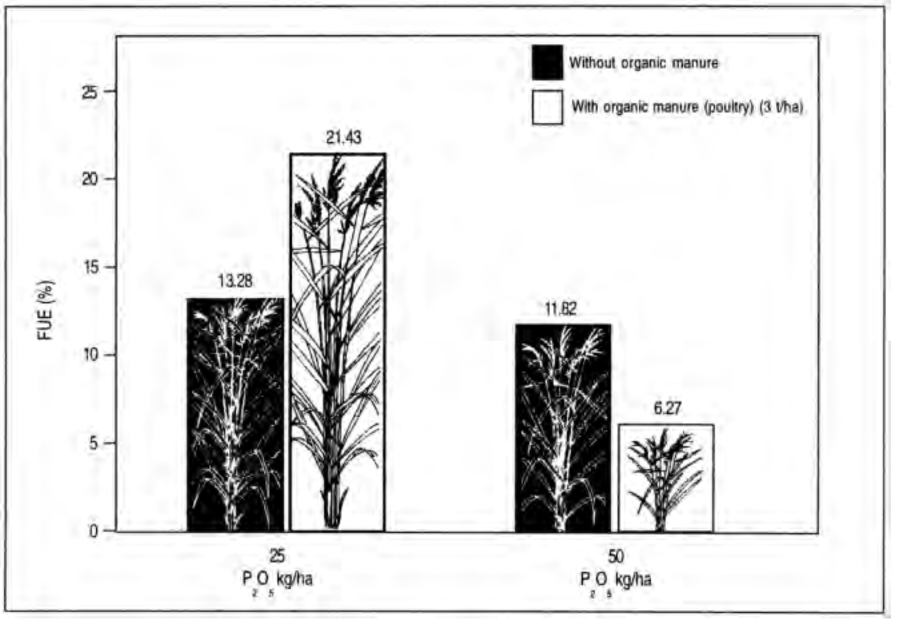
Ndose	P dose	Without organic manure			With organic manure		
(kg/ha)	(kg/ha)	N	P	K	N	P	K
120	0	21.8	3.9	22.8	42.0	8.1	44.0
120	25	33.6	5.4	35.1	45.0	10.5	48.1
120	50	34.1	6.5	37.6	42.1	9.5	44.9

Factors affecting FUE

Types of fertiliser

Choose proper types of fertilisers, such as water-soluble phosphatic fertilisers for normal to alkaline soils or citrate-soluble and mineral acid-soluble fertilisers for acidic soils.

Phosporous use efficiency at two levels of phosphorus and two levels of organic manure application at a constant level (120 kg/ha) of nitrogen



Quantity of fertiliser

Use optimum fertiliser quantity to get proper growth and development of a crop. If yield is low because of the deficiency of the applied nutrient, FUE will also be low.

Balanced fertilisation

The FUE of one fertiliser can be increased by balanced fertilisation.

Improving soil fertility

Maximising yield without deteriorating soil health is one of the biggest challenges to farm scientists. Integrated plant nutrient supply system (IPNS) is one of the best methods developed so far to improve soil fertility. In this method, organic manure can maintain plant nutrients in the available forms for longer periods than chemical fertilisers. The results of the demonstrations in farmers' fields indicate that soil fertility can be improved with the use of organic manure in conjunction with chemical fertilisers.

The following table indicates the improvement in some soil characteristics with the use of organic manure in the rice-wheat cropping system.

Crop season	With chemical fertiliser Rice/wheat: 150:60 kg N and P_2O_5 /ha			IPNS Rice: 20 t FYM+120:30 kg N & P_2O_5 /ha Wheat: 150:60 kg N & P_2O_5 /ha		
	Organic carbon (%)	Available K (kg/ha)	Available P (kg/ha)	Organic carbon (%)	Available P (kg/ha)	Available K (kg/ha)
Initial	0.26	8.71	366	0.26	8.7	366
After rice	0.26	9.02	333	0.39	9.50	389
After wheat	0.22	7.66	311	0.36	9.76	391

Conclusions

- Rainwater harvesting is essential for obtaining good yields under the rainfed ecosystem.
- Application of organic manure improves the available water content of the soil.
- Application of organic manure improves fertiliser use efficiency.
- Application of fertilisers based on soil tests enhances drought tolerance in plants and increases yields and profits.
- Bund placement of fertilisers enhances their efficiency.
- Integrated nutrient management is the key for high productivity and improving soil fertility.

Prepared by:
A. P. Gupta

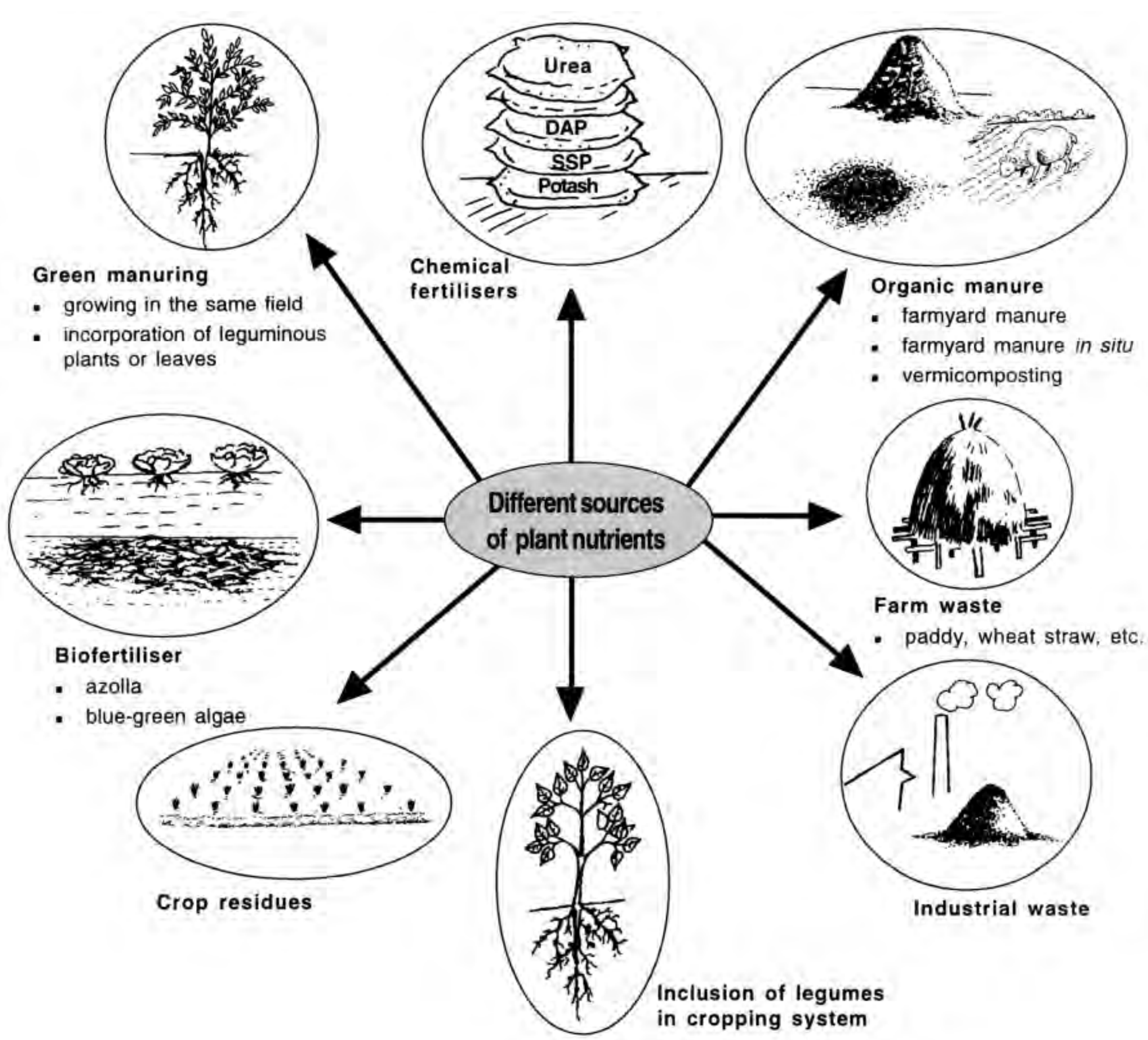
Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Integrated Nutrient Management

What is integrated nutrient management (INM)?

Integrated nutrient management is the maintenance or adjustment of soil fertility and plant nutrient supply at an optimum level to sustain the desired crop productivity. This is done through optimisation of the benefits from all possible sources of plant nutrients in an integrated manner.

In other words, integrated nutrient management is the use of different sources of plant nutrients integrated to check nutrient depletion and maintain soil health and crop productivity.



Why is integrated nutrient management needed?

The increasing use of chemical fertilisers to increase the production of food and fibre is causing concern for the following reasons:

- Soils which receive plant nutrients only through chemical fertilisers are showing declining productivity despite being supplied with sufficient nutrients.
- The decline in productivity can be attributed to the appearance of deficiency in secondary and micronutrients.
- The deteriorating physical condition of the soil, which is a consequence of the long-term use of chemical fertilisers, especially the nitrogenous ones, aggravates the problem of poor fertiliser nitrogen use efficiency (NUE). Excess nitrogen use leads to groundwater and environmental pollution apart from destroying the ozone layer through N_2O production.
- The recent energy crisis, high fertiliser cost and low purchasing power of the farming community have made it necessary to rethink alternatives.
- Unlike chemical fertilisers, organic manure and biofertilisers are available indigenously at cheaper rates. They enhance crop yields per unit of applied nutrients by providing a better physical, chemical and microbial environment conducive to higher productivity.
- The available quantity of animal excreta and crop and aquatic residues cannot meet the country's requirements for crop production. Therefore, maximising the usage of organic waste and combining it with chemical fertilisers and biofertilisers in the form of integrated manure appears to be the best alternative.

Studies in the United States have indicated that increasing incidence of methamolobinarnia (a condition which prevents blood haemoglobin from carrying oxygen to the body cells) was linked to the intensive application of nitrogenous fertilisers.

Benefits of integrated nutrient management practices

Application of organic manure under rainfed lowland conditions

- Improves the bulk density of soil up to a layer of 25 cm.
- Reduces resistance to penetration.
- Supplements N up to 50% of the nitrogenous requirement of the crop.
- Increases available N and N and P use efficiency when combined with 100% of the recommended quantity of NPK + biofertilisers.

Do you know that?

- Green manuring through *Sesbania aculeata* is equivalent to 60 kg inorganic N/ha in rice.
- Mungbean as a green manure crop for rice is as effective as 80 kg inorganic N/ha.
- Incorporation of mungbean after picking pods results in a savings of 60 kg inorganic N/ha for the rice crop.
- Alley cropping of *Leucaena leucocephala, Gliricidia sepium* and *Acacia mangium* can provide 100-300 kg N/ha per year.
- Pruning of *Sesbania rostrata* planted as hedgerows provides 3-4 t/ha dry matter; after decomposition, it releases an average of 70 kg N/ha.

Particulars	NUE (%)
Fertilisers	30.17
Fertilisers + organic manure + biofertilisers	38.73

Particulars	P utilization efficiency (%)
Fertilisers	14.95
Fertilisers + organic manure	21.70
Fertilisers + organic manure	25.58

Particulars	K apparent use efficiency (%)
Fertilisers (50%)	115.12
Fertilisers (50%) + organic manure	124.70
Fertilisers (50%) + organic manure + biofertilisers	138.00

- Increases apparent use efficiency of K when combined with 50% of the recommended NPK.
- Has a residual effect on the next crop.
- Is quite effective in minimising the adverse effects of Al^{3+} and/or Fe^{2+} in acidic lateritic soils through the chelation of these ions by organic molecules liberated from FYM in the course of mineralisation.

Application of biofertilisers such as azolla or blue-green algae

- Adds about 25-30 kg N/ha in the soil.
- Improves bulk density and reduces penetration resistance when it is added with organic manure.
- Has a residual effect on the next crop.

Use of green manuring in crop rotation before transplanting rice

- Supplements about 50% of the total N requirement of rice.
- Provides about 75-100% of the crop's requirement in the case of rainfed lowlands when the requirement for N is relatively low (60-80 kg N/ha).
- Has a mobilising effect on PK and micronutrients in the soil.
- Reduces the leaching and gaseous losses of N, thus increasing the efficiency of applied plant nutrients.
- Can skip the P application to rice when 30 kg P_2O_5/ha is applied to the green manure crop.

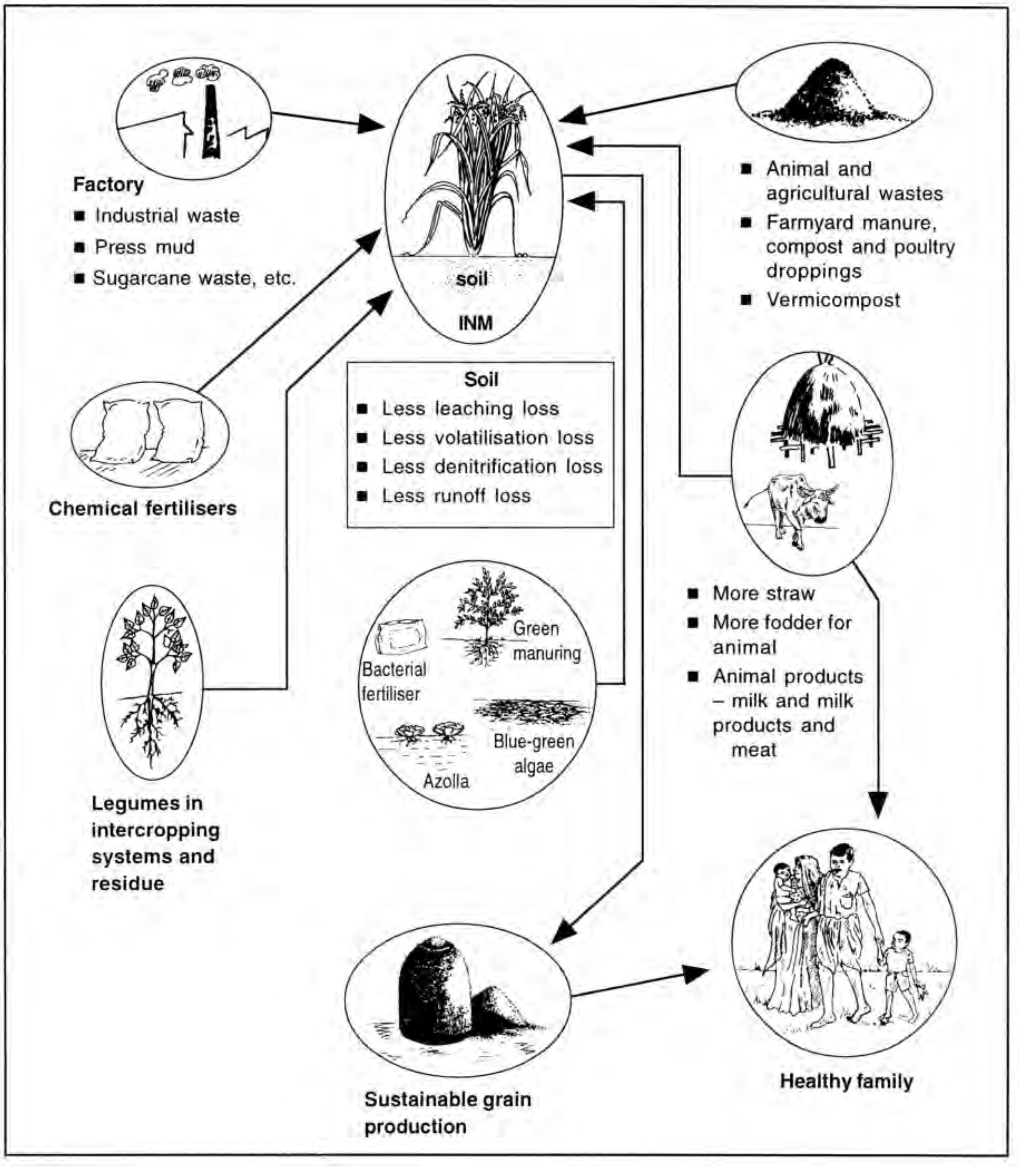
Incorporation of crop residues before rice

- Provides 20-25 kg N/ha.
- Improves the soil organic matter.
- Improves physico-chemical and biological condition of the soil.

Inclusion of grain/fodder legumes in the cropping system such as greengram, chickpea, lentil, fieldpea, lathyrus, cowpea, berseem, etc.

- Contributes as much as 50-60 kg N/ha to the succeeding crop of rice.
- Contributes about 60 kg N/ha when whole plant of mungbean is incorporated into the soil after picking the pods in the summer season.

Integrated nutrient management



Practices to be adopted

- Convert all available biomass on the farm into compost instead of burning or wasting it.
- Make use of cattle excreta as manure rather than as fuel.
- Prepare better quality compost by adding farm waste (paddy or wheat straw) + cattle excreta + rock phosphate in layers.
- Prepare vermicompost.

- Grow green manuring crop such as dhaincha (*Sesbania* spp.), sunhemp (*Crotalaria juncea*), etc., before the rice season.
- Grow some N_2-fixing trees such as *Leucaena leucocephala, Glyricidia sepium, Acacia mangium* and *Sesbania rostrata* as hedgerows in alley cropping 'and incorporate pruned biomass.
- Follow suitable cropping systems such as rice-legumes, rice-wheat, summer legumes, rice + arhar, rice-wheat + chickpea/lentil in crop rotation or in intercropping in the same year or once in two years.
- Before transplanting the rice crop, incorporate whole plants of leguminous crop grown in summer (such as greengram, blackgram and cowpea) after picking the pods.

INM practices for different ecosystems – options

Upland	Favourable lowland	Unfavourable lowland
■ Compost/FYM+ chemical fertiliser ■ Recycling of crop residue + biofertiliser + chemical fertiliser	■ Compost/FYM + chemical fertiliser ■ Recycling of crop residue + biofertiliser + chemical fertiliser ■ Green manuring/green leaf manuring + chemical fertiliser ■ Industrial and agricultural wastes + chemical fertiliser	■ Compost/FYM + chemical fertiliser (basal) ■ Industrial and animal wastes + crop residues

Organic and chemical fertilisers

Preferably to be applied in 1:1 proportion on the basis of nitrogen requirement.

Limitations of INM

Insufficient availability of organic manure
- Reduction in cattle population
- Use of cattle dung for fuel purposes
- Open grazing system

Growing of green manure crops not adopted widely
- Seeds are not availabe everywhere in sufficient quantity
- Needs additional labour/inputs
- Not feasible in all ecosystems
- Difficulty in incorporation and decomposition due to uncertain rainfall
- Lack of farmers' knowledge

Biofertilisers
- Non-availability of proper inoculum
- Lack of farmers' knowledge

Prepared by:
G.R. Singh, S.K. Mohanty, D.S. Yadav, H. Bhattacharya and **V.P. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Minimal Fertiliser Use

Rainfed rice is grown under varied ecological situations ranging from upland dry to deepwater and flooded situations. Most rainfed rice farmers are by and large resource-poor. Frequent droughts and floods involve a lot of risk in rice cultivation, so most farmers do not apply the recommended doses of fertilisers. In fact, even when farmers do use chemical fertilisers, they do so in small quantities.

Fertiliser use efficiency (FUE)

Scheduling of fertiliser application affects fertiliser use efficiency to a great extent. The proper scheduling of fertiliser application is especially critical when low levels of fertiliser are used, such as in Assam.

Optimum doses	**(N: P_2O_5:K_2O)**
Uplands	40-60:30:20
Shallow land	80-100:60:40
Medium deep	60-70:40:20
Deep	40-60:30:0
Very deep and floating	20-30:0:0

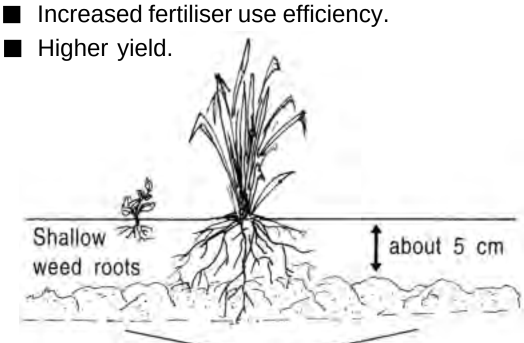
Upland

50% of the recommended fertiliser dose available

1. Apply half nitrogen and full phosphorus and potassium as basal through plough sole placement or by ferti-seed drill. Topdress the rest of nitrogen after weeding about 20-30 days after sowing depending on rainfall. Under inadequate rains, apply nitrogen through foliar spray using 2-3%, urea solution. In high-rainfall areas of Assam, place half of potassium and topdress the rest with nitrogen.
2. If farmers can manage only 20 kg of nitrogen/ha, it should be topdressed at 25-30 days after sowing depending on rainfall or applied by foliar spray of 2-3% urea solution when rain is inadequate. Remove weeds before applying fertiliser.

Advantages of fertiliser placement under upland conditions

- Fertiliser is placed in the root zone to improve availability to the crop.
- Nutrient losses due to volatilisation, denitrification and runoff are minimised.
- Competition for nutrients by weeds is reduced due to unavailability of nutrients at the soil surface.
- Prolonged availability of nutrients to crop plants.
- Reduced phosphorus fixation, especially in acidic soils.
- Increased fertiliser use efficiency.
- Higher yield.

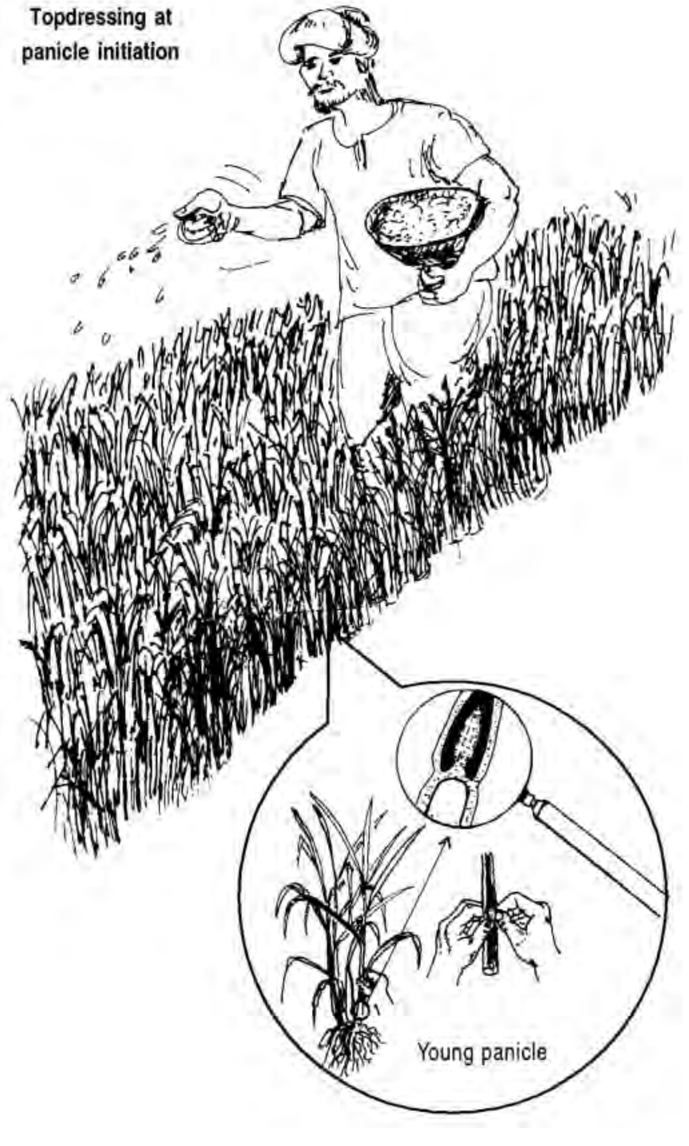


Fertiliser applied to the root zone

Shallow lowland

50% of the recommended fertiliser dose available

1. Place half of the available nitrogen and full phosphorus and potassium by plough sole or with the help of ferti-seed drill.
2. Topdress the rest of nitrogen after 25-30 days after sowing at adequate moisture. If the soil moisture is insufficient, apply nitrogen through foliar spray using 2-3% urea solution.
3. If farmers have the capacity to purchase just enough fertiliser to supply only 20 kg nitrogen/ha, apply it as topdressing after 25-30 days of sowing with adequate soil moisture after weeding.



Semi-deep land

50% of the recommended fertiliser dose available

1. Apply half nitrogen and all phosphorus and potassium as basal through placement.
2. Apply the remaining half nitrogen in two equal splits:
   a. through topdressing after 40-45 days after sowing or 25-30 days after transplanting after the water is drained off.
   b. topdress the remaining nitrogen at panicle initiation. For topdressing, mix the fertiliser with farmyard manure in 1:l0 ratio and incubate for 48 hours.
3. If farmers have the capacity to purchase just enough fertiliser to supply only 20 kg nitrogen/ha, it should be topdressed about a month after seeding/ transplanting when no standing water is in the field. Before application, urea treated with neem cake should be applied in the form of mud balls.

Deepwater

Farmers applying 50% of recommended dose of fertilisers

1. Place all fertiliser at sowing time or during land preparation for transplanting.
2. When 20 kg nitrogen/ha is available to farmers, it should be mixed with soil at sowing time/land preparation for transplanting.
3. Apply urea after coating with neem cake/neem extract.

Very deep water and floating

Apply 20-30 kg nitrogen/ha after coating with neem cake/neem extract at sowing.

Schedule of fertiliser application under different rainfed rice ecosystems

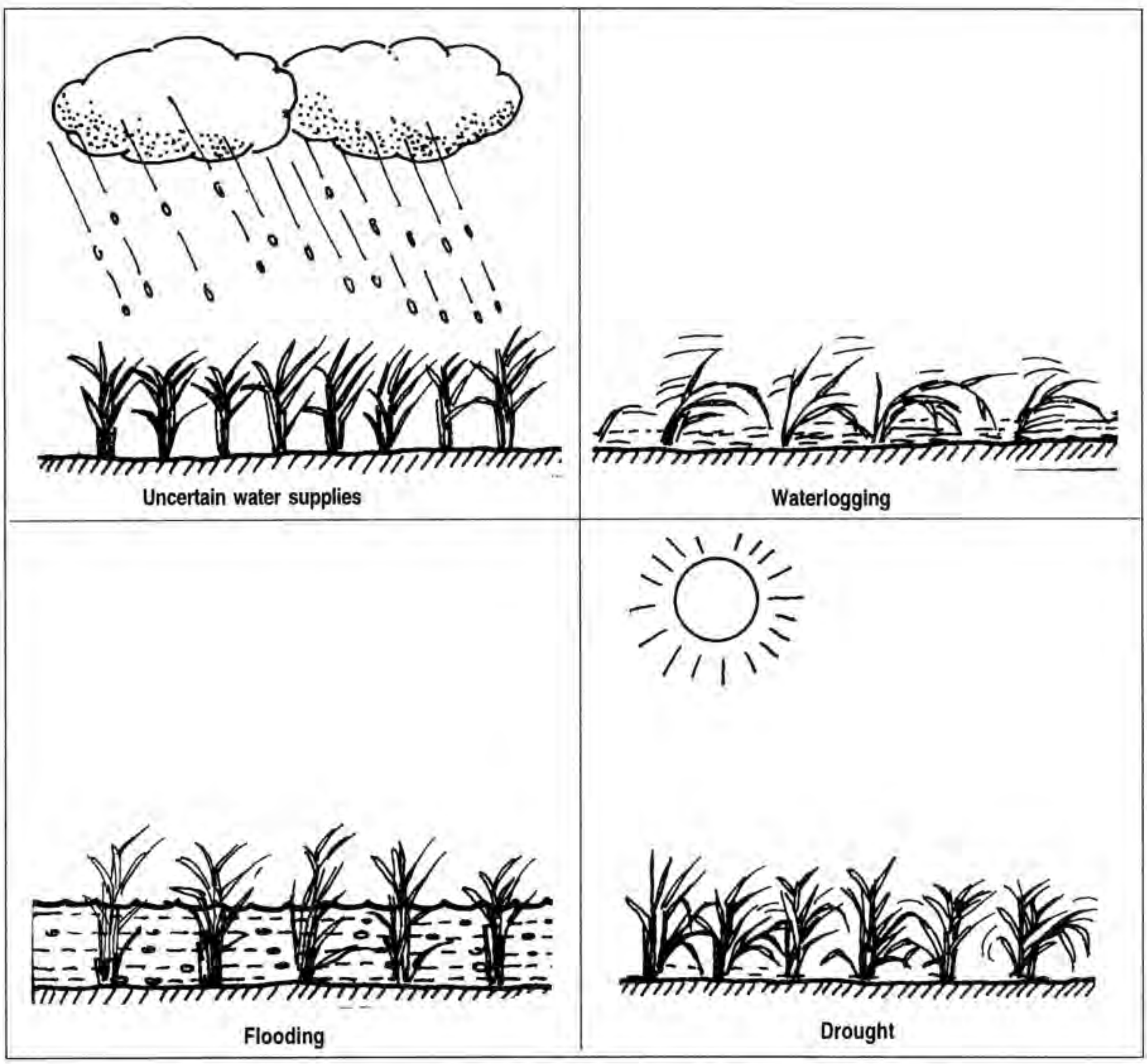
Upland	Shallow lowland	Semi-deep land	Deepwater	Very deep and floating
				
Dry ground	Ankle deep (0-30 cm)	Knee deep (30-50 cm)	Thigh deep (50-100 cm)	Waist deep (above 100 cm)
If only 50% of the recommended fertiliser is available				
■ Place half N and full P and K at sowing ■ Topdress half N with adequate rain after weeding or by foliar application	■ Apply half N and full P and K by placement ■ Topdress the rest of N after 25-30 days at adequate soil moisture or by foliar application	■ Half N and full P and K as basal placement ■ Topdress ¼ N 40-45 days after sowing or 25-30 days after transplanting ■ Topdress rest of N at panicle initiation	■ Place all fertilisers at sowing/land preparation for transplanting	■ Apply 20-30 kg N/ha, urea coated with neem cake/ neem extract at sowing
If only 20 kg N/ha is available				
■ Topdress with adequate soil moisture after weeding or by foliar application	■ Topdress 25-30 days after sowing/ transplanting after weeding or by foliar application	■ Topdress after 25-30 days after sowing/ transplanting	■ Mix with soil at sowing/ transplanting ■ Coat urea with neem cake or extract before application	

Prepared by:
D.S. Yadav

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Comparative Analysis of Different Nutrient Management Practices in Rainfed Rice

Rainfed rice is often grown under uncertain water supplies and usually suffers from either drought or flooding and waterlogging. Nutrient management is one of the most challenging tasks in improving rainfed rice productivity. Fertiliser contributes about 50-80% toward the improvement of rice yields on rainfed farms.



Rainfed rice cultivations is risk-prone.

Rainfed rice categories

Upland

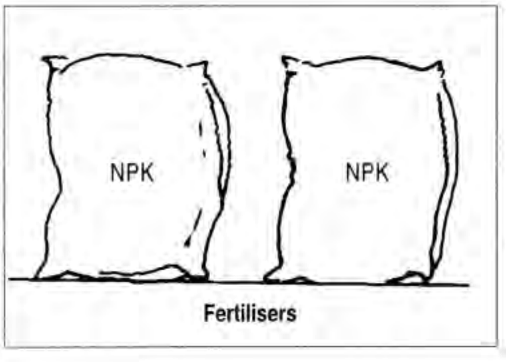
- Favourable uplands (high rainfall)
- Unfavourable uplands (low rainfall)

Rainfed lowlands

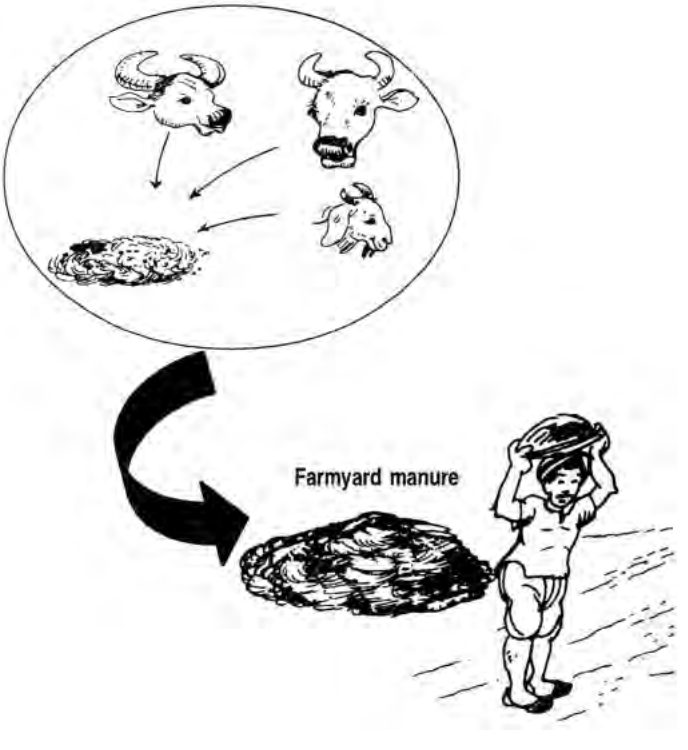
- Shallow lowlands (0-30 cm)
- Medium lowlands (30-50 cm)
- Deepwater lands (50-100 cm)
- Very deep lands (> 100 cm)

Rainfed lowland rice soils are alluvial soils deposited by rivers and their tributaries. Old alluvial soils are deficient in N and P and respond to N and P fertilisation. New alluvial soils are rich in P and K, are moderate in organic matter, and respond to N.

Rainfed upland soils are acidic, neutral to moderately alkaline and calcareous, with occurrence of lime concretions at varying depths. Most of the soils are poor to medium in nutrient content.



Fertilisers


Farmyard manure

Nutrient management practices

The following nutrient management practices are mainly used under rainfed conditions:

Fertilisers

Mineral fertiliser application is the most widely used nutrient management practice. The recommended nutrient doses for different situations are applied using chemical fertilisers. Generally, all P and K fertilisers are placed in the soil. Nitrogen is applied as basal and topdressing. Foliar spray of zinc and other nutrients is also practiced.

Fertilisers and FYM

In this practice, the available FYM quantity is applied when the land is prepared. Since the availability of FYM is very limited, the required nutrient quantity is supplemented with fertilisers.

Green manure

Fertilisers and green manuring

Green manure crops, such as sesbania, sunhemp, green gram, black gram and cowpea, are either grown in the same field (*in situ*) or transported from another field and incorporated into soil for their nutrient supply. The available nutrients from green manure are not enough to supply the total nutrient requirement of the crop, so the rest of the nutrients are applied through fertilisers. The green manure. crop can provide 20 to 60 kg N/ha. ***Gliricidia sepium*** green leaf manuring (*ex situ*) can also be used.

Crop residue

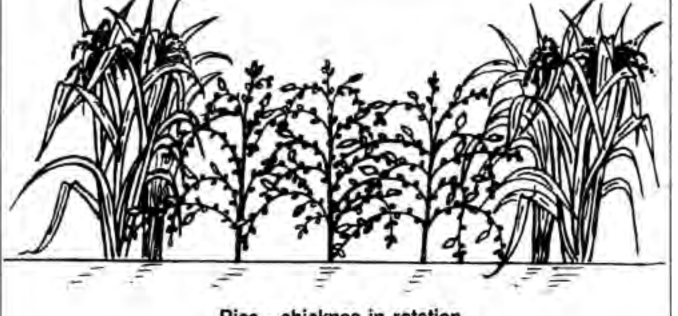
Fertilisers and crop residues

The largest portion of crop residues in India is used for fuel. Crop residues incorporated into the soil supply some of the nutrients, while the rest are applied through fertilisers.

Water hyacinth

Fertilisers and other organic materials

Large quantities of organic materials, such as water hyacinth, etc., are available and used to meet the partial requirement of nutrients for rice. This is supplemented with fertilisers.



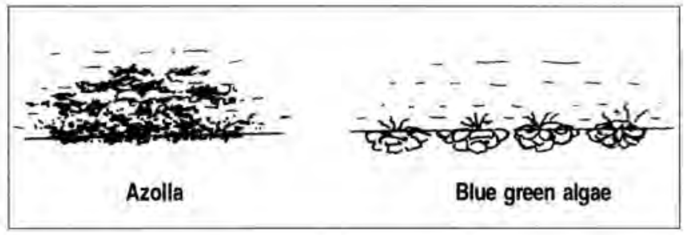
Rice - chickpea in rotation

Fertilisers and legumes in rotation

By incorporating legumes in rotation after rice, 20 to 30 kg of N is saved and the rest of the nutrients are supplied by fertilisers.

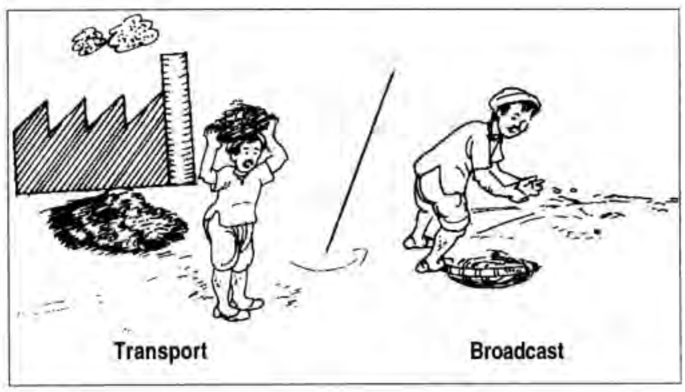
Fertilisers and biofertilisers

Various biofertilisers such as blue-green algae (BGA), azolla, etc., are capable of fixing atmospheric N, which is used by the rice crop. About 20 to 25 kg of N could be available through biofertilisers. Vascular-arbuscular mycorrhizae can be used to increase the availability of soil-fixed phosphorus. The rest of the nutrients are applied through fertilisers.



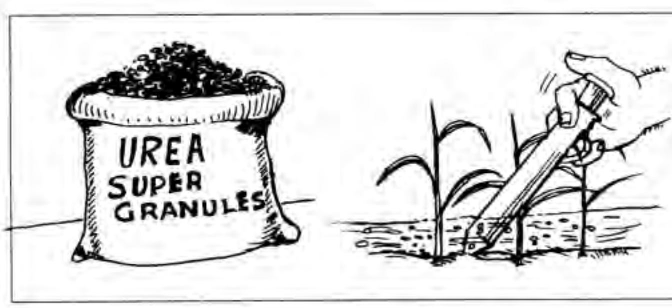
Fertilisers and agricultural/ industrial wastes

A large quantity of agricultural and industrial wastes are available to supplement nutrients to rice. Pressmud available from sugar factories contains 0.5-0.9% N, 1.2-2.0% P_2O_5, 1.5-2.0% K_2O and S, Ca, etc.



Slow-release N fertilisers

Slow-release N fertilisers are modified nitrogen carriers. When applied, they release nitrogen at a comparatively low rate and reduce leaching losses.



Comparative analysis of different practices of nutrient management in rainfed rice

Particulars	Fertilisers	Farmyard manure	Green manure	Crop residues	Other organic materials	Legumes in rotation	Biofertilisers	Industrial waste	Slow-release N fertiliser
Availability	Easy	Very limited	Difficulty in raising GM crop	Very limited	Available at specific locations	Restricted cultivation due to poor productivity and risk in cultivation	Limited manufacture of biofertilisers and very poor quality	Available at limited locations	Very limited
Nutrient content	Very rich	Low nutrient content and slow release					Fixes low quantity of N only	Low nutrient content	Very rich in nutrient
Adaptability to lowland	Very wide	Very wide	Restricted	Wide	Wide	Limited	Large scale	Large scale	Limited
Transportation	Easy	Difficult	–	–	Difficult	–	Easy	Difficult	Easy
Field application	N easy; P and K placement difficult	Easy	Difficult	Soil incorporation difficult	Soil incorporation difficult	N. A.	Requires better technical know-how	Easy	Very difficult
Cost	Costly	Very costly	Very costly	No cost	No cost	Cheap	Cheap	Cheap	Very costly
Effect on yield	Good	Very good	Very good	Fair	Good	Good	Very good	Good	Very good
Effect on grain quality	Favourable; K improves luster and disease resistance	Favourable effect							

Comparative analysis of different practices of nutrient management in rainfed rice, cont.

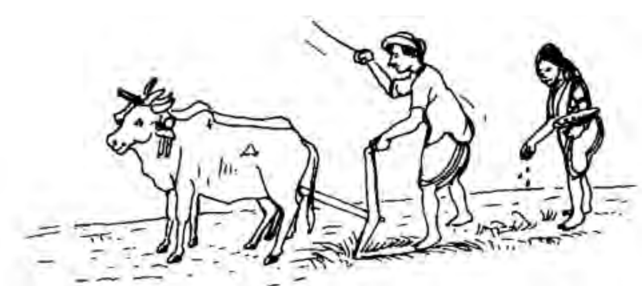
Particulars	Fertilisers	Farmyard manure	Green manure	Crop residues	Other organic materials	Legumes in rotation	Biofertilisers	Industrial waste	Slow-release N fertiliser
Effect on soil	Continuous application deteriorates physical and and chemical properties of soil	■ Increases water-holding capacity and organic matter content and reduces bulk density ■ Reduces pH of salt-affected soil, increases nutrient availability in balanced form							Continuous application adversely affects physical and chemical properties of soil
Effect of soil microbes	Adverse effect	Favourable effect							Adverse effect
Sustainability	Continuous application of fertilisers results in yield decline after a few years	Sustains yield							Continuous application of fertilisers results in yield decline after a few years
Atmospheric pollution	Heavy doses of fertilisers result in release of gases which pollute the atmosphere and their leaching creates groundwater pollution	No effect							Heavy doses of fertiliser result in release of gases which pollute the atmosphere

N : nitrogen; P : phosphorus; K : potassium; NA : not applicable

Comparative analysis of different methods of fertilizer application in rainfed rice

Particulars	Broadcasting		Placement			Spray fertilisation
	Broadcasting at planting	Topdressing	Plough sole placement	Deep placement	Subsoil placement	
Suitability	For moist soils	Adequate moisture condition	Under dry and upland situations	Submerged and flooding situations	Where subsoils are strongly acidic	Both moist and dry situations
Nutrient availability	Good	Good	Very good, less fixation of P and K	Very good	Extremely low	Excellent
Type of fertiliser	Nitrogenous	Nitrogenous	Any	Nitrogenous	Phosphatic and potassic	Most of the nutrients
Application procedure	Very easy	Very easy	Easy	Difficult	Very difficult. Requires heavy machinery	Easy
Application cost	Low	Low	Nominal	High	Very high	Nominal
Leaching losses	More	Less	More	High	More	Na
Volatilisation	More	More	Less	No	No	No
Denitrification	More	Less	Less	Less	Less	No
FUE	Very low	High	High	Low	Low	Very high






Prepared by:
D.S. Yadav

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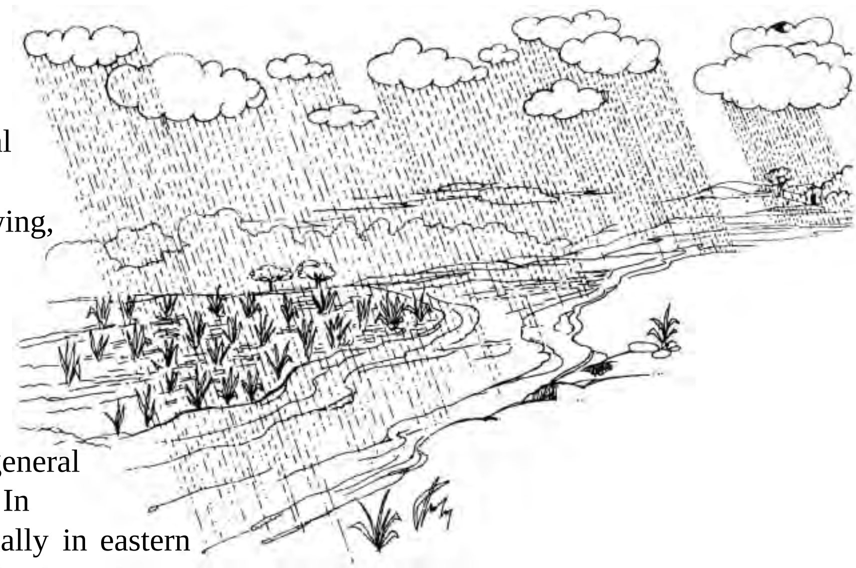
Rainfall, On-Farm Water and Soil Moisture Management

Rainfall and Its Agronomic Interpretations



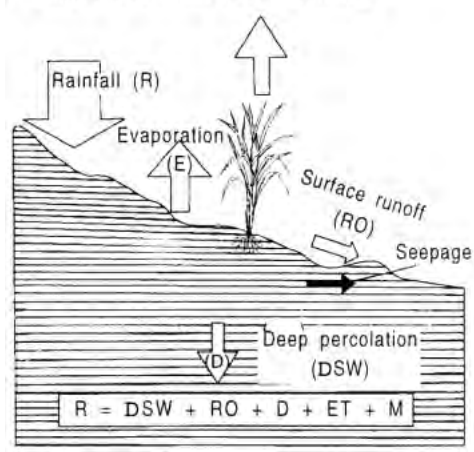
All facets of agricultural activities, from field preparation to sowing, weeding, application of fertilisers and weedicides, harvest and post-harvest operations, all the way to storage of grains, are influenced by climate in general and rainfall in particular. In rainfed agriculture, especially in eastern India, rainfall plays a vital role, either positive or negative, in crop growth and development. Rainfall also influences the final usable grain yield at harvest and even after harvest.

Rainwater balance

The rainwater, after touching the surface of the earth, undergoes different processes which can be understood using a simple rainwater balance equation.

$$R = DSW + RO + D + ET + M$$

A simple schematic water balance



where

R = Rainfall

D**SW** = Soil water change (from the pre-monsoon dry soil, the soil water reaches field capacity/saturation point during the rainy season)

RO = Runoff (when the intensity of rainfall is higher than the infiltration rate, the water runs off from that area and reaches rivers through riverlets and small canals)

D = Deep percolation (after saturation point, the excess water that goes into the soil percolates down and joins the groundwater)

ET = Evapotranspiration (the water over the bare soil evaporates through the surface. The soil water works as a transporter and is finally absorbed into the atmosphere through the process of transpiration. Thus, evaporation from the soil and transpiration through the plant occur simultaneously as ET)

M = Metabolic water (a very small portion of the soil moisture gradually accumulates in the plants as they grow)

Thus, the DSW that is stored in the soil is used for evapotranspiration and is replenished by the rainfall. Therefore, the ET amount is the only amount needed by the plant for its growth and development.

Importance of water to plants

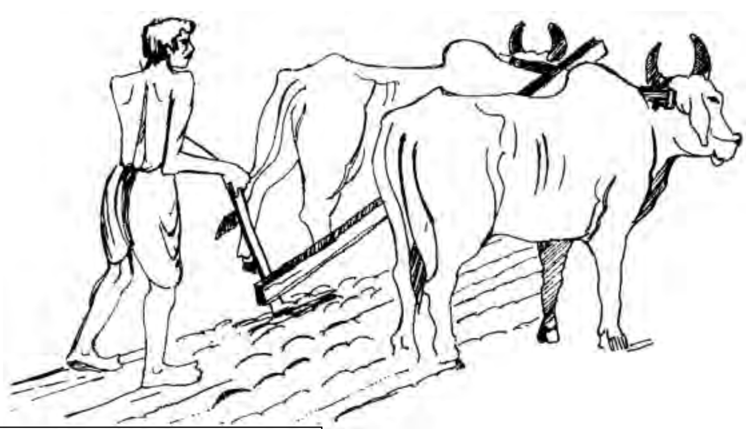
- Transporter of nutrients from the soil to the plant
- Permits ionisation within the plant
- Enhances chemical reactivity of simple and elaborated compounds
- Maintains turgidity and plant temperature

Rainfall and its agronomic effects

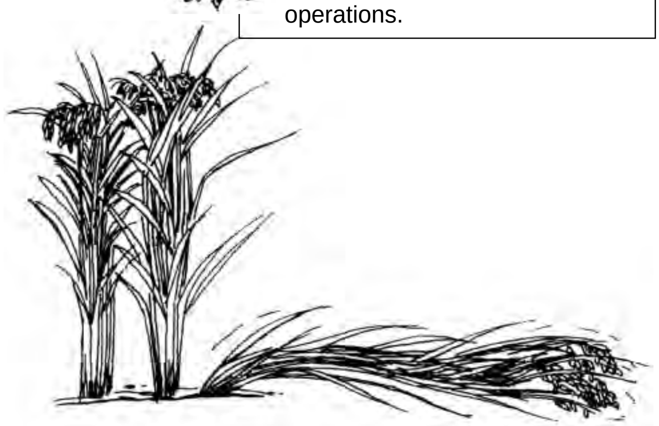
Helpful aspects

FACILITATES PLOUGHING

As soon as it rains, the completely dried soil gets wet and ploughing becomes easier on wet soil. In eastern India, the summer rains in May and the early parts of June simplify the ploughing of the soil. This saves the farmers considerable time because, as soon as the monsoon rains start, farmers can directly sow the crop in these pre-ploughed fields.



In agriculture, rainfall is often compared to the Indian God "Rudra" (if pleased, this God helps; if unhappy, He destroys). One should monitor rainfall and rain forecasts to successfully handle the day-to-day field operations.



MAINTAINS SOIL WATER

The rainwater balance indicates that the plants absorb water with soluble nutrients/minerals through soil water. This water finally reaches the atmosphere through transpiration. Rainfall also maintains the soil moisture.

Harmful aspects

UNTIMELY OCCURRENCE

- Delay in sowing
- Delay in *biasi*/beushening
- Water stress during crop growth period

INTENSE AND HIGH QUANTITY

- Loss of nutrients
- Mechanical damage to plants
- Crop inundation
- Rainfall somewhere in the catchment areas, causes flash floods in the fields
- Washing off of pesticides/fertilisers

Mitigation methods

- Analyse and understand the rainfall pattern.
- Be knowledgeable of the rainfall pattern of the region for time of sowing, total duration of water, availability, probability of drought, probability of floods, probable duration and intensity of drought and floods, etc.
- Based on the analysis of the rainfall patterns of eastern India, probable sowing periods have been worked out as follows:

Probable sowing periods based on rainfall patterns in eastern India

States	Sowing period	Duration (days)
Eastern Madhya Pradesh	31 May - 21 June	21
Eastern Uttar Pradesh	11 June - 9 July	28
Bihar	5 June - 7 July	32
Orissa	19 May - 9 June	28
West Bengal	28 April - 9 June	42
Assam	2 February - 28 March	54

- Sowing time starts early in Assam.
- Sowing duration is longest in Assam and shortest in eastern Madhya Pradesh.
- Except in Assam and West Bengal, the sowing time in the other states is from early June, but in Orissa it is from the third week of May.

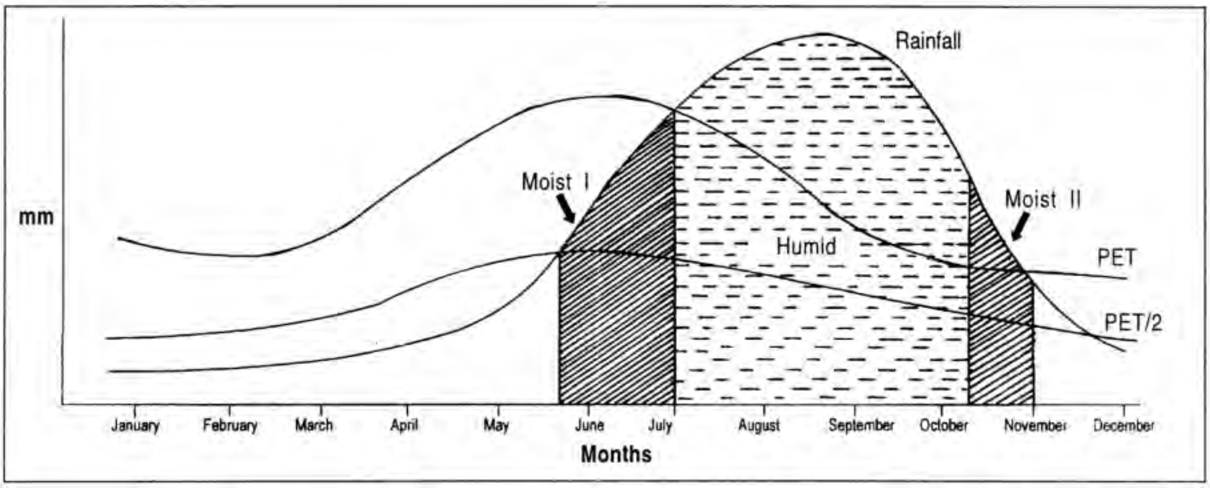
Water availability periods

Water availability periods help in choosing the right kind of variety for a given area and soil type. Water availability periods are calculated on the basis of rainfall (input) and potential evapotranspiration (output).

The period when the rainfall exceeds potential evapotranspiration (R>PET) is known as the humid period. This period is useful for the vegetative and reproductive stages of crop growth.

The period when rainfall is less than potential evapotranspiration but greater than half of it is known as the moist period (when PET>R>PET/2). This period is useful for seedling and maturity stages of crop growth.

Schematic diagram of water availability periods



Rainfall probabilities

Stable rainfall periods

In eastern India, both the daily ET and percolation losses are around 3-4 mm/day. Thus, the water requirement of rice without stress is about 50 mm/week.

A stable rainfall period is a period when the weekly rainfall is 50 mm or more in a given place. Based on this, the stable rainfall periods at 30%, 40%, 50%, 60% and 70%) probability levels of all meteorological stations of the states in eastern India were worked out. It was found that the stable rainfall period at 60% probability level exceeds 60 days in most places in eastern Madhya Pradesh. The implication of this finding is that, with 30 days for the seedling stage and 30 days for the maturity stage in eastern Madhya Pradesh, rice varieties of 120-125 days duration can be used successfully in two out of three years.

The stable rainfall periods at different probability levels in different states are shown in the table.

Stable rainfall period duration (days) at different probability levels in different states of eastern India

States/probabilities	30%	40%	50%	60%	70%
Eastern Madhya Pradesh	83-113	73-95	68-88	8-83	0-45
Eastern Uttar Pradesh	74-98	60-83	17-47	0-8	0
Bihar	92-116	73-89	0-53	0-54	0
Orissa	84-137	0-101	0-81	0-65	0-51
West Bengal	111-124	92-100	39-68	16-37	0-6

- In most of the states, the stable rainfall period at 70% probability is either zero or negligible.
- Even at 50% probability level, the stable rainfall period is zero in some stations in Bihar and Orissa.

Minimising economic losses due to intensity and quantity of rainfall

High intensity

- Select varieties tolerant to lodging.
- Choose a suitable variety which matures before the probable occurrence of high rainfall and thus escapes mechanical damage during the reproductive and maturity stages.
- Keep the drainage channel clean.
- Always be prepared for the situation by constantly watching the weather forecast.

Drought/water stress

Drought is the most common problem for rainfed rice cultivation in the whole of eastern India.

Mitigation of drought

Varietal manipulation

- Select varieties having drought-avoidance/ tolerance mechanism.

Soil moisture conservation

- Line-sow
- Weed through inter-culture operations
- Decrease plant population if drought persists and intensifies

Agronomic management

- Adopt a technology of, sowing varieties with a difference in duration of at least 15 days so that the earlier variety can have some yield in case of a late drought or both an early and late variety can be harvested in the case of a good rainfall year. Also, threshing can be done separately at different intervals due to the difference in maturity time.
- Adjust the planting dates if the areas suffer from terminal drought.
- Practice mixed cropping in uplands.

Drought

Drought can occur at any stage of crop growth (seedling, vegetative and reproductive stage)

- If drought comes during the seedling stage, especially immediately after germination, re-sowing with another suitable variety is recommended.
- If drought occurs during the other stages, mitigation practices such as life-saving irrigation, moisture conservation, plant population management, etc., are practised.
- If drought occurs in the reproductive stages, adjusting the planting time using short-duration varieties may help.

Assessment of *in situ* drought

Go to the field, take some soil and make a ball.

- If soil sticks to the palm of the hand — no drought.
- If the ball can be made but is soft — no drought. However, take precautions as this is an indication that the soil moisture is just over field capacity.
- If the ball can be made. but is hard — drought has started.
- If the ball can't be made — severe drought has already occurred.

Mitigation of floods

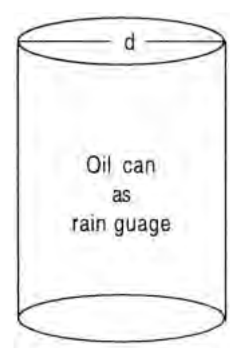
- Study flood characters such as height, time and duration.
- Keep drainage channels weed-free and wide.
- Increase infiltration rate.
- Use submergence-tolerant varieties.

Flood analysis at Ghaghraghat

Year	Frequency	Months	Total duration (days)	Peak water depth (cm)
1984	3	July, August	12	108
1987	3	July, August, September	6	44
1990	5	July, August, September	45	97

Rainfall measurement—a simple method

Take an oil can with a diameter of 15-20 cm and height of 30 cm. Expose the oil can in an open area during the rainy season. To measure daily rainfall, take the rainwater and measure the volume in liters or milliliters. (This type of measuring glass is easily available.)



r = d/2
area = p r^2
Rainfall (cm) = volume of rainwater (cc)/area of the oil can

Calculate the area as p r^2 where p value is 3.14 and r is the radius of the oil can (cm). Divide the volume of water measured into milliliters (ml) or cubic centimeters (cc) by the exposed area of the oil can (cm^2). For daily values, measure rainfall every day at 8.30 a.m.

To measure the intensity of rainfall, measure the volume of rainwater at 15-, 30- or 60-minute intervals (depending upon the intensity of rainfall) while it rains. Compute the rainfall (in cm) in the same way as is done for daily measurement. These measurements are a good source of rainfall data for the area.

Prepared by:
A.S.R.A.S. Sastri

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Moisture Availability, Water Balance and Crop Planning

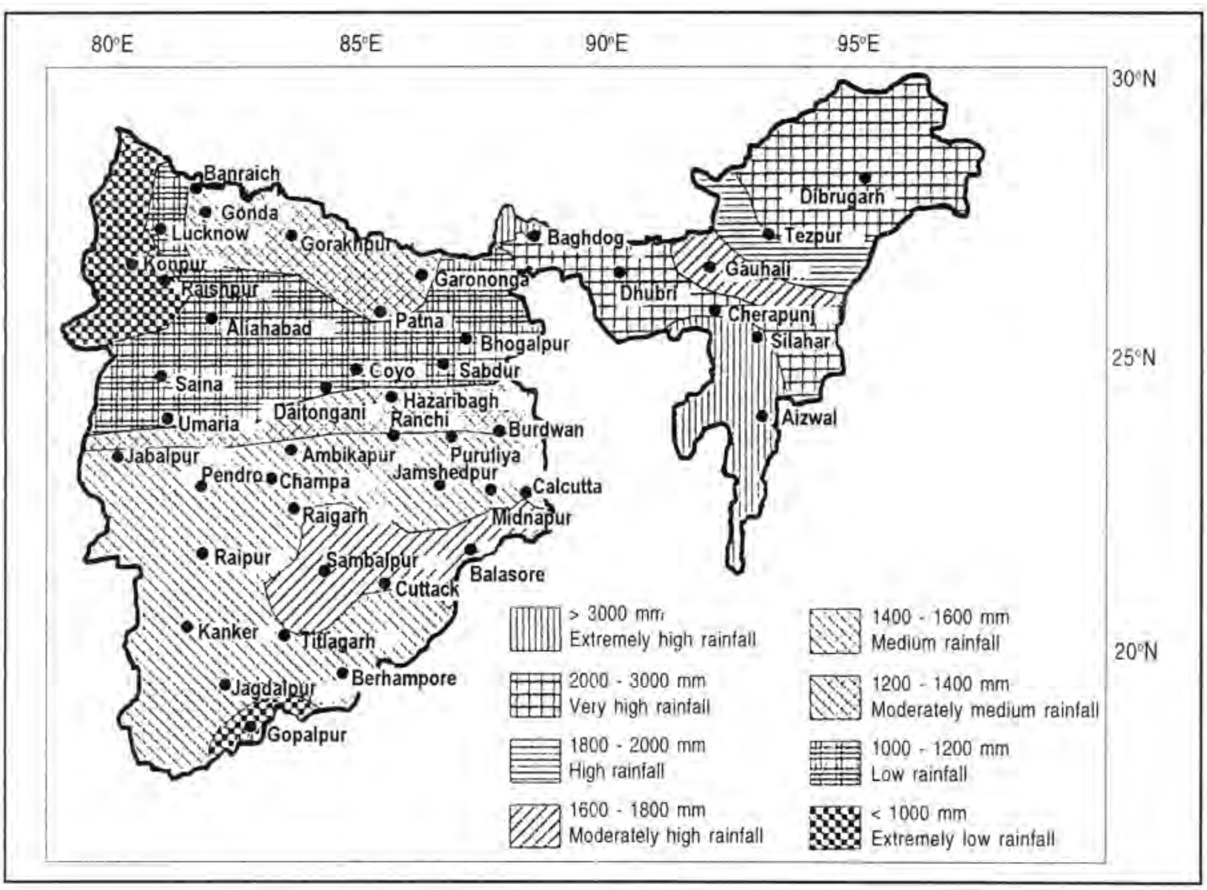
Rainfall is a crucial resource for crop production in rainfed areas. Its amount, distribution pattern and intensity of occurrence vary tremendously across locations and over time. Therefore, an in-depth analysis is necessary to use this resource productively.

The long-term rainfall and potential evapotranspiration (PET) analysis

To analyse the long-term rainfall and potential evapotranspiration, the following activities were done:

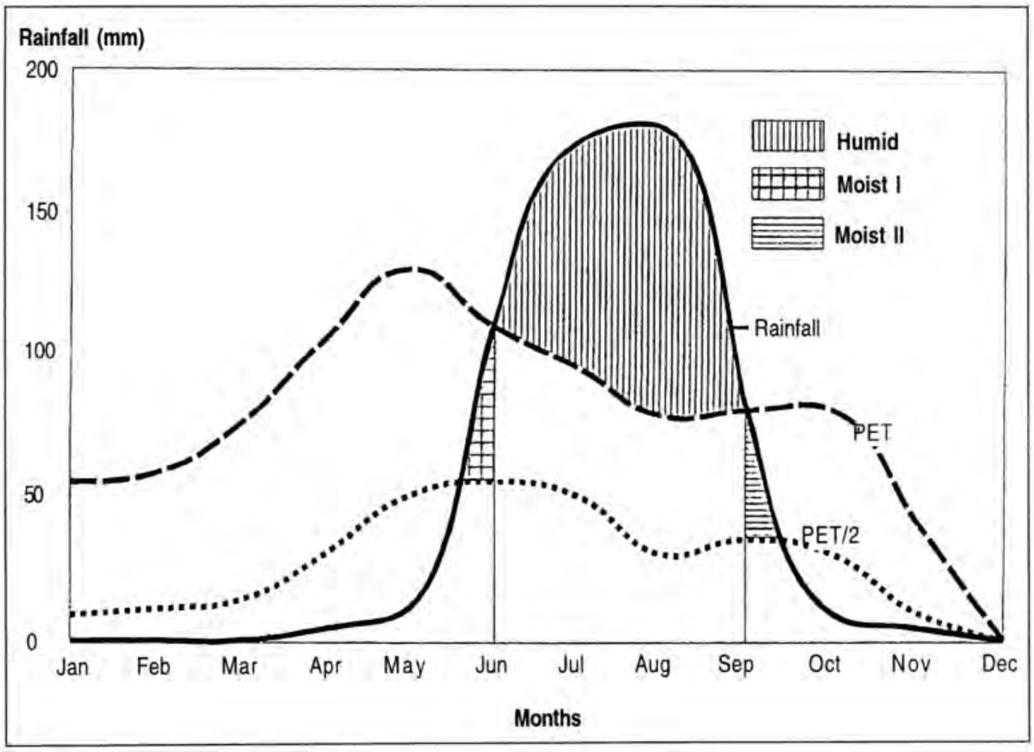
- Data from different stations in the area of consideration, e.g., eastern India, are collected. According to its total amount, the area in consideration is classified into different categories.

Annual rainfall in eastern India



- The rainfall and PET distribution patterns are plotted over months.

Moisture availability analysis with respect to rainfall and potential evapotranspiration (PET)



Depending on the balance between rainfall and PET, the moisture availability periods are divided into three subclasses.

Moist I

This is the period at the beginning of the rainy season when PET is quite high, even with low crop canopy due to high temperatures and longer day length. Most crop establishment operations are done in this period.

Moist II

This is the period at the end of the rainy season when, in spite of the high crop canopy, PET becomes low due to lowering of the temperature and shortening of the day length. Most crop harvesting and processing operations are done in this period. This type of analysis accounts for the total amount of rainfall and number of rainy days with respect to the cropping season and the level of crop water requirement.

Humid

This is the period when rainfall exceeds PET.

Moisture availability analysis in eastern India

The results of a case study from eastern India indicate that:

- The rainfall, PET and moisture availability periods vary significantly across locations and time.
- Across locations, significant variations also exist in the total duration of moisture availability periods within a classified rainfall zone and in the duration of moisture availability sub-classes within a given total duration of moisture availability.
- The moisture availability periods (months of the year) are different across sites, even if they all have the same rainfall and the same total duration of moisture availability.

Variation in the moisture availability in eastern India

Site	Annual rainfall (mm)	Moisture availability					
		Moist I		Humid		Moist II	
		D	P	D	P	D	P
Gaya, Bihar	1200-1400	17	15 Jun-10 Jul	95	11 Jul-13 Oct	28	14 Oct-10 Nov
Sabour, Bihar	1200-1400	16	7-22 Jun	128	23 Jun-28 Oct	18	29 Oct-15 Nov
Raipur, M. P.	1400-1600	14	16-29 Jun	117	30 Jun-24 Oct	18	25 Oct-11 Nov
Cuttack, Orissa	1400-1600	18	30 May-17 Jun	153	18 Jun-17 Nov	18	18 Nov-5 Dec

D = duration in days; P = period

- The duration of the Moist I and Humid periods is shorter in Uttar Pradesh (UP), Madhya Pradesh (MP) and Bihar and longer in Orissa, West Bengal and Assam. However, the duration of the Moist II period is longer in the first three states than in the last three.
- The duration of the Moist I and Humid periods progressively increases from UP and MP towards Assam.
- On the other hand, the Moist II period decreases at the same geographic locations. Below is the table for the duration of the moisture availability periods under each of the three categories for the six eastern states.

Range of moisture availability period in different states of eastern India

States	Range of moisture availability periods in days		
	Most I	Humid	Moist II
Uttar Pradesh	12-18	81-123	17-22
Madhya Pradesh	10-16	103-147	12-21
Bihar	12-18	95-139	17-22
Orissa	12-14	131-165	15-18
West Bengal	16-28	130-187	13-22
Assam	21-33	191-205	11-22

Moisture availability and crop planning

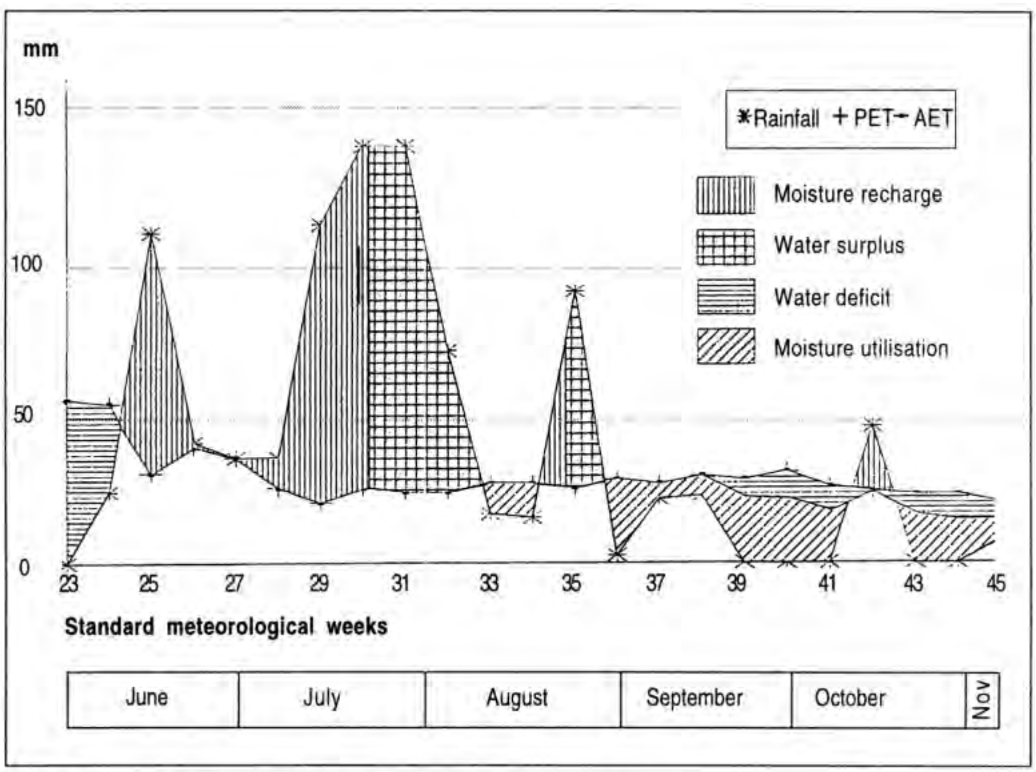
After the moisture availability analysis, weekly water balance computations are done for each site using weekly rainfall and potential evapotranspiration values with the help of Thornthwaite's bookkeeping procedure. To compute the water balance:

- the field capacity of heavy-textured rice soils is assumed to be 250 mm.
- weekly values of different water balance parameters for a crop season are calculated and plotted for the crop calendar; and
- this analysis provides the periods and quantities of water surplus or deficit and moisture utilisation and recharge patterns.

The figure below shows the weekly values of water balance parameters for a rice crop at one of the sites in eastern India as an example.

Up to the end of July, the rainfall exceeded the evapotranspiration demand and recharged the soil moisture. From the last week of September (i.e., the 39th standard meteorological week), however, water stress conditions prevailed at this site.

Weekly water balance during crop-growing season of 1995 at Tilda, Madhya Pradesh, India



PET = potential evapotranspiration, AET = actual evapotranspiration

This analysis points out that, in rainfed situations, because crop establishment for crop varieties of all durations is fixed at a particular time, long-duration varieties would suffer more from water stress conditions during the reproductive and maturity stages than medium-duration varieties. The experimental results with a set of two durations of rice varieties and the moisture availability index analysis for different growth stages of the two groups of varieties confirm this observation. The difference in the required and available moisture index was the same for the seedling and vegetative stages for the two varietal groups, whereas, at reproductive and maturity stages, it was greater for the long-duration varieties than for the medium-duration ones.

These results provide a basis for preparing production strategies and cropping calendars, including the selection of technological components and packages to be applied in planning resource allocations for this work. Such an analysis also provides guidance for avoiding/minimising risks in rainfed situations. This also directly feeds into the technology extrapolation procedures and delineation of technology application domains.

Prepared by:
V. P. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Indigenous Rainwater Management

Rainwater management for irrigation, domestic use and cattle feeding has been practiced in India since the beginning of civilisation. These indigenous practices refer to proven farmer practices developed over long periods from the experiences of farmers themselves. With indigenous practices, rainwater is stored according to local needs and geographical situations. In these systems, groundwater recharging, irrigation and domestic needs are taken care of.

Methods of rainwater management

Agronomic measures

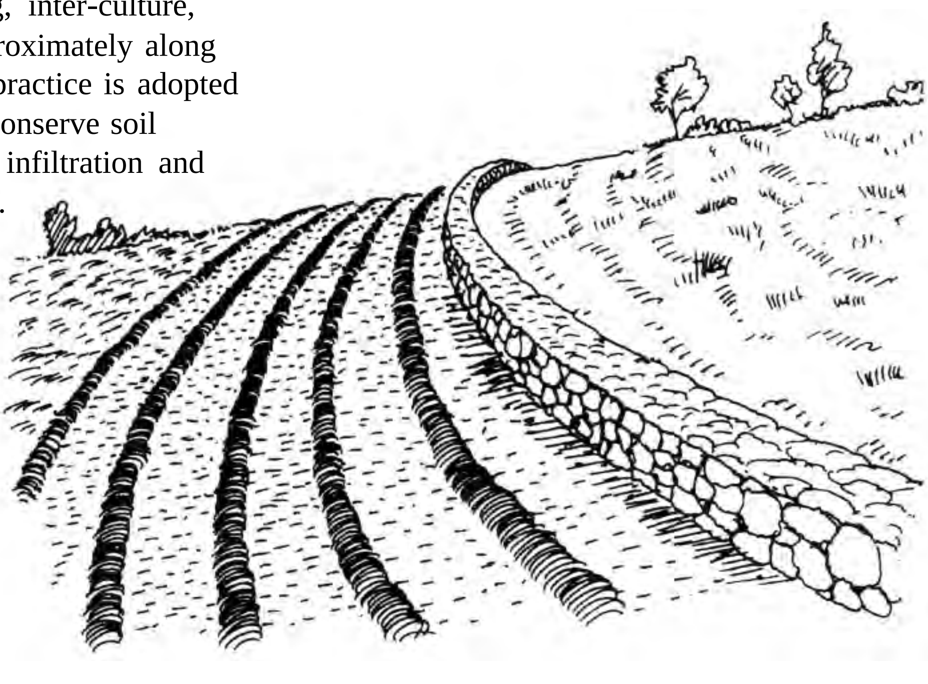
- Facilitate a better intake of rainwater into the soil by improving organic matter content and soil structure.
- Reduce surface runoff.

Contour farming

All agricultural operations (such as ploughing, seeding, inter-culture, etc.) are done approximately along the contour. This practice is adopted to control runoff, conserve soil moisture, increase infiltration and reduce soil erosion.

Special features of indigenous systems

- Promote community and participatory approaches in resource generation, maintenance and use.
- Have an integrated approach that caters to household, cattle and irrigation needs.
- Start at the village level and expand to the community level, which help in soil and water conservation.
- Help in water resource development and environmental protection.
- Are cost-effective and equitable.
- Have multi-purpose uses.
- Help solve water problems (floods, groundwater depletion, etc.) that cannot be solved individually.

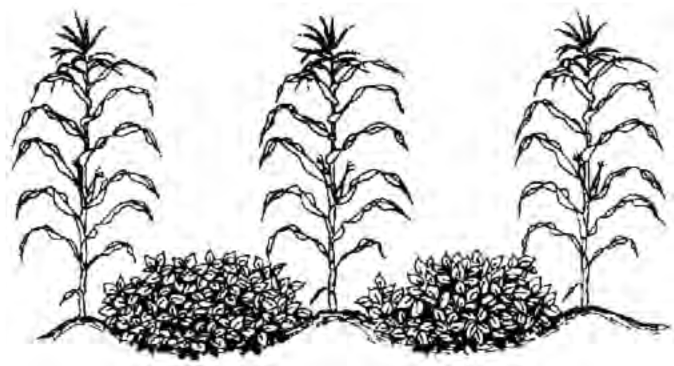


Cover cropping

Leguminous crops are grown to cover the soil surface to prevent moisture loss and to minimise soil erosion. Cover cropping also gives rainwater more time to infiltrate the soil, surface. The roots and residues of the crops improve the soil structure and make it more porous and more capable of absorbing rainwater.

Inter-planting/cropping

This is growing two or more crops simultaneously in the same field where at least one crop is planted in rows, e.g., mongo sown in between rows of maize. This helps in soil and water conservation and use.



Inter-planting/cropping

Mixed cropping

This is growing two or more crops simultaneously intermingled in the same plot with no distinct row arrangement. The advantages of mixed cropping are better and continuous land cover, rainwater conservation, protection against soil erosion and the assurance of one or more crops to the farmer.

Addition of organic and green manures

Organic and green manures help improve the soil's physical condition and improve the infiltration rate and soil structure.

To achieve the best results for soil and water conservation by tillage:

- till no more than required;
- till only when moisture is within the favourable limit; and
- vary the depth of ploughing.

Tillage practices

Tillage is the primary tool for soil and water conservation. Tillage has several effects on soil, such as aggregation, surface sealing, sub-soiling, infiltration, etc.

Mulch tillage

This is performed by making the soil surface cloddy or mulched with the help of crop residues. Mulch tillage is an effective measure to conserve rainwater.

Mulching

- Conserves soil moisture
- Increases infiltration capacity
- Reduces runoff
- Checks weed growth
- Improves soil temperature
- Modifies the micro-environment of soil
- Protects soil and emerging crops from cold

Advantages of summer ploughing

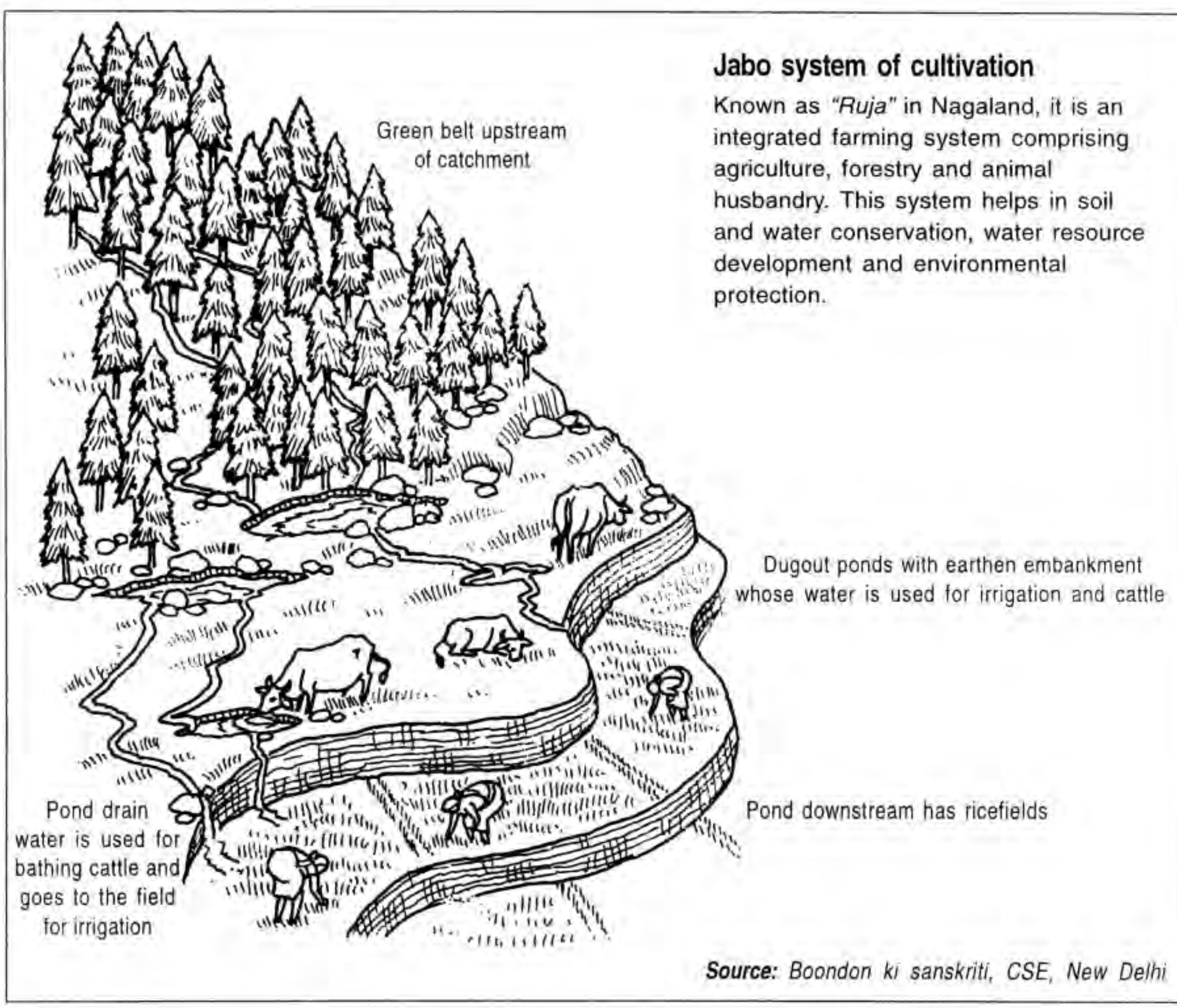
- Weed and insect pest control
- Decomposition of crop residues and weeds
- Soil erosion control
- Soil solarisation
- Groundwater recharge

Summer ploughing

Summer deep ploughing (20 to 30 cm) is done using a bullock-drawn mouldboard plough or tractor- drawn mouldboard/disc plough after crop harvesting to help absorb rainwater.

Dead furrowing/shallow trenching

Dead furrows/shallow trenches are formed on contour lines to absorb rainwater at about 5 to 10 m apart.



Source: *Boondon ki sanskriti, CSE, New Delhi*

Listing and ridge planting

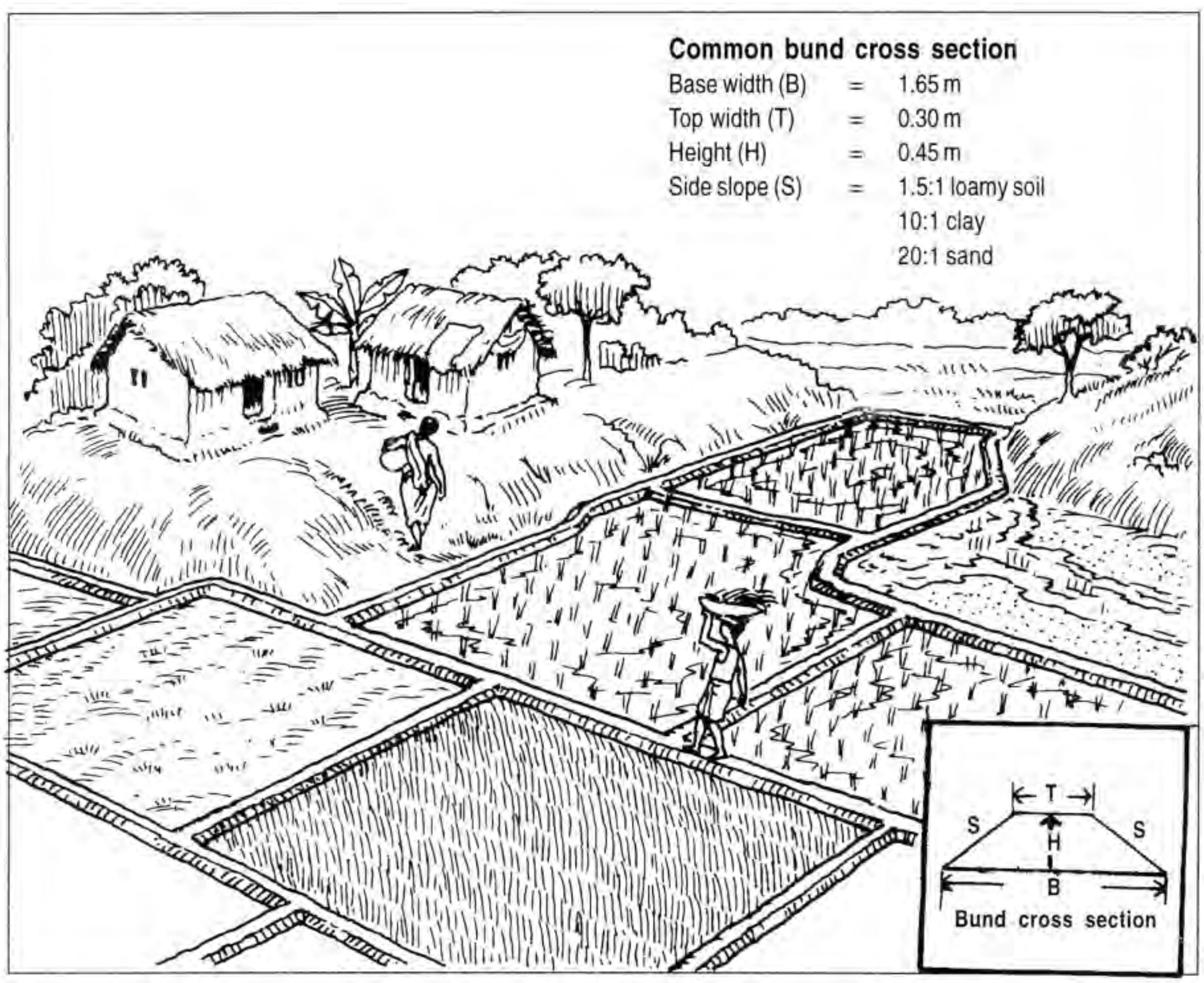
It is performed in low-rainfall areas where a large percentage of rainfall is received from short, intense storms. Listing is done using a lister plough. In some cases, listing is done by making dams at intervals in the furrows called basin listing. This controls row drainage and increases the water conservation value of the furrows.

Mechanical measures

Indigenous mechanical measures adopted for harvesting and managing of rainwater are effective, equitably adoptable and location-specific. However, mechanical measures have been neglected and need revitalising. Mechanical measures consist of constructing mechanical barriers across the direction of water flow to retard or retain the runoff and help to conserve soil and water.

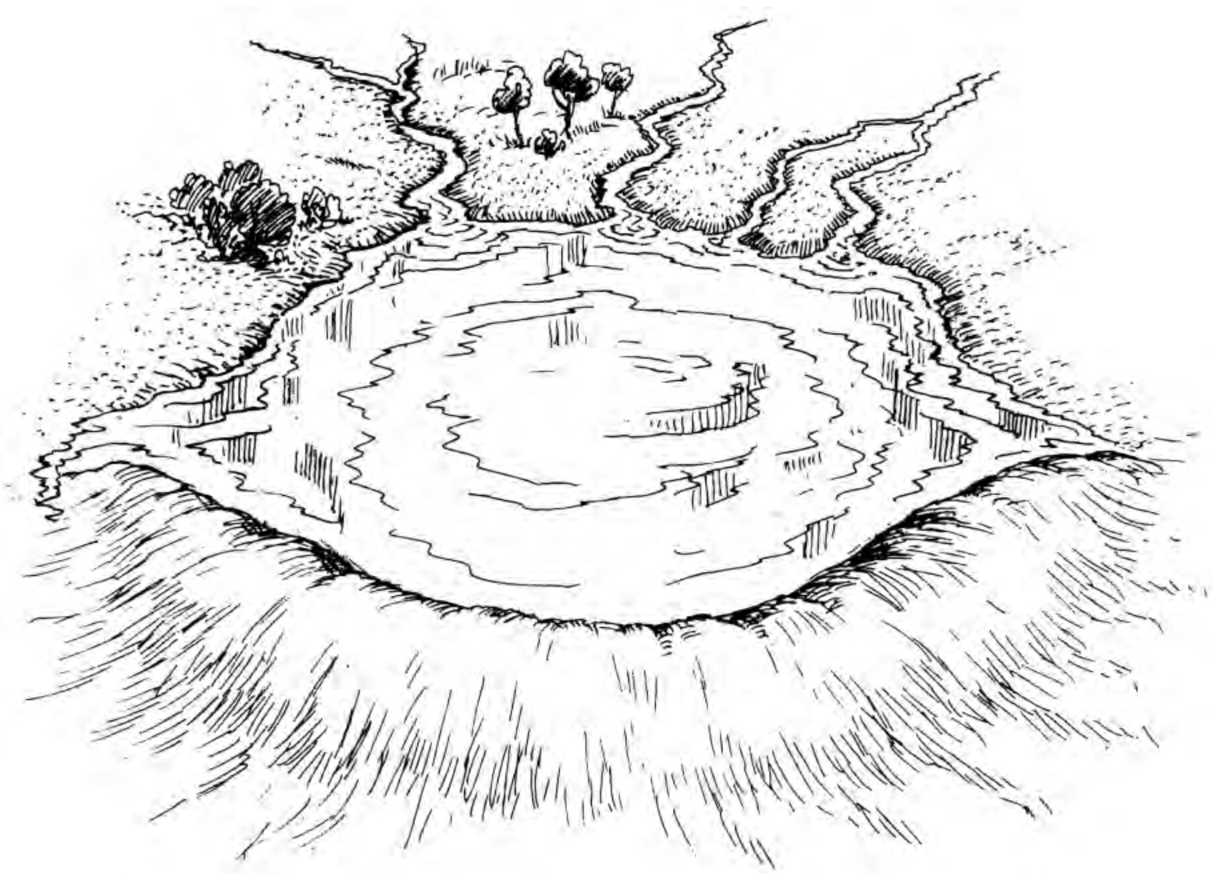
Field bunding

Bunds are constructed along field boundaries. In rainfed farming, bund construction is needed to conserve moisture, captured through rainwater. Bunds are made of different cross-sections according to the convenience and need of farmers. The recommended average bund cross section is 0.438 m^2.



Semi-circular hoop

This is an earthen embankment constructed in a semi-circle. The tips of the semi-circular hoop go up to the contour. The runoff water from the area is collected within the hoop to a maximum depth equal to the height of the embankment. Excess water is discharged from the points around the tips to the next lower hoop. The rows of semi-circular hoops are staggered so that overflowing water from the upper hoop can easily flow to the lower hoop. The height of the hoop is kept from 0.1 to 0.5 m, with a radius of 5 to 30 m.

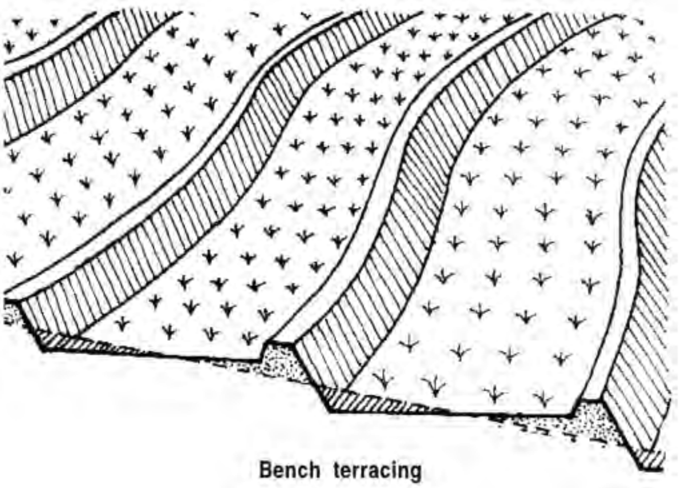


Ahar and Paeen system

This is similar to the semi-circular hoop and is used mainly in south Bihar. It is an earthen embankment 2 to 3 m in height, constructed in a semi-circular hoop for storing water. Stored water is used through the Paeen (channel) for irrigation.

Bench terracing

This involves constructing step-like fields along contours by half-cutting and half-filling on steep sloping (6-33% slope range) and undulating lands. The original slope is converted into level fields so all erosion hazards are eliminated and rainwater is conserved and used for crop production. There are three types of bench terracing.



Bench terracing

Level bench terrace

These terraces are generally used in medium-rainfall areas with highly permeable soil. They absorb most of the surface runoff and the remaining portion goes safely into the drain through a grassed outlet.

Outward-sloping bench terrace

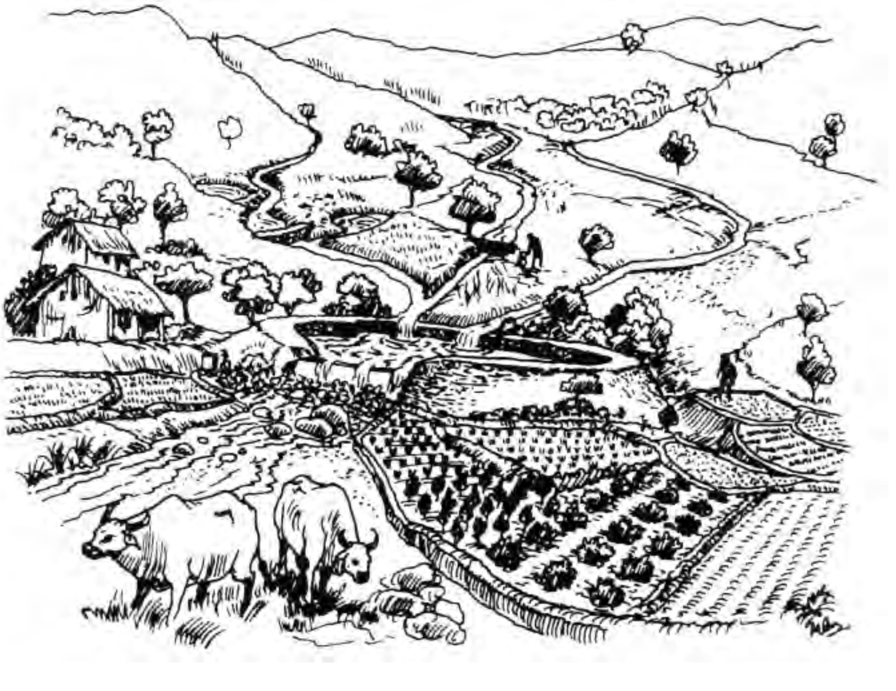
These bench terraces are adopted in low-rainfall areas with moderate permeable soil. In these terraces, a shoulder bund is constructed to provide stability to the outer edge of the terrace and retain surface runoff.

Inward-sloping bench terrace

These terraces are preferred in areas of heavy rainfall and less permeable soils, where a large portion of rainwater is drained as surface runoff through a grassed waterway.

Farm ponds

Farm ponds are constructed for storing surface runoff generated from the catchment area. They play a key role in flood control when constructed in large numbers in the catchment area. Pond water is used for irrigation, cattle feeding and fish production. There are two types.

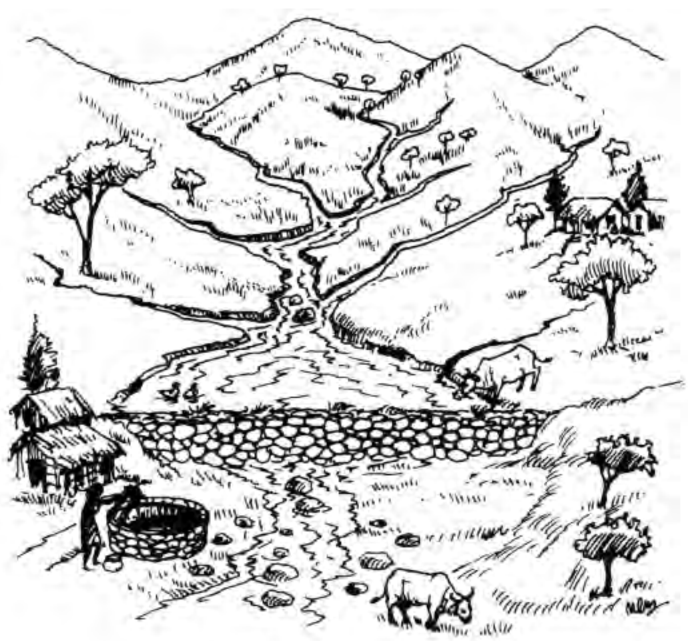


Embankment-type ponds

This type of pond is made by forming the embankment around the valley or deep depression of the catchment area. The runoff water is collected into these ponds and is used when required.

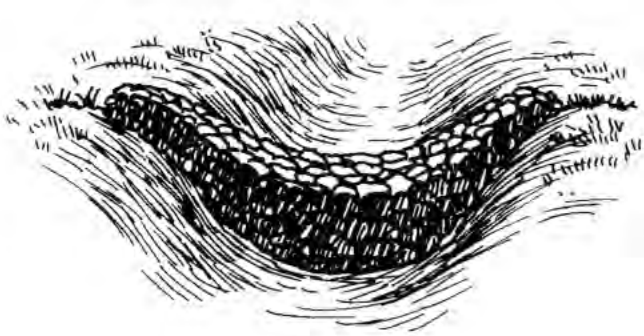
Dugout-type ponds

These ‘ponds are excavated in areas having a land slope of less than 4% and where the water table lies within 1.5 to 2.0 m. Sometimes, these ponds are constructed on existing waterways to use them as both an inlet and outlet. At the inlet of the pond, a small vegetative silt trap is used to retain the silt from the runoff.



Community ponds

These ponds were made in natural depressions to store water in the past. The maintenance was undertaken on a community basis by beneficiaries. Some of these ponds are currently being used, though their maintenance is neglected. Because of this, their capacity has been reduced. Desilting of these , ponds is essential to enhance their water storage capacity.

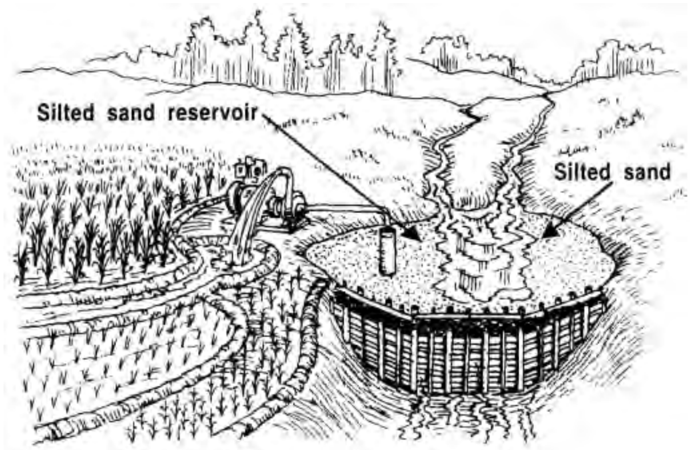


Small rock-check dams

Small rock-check dams are constructed across riverlets/drains (nalas) to check the flow of water and allow it to infiltrate into the alluvium under the bed. Water is stored in the aquifer and is used by extracting through wells or bore’ holes. In this system, peak flows are allowed to overflow over a smaller rock-check dam.

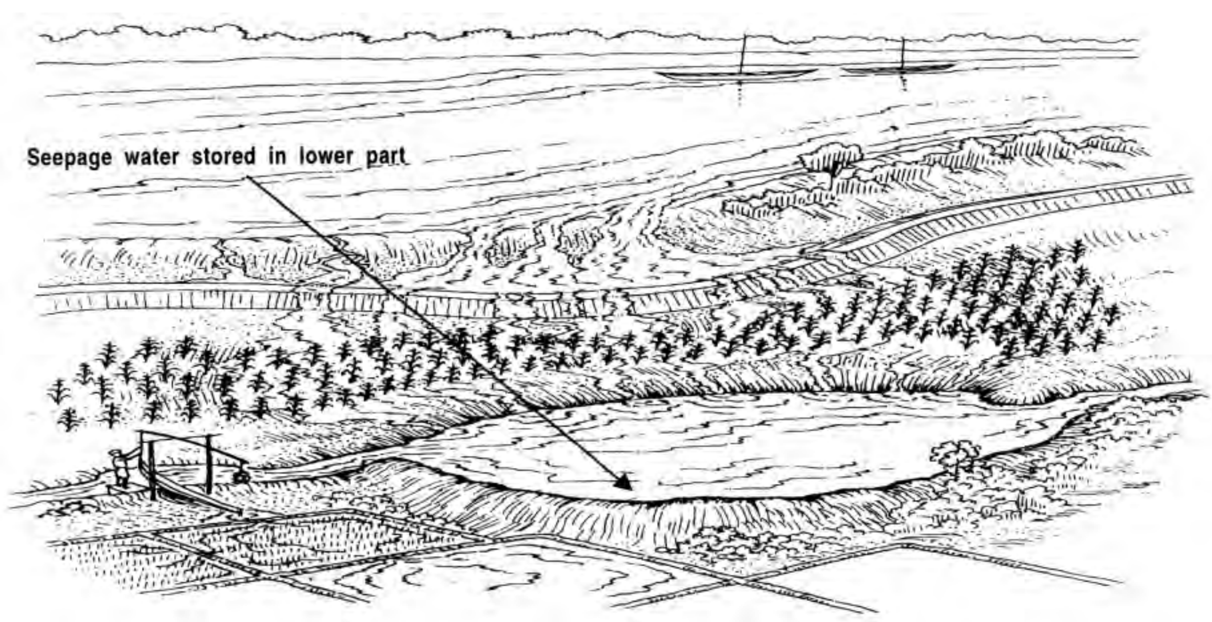
Sand dam

Water harvesting by using a sand dam consists of constructing a dam across a valley to reduce- the velocity of flow of runoff water mixed with sand. By doing this, the silt load of runoff deposits over the bed. After some time, the bottom of the valley is raised by the deposited sand. The silted part of the area covered by the dam is known as the sand reservoir. Water flowing through the valley is stored in this sand dam reservoir and is used for irrigation through bore holes or dug wells.



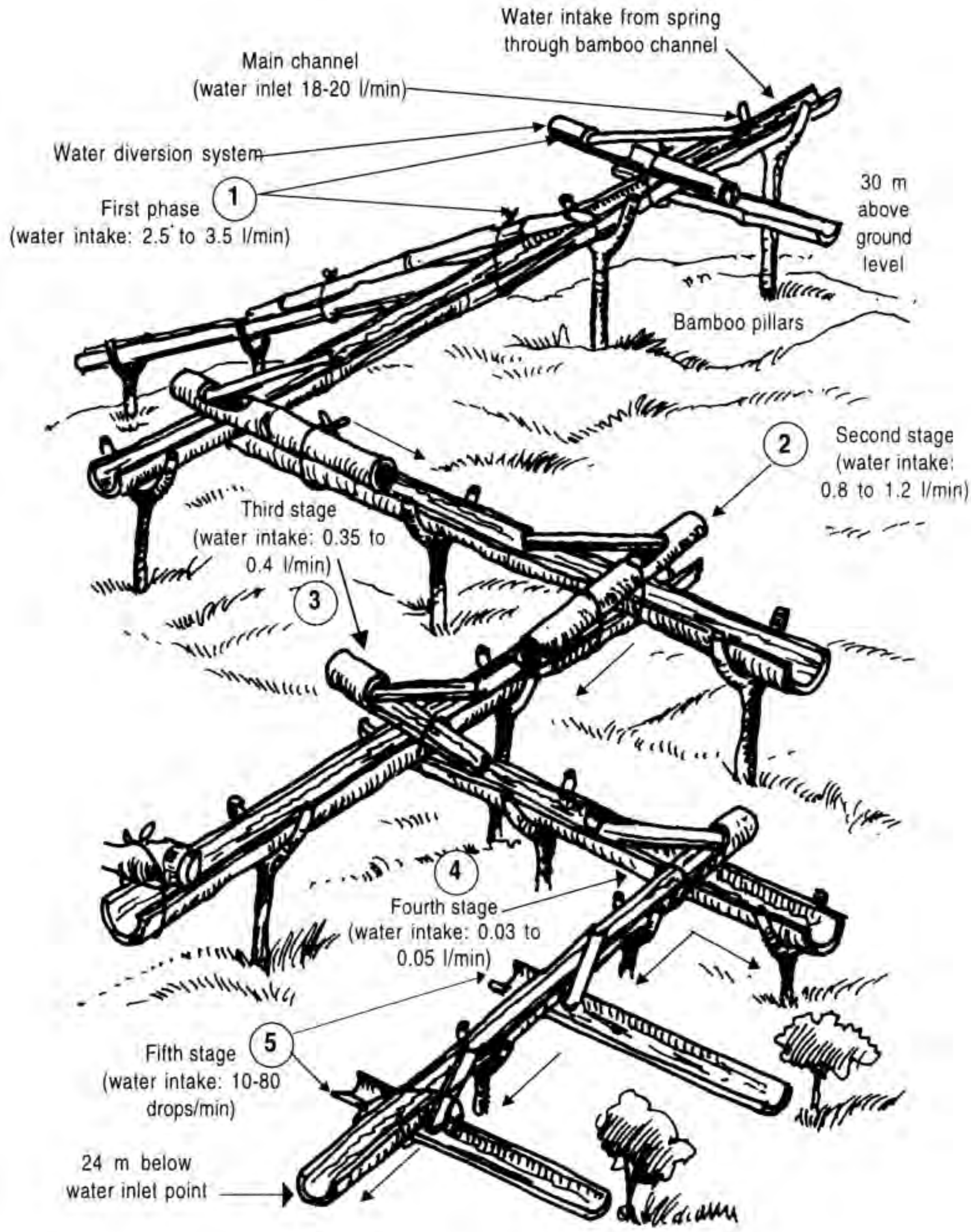
Lot water storage system

This is a large earthen embankment in a shallow river basin along the river bank which provides seepage water for irrigation at the lower stream. Sometimes, seepage water stored in the lower part is used for irrigation upstream, as well as at the lower stream through a channel using a water-lifting device.



Indigenous bamboo drippers

In Meghalay, bamboo channels have been used efficiently to carry water from mountainous springs and water courses for the last 200 years. About 18 to 20 litres of water is carried up to 100 m for irrigating plants. Water is so perfectly distributed through these bamboo channels that it applies 20 to 80 drops per minute to each plant. This shows that an excellent indigenous irrigation system exists in this area.



Summary of indigenous rainwater management practices

Method	Location	Common use
AGRONOMIC MEASURES		
1. Contour farming	Undulating slopy land, Chhota Nagpur Plateau and Assam	To conserve moisture and control soil erosion
2. Cover cropping	Almost in whole eastern India	To conserve soil and water
3. Jabo cultivation	Assam, Nagaland mountainous region	Rainwater used for integrated farming, forestry, animal husbandry and crop cultivation
4. Interplanting/cropping	Almost in whole eastern India	To conserve moisture and control soil erosion
5. Mixed cropping	Drought- and flood-prone area	To provide continuous soil cover and ensure drop
6. Adding organic and green manures	Almost in whole eastern India	To conserve moisture and control soil erosion
7. Tillage practices	Almost in whole eastern India	To conserve moisture and control soil erosion
8. Mulch tillage	Almost in whole eastern India	To conserve moisture and control soil erosion
9. Dead furrowing/ shallow trenching	Almost in whole eastern India	To conserve moisture and control soil erosion
10. Summer ploughing	Almost in whole eastern India	To increase initial rainwater-absorbing capacity of soil, weed and pest control
11. Listing and ridge planting	Low-rainfall areas	To conserve moisture and control soil erosion
MECHANICAL MEASURES		
12. Field bunding	Almost in whole eastern India	To store maximum possible rainwater in the field itself
13. Bench terracing	Hilly region (slope 6%-33%)	To conserve rainwater and use for crop production
14. Farm pond	Mostly in rainfed plain area	Domestic and cattle use, irrigation and groundwater recharge
15. Community pond	Almost in whole eastern India	To store maximum possible rainwater in the catchment area
16. Permanent natural water bodies	Almost in whole eastern India	To store maximum possible rainwater in the catchment area
17. Dugout pond	Areas having high water table (1.5-2 m) as well as in existing waterways	To store water for multiple uses and groundwater recharge
18. Small check dam	In existing riverlets, *nalas* and springs	Groundwater recharge and life-saving irrigation through wells or bore holes
19. Lot water storage	Azamgarh (UP)	Irrigation and flood control system
20. Ahar and Paeen	South Bihar	Irrigation
21. Sand dam	River basins and valleys	Sub-surface water storage used for irrigation through dug well or bore holes
22. Indigenous bamboo drippers	Assam and Meghalaya having mountainous water springs	Drip irrigation of vegetable and plantation crops, domestic use

Prepared by:
M. R. Varma

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

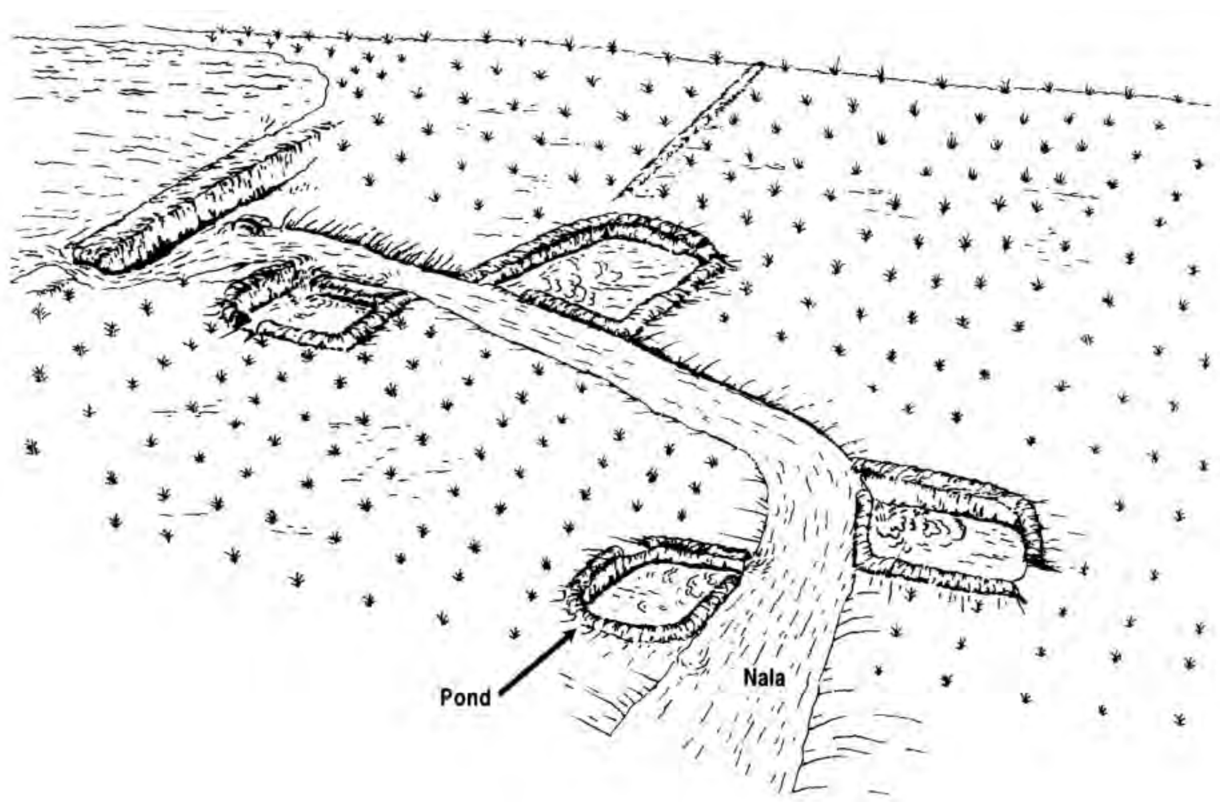
Water Saving, Recycling and Sequential Use Technologies: A Case Study

In rainfed rice areas, drought is a major constraint to improving productivity. Drought may occur at any stage of crop growth. To improve rice productivity in rainfed areas, rainwater-saving technologies such as rainwater harvesting, conservation and recycling are essential.

In village Handio, Hazaribagh District, Bihar, water-saving devices were developed to collect and store water for future use. This effort was undertaken in partnership with local NGOs and farmers. The following are some examples of what the villagers in Handio currently do.

Water-saving methods in the villages

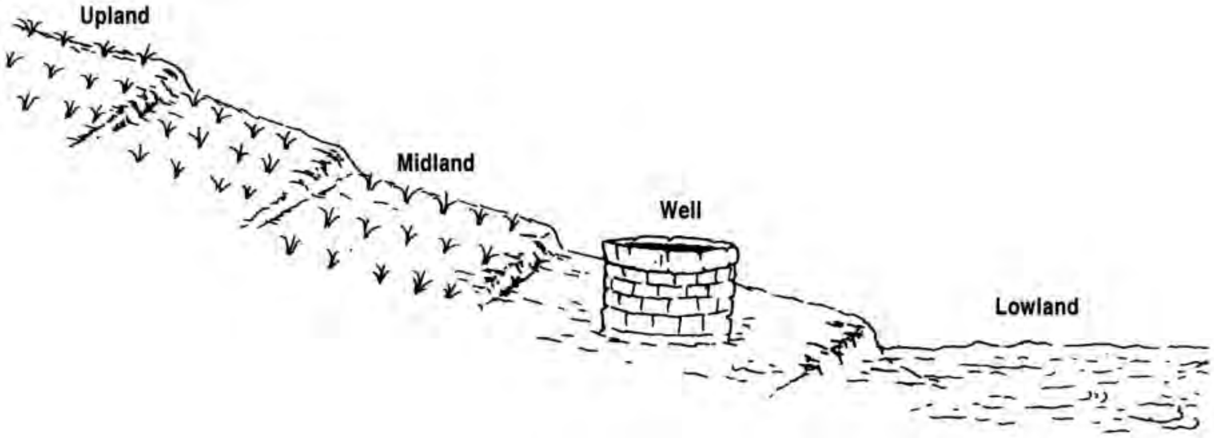
- Construction of ponds at different intervals along the nala (creek) flowing in the village. The village has 16 ponds at different points along the nala.



- Open wells with large diameters located in the midland region, which has 37 open wells charged with seepage water and water from adjacent fields.
- Deepening of existing ponds to hold additional water.

Pond water available after deepening

	Before	After
Pond area (ha)	0.25-1.30	0.25-1.30
Depth (m)	0.50-0.70	1.00-1.30
Duration (mo)	4-7 (Jul-Jan)	6-11 (Jul-May)
Volume (ha m)	0.12-0.91	0.25-1.69

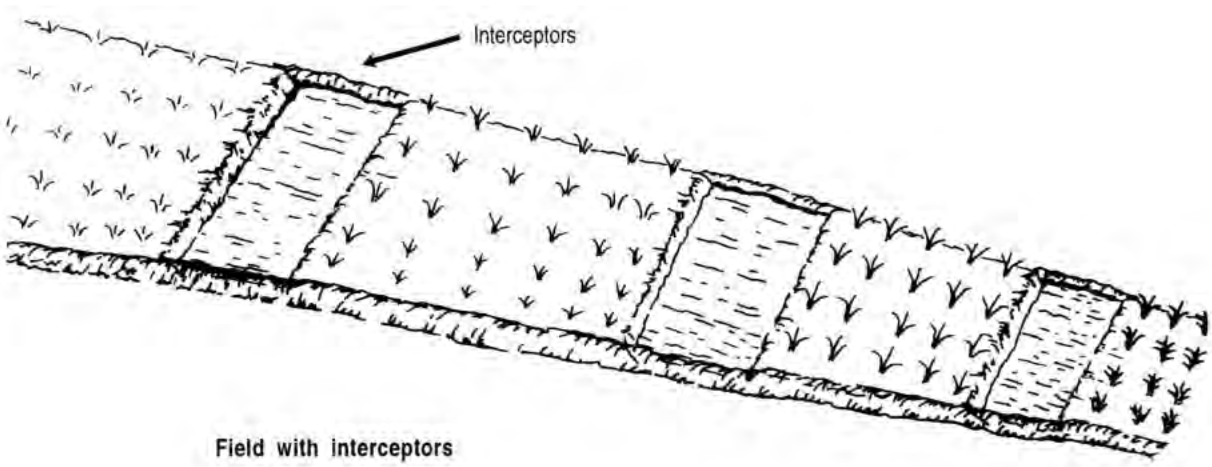


In situ water conservation

Runoff collectors across the slope in uplands

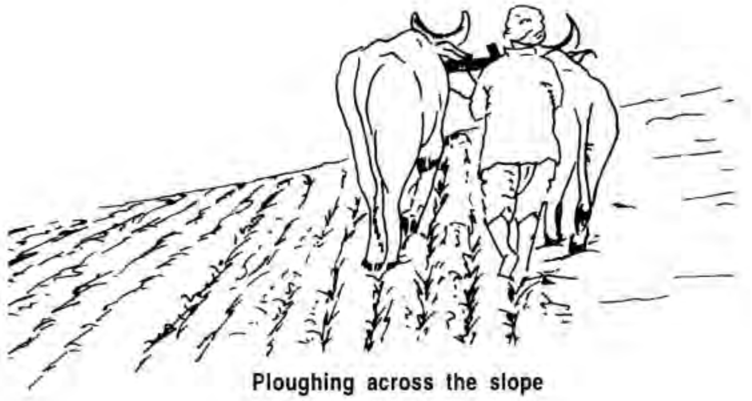
The runoff collectors check the loss of surface rainwater. The water that collects in the interceptors moves laterally and serves to charge the root zones. This keeps the soil wet, thus facilitating the' growth of good rice crops. The effects of runoff collectors on rice yields are given in the table.

Locations of runoff interceptors	Grain yield (t/ha)	Straw yield (t/ha)	Total /m^2
Upper slope	1.87	2.94	36049
Middle slope	1.98	3.03	36668
Lower slope	2.00	2.63	43550
Lowest slope	2.22	3.14	44370
Without interception	1.43	2.39	30827



Field with interceptors

Ploughing along the slope



Ploughing across the slope

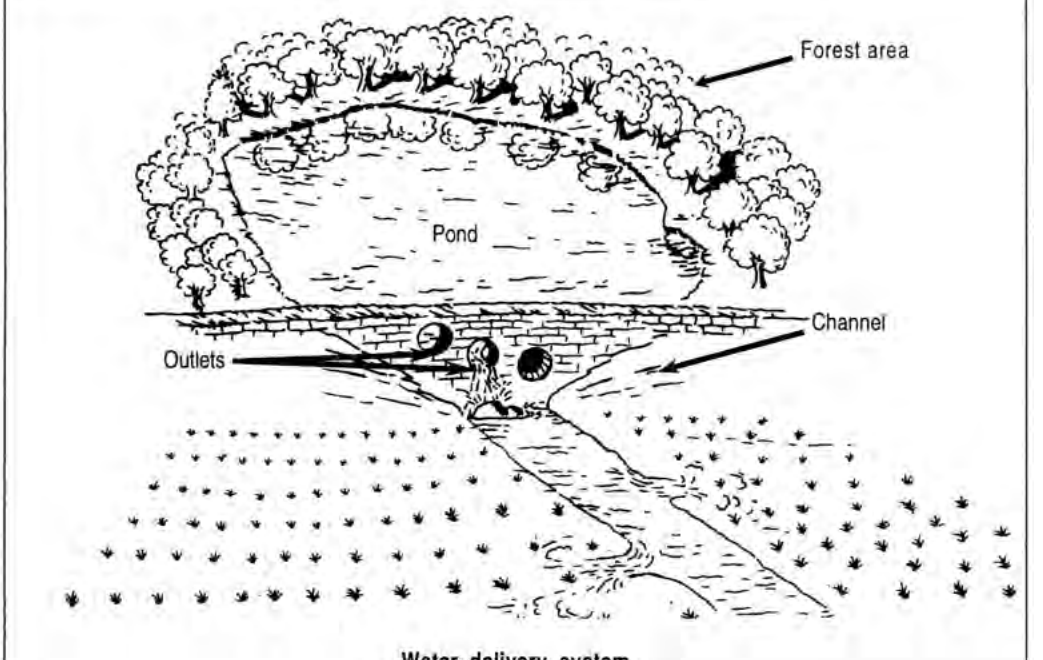
Ploughing across the slope

Ploughing and other cultural operations are undertaken across the slope. This controls surface runoff of rainwater. This water then percolates into the soil.

Water recycling

This refers to the judicious use of stored rainwater in ponds/wells to provide life-saving irrigation to rice during periods of drought and for growing sequential crops. The recycling of water in the village helps in:

- timely nursery raising;
- mitigation of drought;
- improving the chances of an assured crop;
- increasing cropping intensity;
- improving crop productivity;
- generating employment throughout the year; and
- improving livestock health through more fodder production.



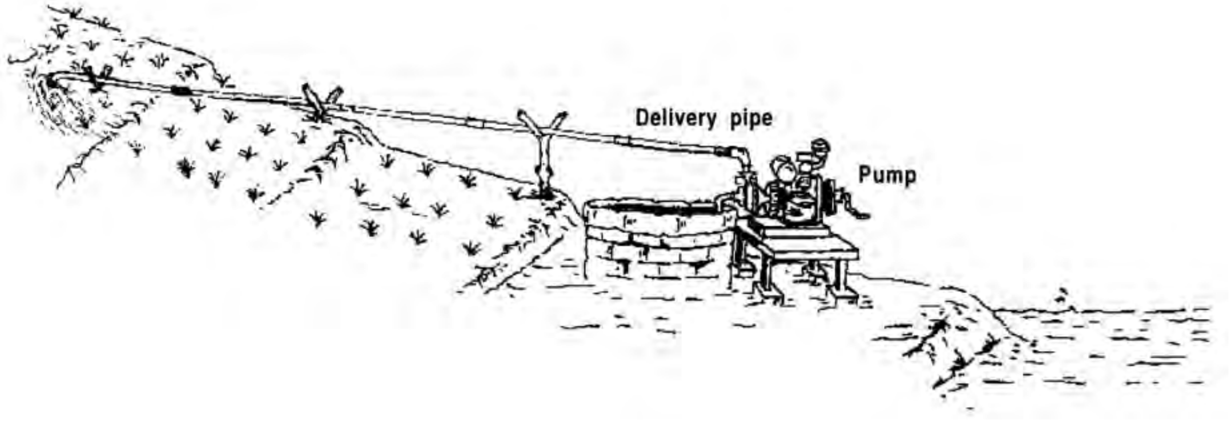
Water delivery system

Improving the delivery system for water stored in a pond

Farmers often cut the embankment of ponds to divert water for irrigation which results in heavy outflow that can destroy the earthen channels. Water is also wasted while being transported to the fields. To minimise the loss during delivery, round cement pipes are fixed at different heights in the embankment of the pond and plugged. The delivery of water is controlled by opening the hole of one delivery pipe at a time depending on the level of water in the pond. This mechanism provides for a controlled release of water.

Irrigation from open wells

The water from open wells in the midland region is lifted by diesel pumps. This water is transported to the upland fields through plastic delivery pipes without loss.



Impact

Farmers previously grew only rice in upland and lowland fields. Ponds and wells with water-storing facilities have improved cropping intensity and helped in the rearing of fish. Thirty-five farming families have benefitted from this experience.

Crops grown in different land types

Land type	Before water harvesting	After water harvesting
Upland	Rice	Rice-vegetable (pea/wheat/ cauliflower/cabbage/eggplant/ coriander/potato/tomato)
Shallow lowland	Rice	Rice-wheat/tomato, summer tomato, vegetables
Lowland	Rice	Rice-summer vegetables

Prepared by:
R.K. Singh and V.P. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Weed Management

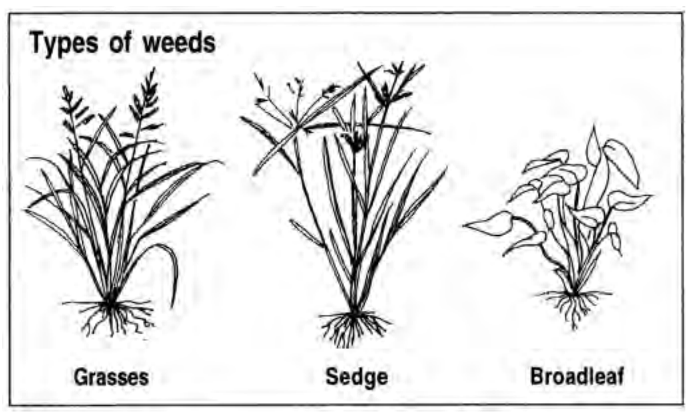
Weed Management in Different Rainfed Rice-Farming Systems

Weeds and their ecological variation

The nature of weed vegetation is greatly affected by edaphic, climatic and cultural parameters. Among these, soil moisture is the most important. Although several hundred weeds are associated with rice, not all are present in all situations. Usually, only 15 to 20 weeds are problem weeds. Broadly, weeds are classified as grasses, sedges and broadleaf weeds.

Occurrence of weeds varies:

- moist to saturated soils favour grasses and sedges;
- aerobic conditions favour all weeds; and
- puddled soils favour sedges.



What is weed management?

Weed management is the shifting of crop/weed competition in favour of rice, so that yield reduction is not significant. This is because the cost of weed control is more than the loss of yield up to a significant level of reduction.

Direct weed management

- Hand weeding
- Mechanical weeding
- Chemical weeding

Indirect weed management

- Land preparation
- Efficient fertiliser management
- Efficient water management
- Using cultivars with better weed competitive ability
- Using economic threshold level of weeds
- Manipulating sowing dates
- Various cultural practices

Caution

Repeated use of a certain method of weed control independently may result in an undesirable shift in weed flora.

When using herbicides, remember:

- to apply herbicides strictly at the recommended dose and crop stage. As older weeds are not suppressed or killed, there should not be any weed with more than one to two leaves for early post-emergence/pre-emergence spraying; and
- to change the herbicide each year to avoid an undesirable shift in weed flora and to stop resistance to the herbicide. A large number of herbicides suitable for rice have varying degrees of weed control efficiency, such as anilofos, butachlor, thiobencarb, pendimethalin, pretilachlor, pyrazosulfuron ethyl, oxadiazon and oxyfluorfen, etc.

Hand weeding

Hand weeding is the removal of weeds by hand or *khurpi.* It is done in both nurseries and main plots. Complete the first hand weeding within 20 days of sowing when the weeds are of suitable size for removal.

For nurseries, one weeding is enough. However, in main plots, depending on the duration of the variety and weed growth, two to three hand weedings may be needed. The interval between the first and second weedings must not exceed three weeks.

Mechanical weeding

Mechanical weeding is a method that uses different types of weeder or hoe, such as the sweep hoe, wheel hoe, Japanese paddy weeder and pulo weeder. In broadcasting, however, the seeded rice weeder or hoe cannot be used.

Mechanical weeding is best practiced only when the physical condition of the soil, particularly moisture or water, is at an optimum level for moving tools. Mechanical weeding can be' combined with hand weeding.

Chemical weed control

Phytotoxic chemicals used to suppress weed growth in crops are known as herbicides.

Chemical weeding

What is integrated weed management?

A combination of two or more methods of weed control practiced at a time is known as integrated weed management. Apart from reducing the weed problem, integrated weed management takes into account the environmental, social and economic impact of the combined control strategies. Direct and indirect methods should be used together to solve weed problems.

Weed management schedule

Upland rice

Method

Use either two hand weedings or a combination of chemical and manual weeding.

First weeding

For manual weeding, remove the weeds within the first three weeks of sowing.

Second weeding

Adjust the next weeding in accordance with the split application schedule of nitrogen, within 40 days of sowing.

For chemical weed control, use only the liquid herbicide when the soil is not too dry. Apply butachlor or thiobencarb at 1.5 - 2.0 kg ai/ha or pendimethalin at 1.0 - 1.5 kg ai/ha at early post-emergence. Normally, this stage comes one to two days after rice emergence. This should be followed by spraying 2,4-D at 0.5 kg ai/ha 25-30 days after sowing. One hand weeding can follow the spraying.

Conditions

If the soil is not too dry or sticky, combine hand weeding with mechanical weeding.

Dry-seeded rice in lowland

Method

The crop condition is similar to upland rice initially but later becomes impounded with water. In broadcast rice, mechanical weeding is possible only with *khurpi* or beushening at 30 to 50 days after sowing rice in 15-20 cm of standing water.

If a herbicide is to be used and if the soil is dry, apply only the liquid form. If there is standing water, farmers can use either the granular or liquid form as described for transplanted lowlands.

First weeding

In chemical weed control, use herbicides one to two days after rice emergence. If farmers adopt manual or mechanical weeding, it should be completed within three weeks of sowing. Where applicable, first weeding can be achieved by beushening.

Second weeding

Do manual and/or mechanical weeding after four weeks of herbicide spray or three weeks after manual weeding, whichever is required.

Nursery for transplanting

If the weed population is not very high, one hand weeding at 15 to 20 days after seeding is adequate. Where weeds are expected to be prolific, use a herbicide as recommended for upland rice.

Transplanted lowland

Method

Do two to three hand weedings at three-week intervals after transplanting or use a combination of chemicals and hand weeding like in upland rice farming. In transplanted conditions, apply herbicides preferably in the granular form. If the granular form is not available, mix the liquid form with sand as a carrier and apply in a thin film of water, six to seven days after transplanting. The liquid form of herbicide may also be sprayed if there is no standing water. After seven to 10 days of herbicide application, flood the field to check the further growth of weeds.

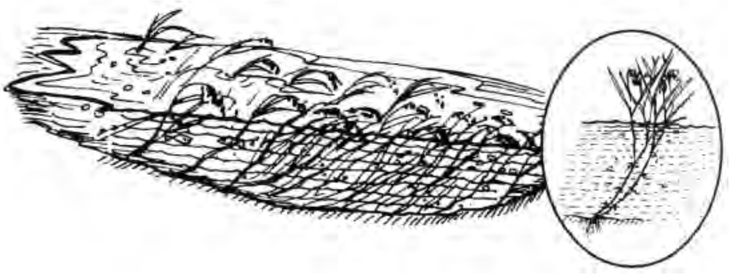
Wet-seeded lowland

This type of rice culture replaces transplanting. This rice ecosystem is becoming important due to increased labour wages and water scarcity. In this ecosystem, the problems of weeds and weed management costs are more than with transplanting. However, the reduced cost of establishing the crop due to savings in water more than compensates for the problem.

Method

Use a herbicide in a granular form (more economical than manual weeding) one to two days after rice emergence, followed by hand weeding 15 to 30 days after sowing.

Deepwater and flooded



The crop growing period is long, and needs proper weed control throughout. If feasible, manual weeding should be preferred over other methods because of its better weed-controlling efficiency.

Here, crops are established as direct-seeded or transplanted. In the early stages of the crop, the weed control practice is similar to that of transplanted or dry-seeded lowland rice.

For the second weeding, the *pula* weeder is very effective. In addition to the above practices, there are some specific practices for aquatic weed control.

- In certain cases, when aquatic weeds are submerged in a standing crop, clip the portion of weed above the water surface to suppress weed growth.
- Rearing grass carp fish is also helpful in reducing the problem of aquatic weeds. About 1500 fingerlings of approximately 100 g each are adequate for one hectare of rice land. When weed vegetation is reduced, fish may be either consumed or transferred to another plot.
- Applying 2, 4-D at 0.75 kg ai/ha or MCPA at 0.75 kg ai/ha four to six weeks after establishing the crop substantially reduces the weed problem, especially broadleaf weeds.
- Algal weeds are also a problem in lowland rice. Use copper sulphate or copper oxychloride at 8 to 10 kg/ha or Breston 60 at 0.7 to 1.7 kg ai/ha or potassium azide at 3 to 4 kg/ha for effective control.

If the water depth is abnormally high and the aquatic weed is a severe problem, increase the dose of the herbicide in consultation with a weed scientist.

Indirect weed management

Land preparation

Time, degree and methods of land preparation influence the incidence of weeds. Hastening the germination of a flush of weeds and controlling them before crop establishment help in weed management. This can be achieved by the stale seedbed technique in uplands when the growing season permits. Summer ploughing minimises the weed problem. Deep ploughing once in three to five years helps reduce weed seed.

Under puddle conditions, churn the soil so that it mixes thoroughly with the weeds, stubble and straw. Level the land so that there is a uniform layer of water to give an even herbicidal weed control and to suppress weed growth.

Using weed-free seeds

Rice seed is one of the major sources of dissemination of weed seed and infestation of new areas by weeds.

Strict vigil through quarantine and seed certification can help. As far as practicable, seed should be free from weed seed. But in any case, 50 g of rice seed should not have more than one seed of problem weeds.

Morpho-physiological traits useful for better competitive ability of rice

- Rapid and uniform germination
- Faster growth rate at the seedling stage
- Early prolific root growth near the soil surface and a deep main root system
- High nitrogen absorption at an early stage
- Good vegetative vigour
- Tall height and more canopy, especially during the early stages of rice

Using varieties with better competitiveness against weeds

Some rice varieties either suppress weed growth or compete with weeds without sacrificing yield. Vandana is one such variety for upland rice farming.

Proper schedule of fertiliser application

To prevent weed proliferation without sacrificing yield, do not apply nitrogen fertilisers until weed control is adequate. In acidic uplands, use a rock-phosphate at the time of sowing in place of a single super-phosphate to help reduce weed growth. Weed control is mandatory when fertiliser is applied. Otherwise, fertiliser will favour weeds over rice.

Water management

In lowland rice ecosystems, water can minimise weed problems by 52%-85%. Weed growth is directly influenced by the depth and duration of their submergence, particularly during the early stage of the crop. Grasses are completely eliminated in continuous submergence of 16 cm depth throughout the crop period. A 3-5 cm submergence depth also gives substantial control of grasses, followed by sedges.

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Prepared by:
G.N. Mishra

Indigenous Weed Management Practices in Rainfed Rice Farming

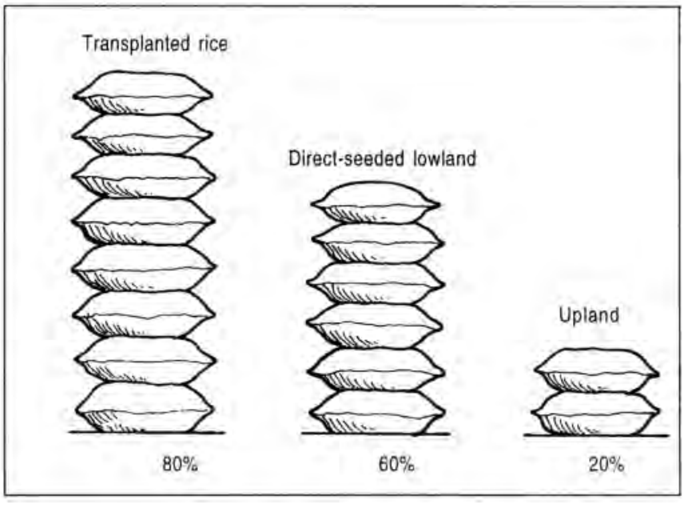
What are indigenous weed management practices?

Indigenous weed management practices are methods of weed management that have originated locally and are being used extensively by farmers based on their experience. Some of the methods are common to all ecosystems of rice while others are situation-specific.

Summer ploughing

Summer ploughing is the most common practice applicable to almost all ecosystems of rice. It disturbs the natural establishment of weeds and helps check their proliferation. Summer ploughing leads to:

- weed seeds from the sub-surface of the soil being brought to the surface;
- the destruction of the already germinated weed seedlings on the surface and the exposure of the moistened seed to the sun. (This process helps in the destruction of most weed species.)



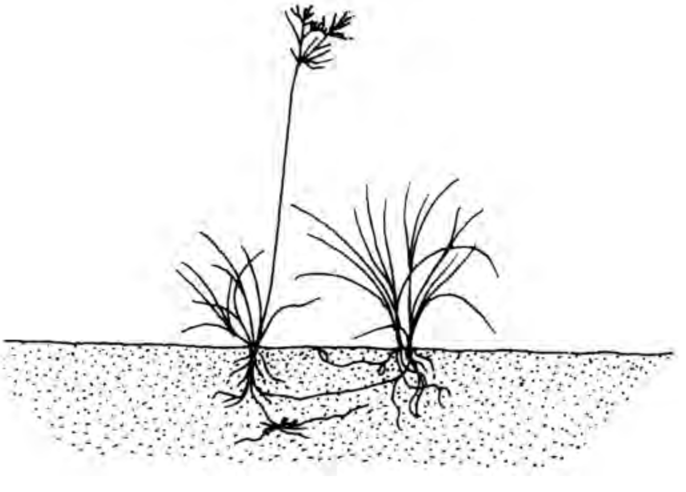
Yield under unweeded conditions


Summer ploughing

Digging topsoil with a spade

Reminder!

Spade-digging is feasible only over small areas. In the case of larger areas, farmers can use tractor-mounted chisellers.



Underground stems and tubers of *Cyperus rotundus* L.

Digging with a spade during summer

In this practice, the soil is dug manually with a spade. The depth of the soil tilled in this method is greater than what can be done with the country plough. This practice is adopted where perennial weeds such as bermuda grass (*Cynodon dactylon* L.), nut grass (*Cyperus rotundus* L.) and wild cane (*Saccharum spontaneum* L.) proliferate. This practice is cumbersome but effective.

- The underground vegetative propagules (nuts/rhizome/tuber, etc.) of these weeds are cut and exposed to the sun, resulting in their dessication.
- Continuous use of this method year after year helps the farmers get rid of the weeds whose proliferation cannot be checked by other methods.

Tevai followed by hand weeding

Tevai is a vernacular word meaning third. This practice is adopted by the upland rice farmers who grow traditional cultivars. In this method, rice seeds are broadcast in moist soil. On the third day of sowing, shallow ploughing of the field is done using a country plough. This helps farmers in two ways:

- the emerging weeds are uprooted and their growth is suppressed/ checked; and
- the crust formed is broken, facilitating the easy germination of rice.

After ploughing (using a country plough), some farmers undertake seeding again to compensate for the loss, if any, from ploughing. The size of the clods determine whether laddering is required after *tevai.* Depending upon the availability of labor, the weeds are removed by hand 30-40 days after sowing.

In Assam and Orissa, upland rice farmers use a spike-toothed bullock-drawn implement in place of the country plough to break the crust of the soil and destroy weeds. This implement is called *bindha* or *bida.*

Hand weeding

This is a very practical and common method of weed control applicable to all ecosystems in which rice is grown. Depending upon the growth of the cultivar, the weeds are removed manually within an interval of approximately three weeks from transplanting/direct seeding. Farmers often make use of a sickle or hand shovel (*khurpi*) as it is easy to use.

Hand weeding

Advantages of hand weeding

- Effective against all weeds
- For poor farmers, family labour can be deployed for weeding
- Provides employment

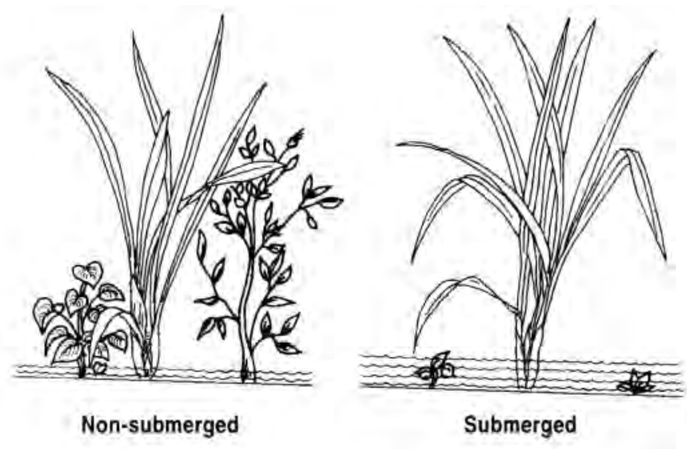
Hand weeding with sickle

Beushening (cross-ploughing and laddering in standing crop)

In shallow rainfed conditions, farmers adopt this practice on direct-seeded rice. Farmers grow traditional varieties which are directly seeded after the onset of the monsoons. When the crop is 30-50 days old, the field is beushened in 15-20 cm of standing water. After this, the leftover weeds are removed manually. Some farmers opt for gap filling while others do not. This method is cost-effective as it substantially reduces the labour required for weeding.

Puddling

Wherever possible, farmers flood the field two to three weeks prior to puddling. This helps to decompose the weeds as puddling is done one to two days before transplanting. Puddling disturbs the weed seed reserve and the physical condition of the soil and checks the proliferation of weeds.



Flooding (submergence)

After the transplanting of traditional rice cultivars, farmers maintain a depth of 5-10 cm of standing water in the field and continue with this up to the flowering stage. This prevents the growth of weeds, particularly grasses and sedges. This practice is possible only where water is in natural abundance. Some improved varieties of rice are not suitable for this as their tillering is inhibited.

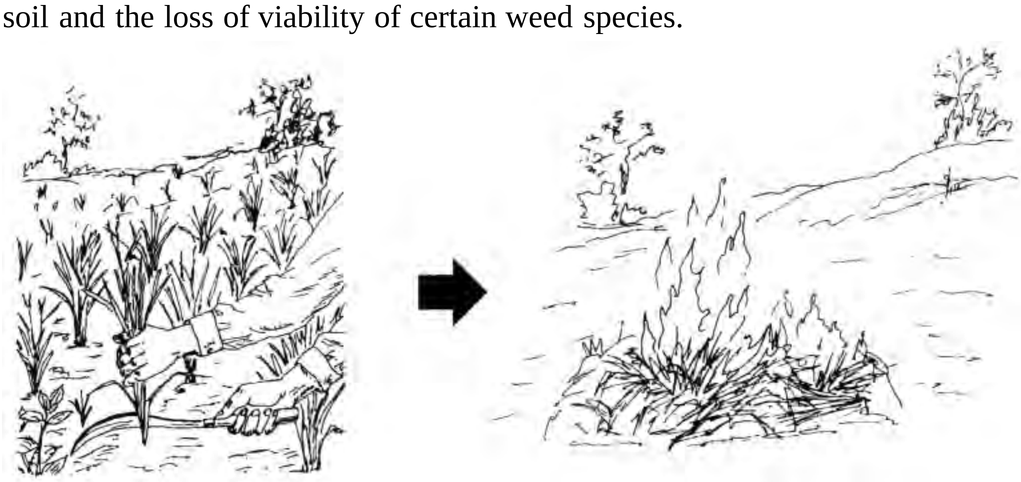
Use of clean seed

Farmers should use high-quality seeds that are free from weed seeds. To ensure weed-free seed:

- select plots with less weeds;
- thresh the produce in a clean spot (to reduce the chances of contamination with weed seed); and
- winnow the seeds thoroughly.

Burning of weed plants in crop field

Some weeds that grow massively are uprooted after ploughing or their aerial portions are cut and accumulated in one place and burned. Sometimes, particularly after the harvesting of the dry-season crop, its stubble is also burned in the field. This raises the temperature of the surface soil and the loss of viability of certain weed species.



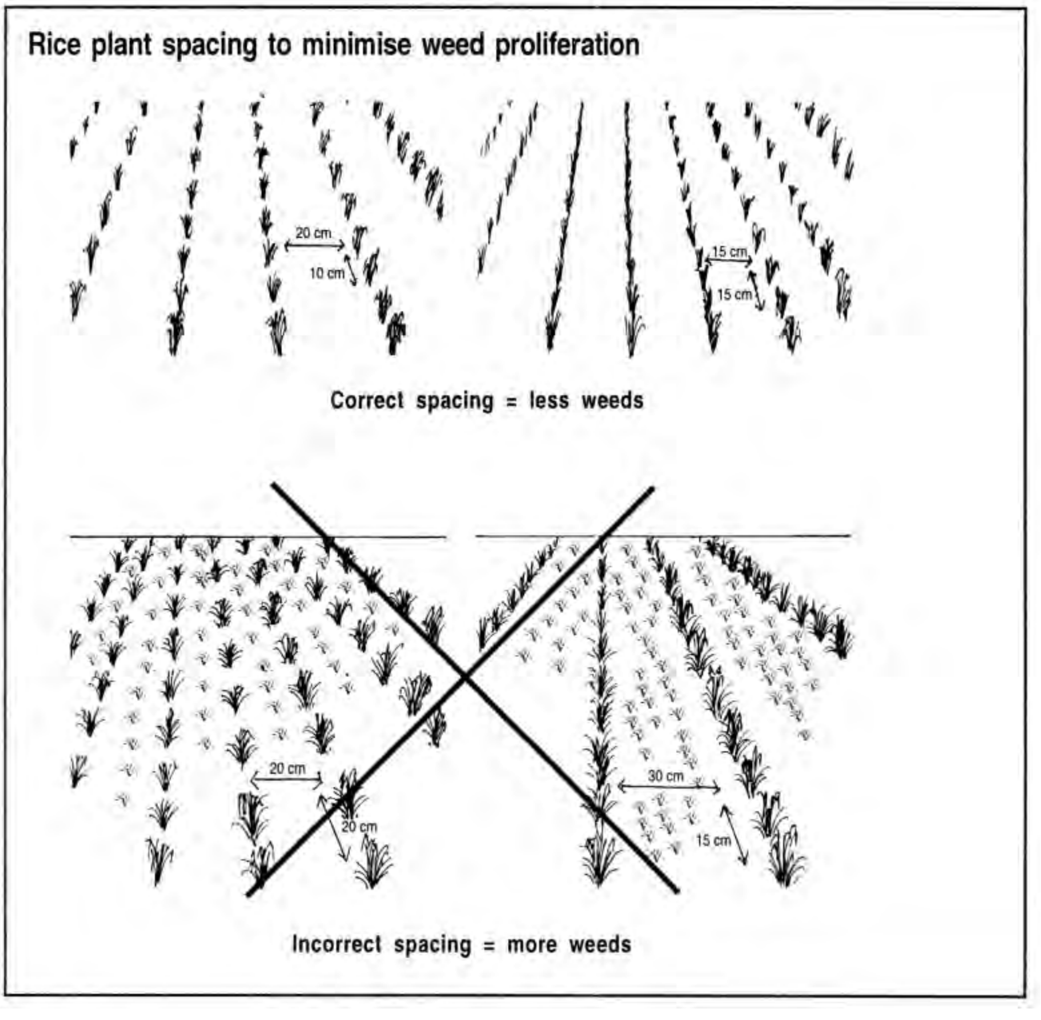
Cutting and burning of weeds

High plant population of rice

Larger quantities of seeds are used under nursery or main plot conditions to increase the plant population. Under transplanted conditions, row spacing and plant spacing are reduced to increase plant density. The increased canopy of rice helps prevent weed proliferation. However, this method alone may not be adequate to check the growth of weeds.

Use of pigmented rice varieties

In some rice-growing areas, the presence of wild rice is a problem as the known methods of weed control are not effective. This is because of the weed's morphological similarity with rice. In such areas, farmers use a variety with a purple stem or the completely pigmented variety. In this category, some recently released varieties are *Shyamala, Kalasri* and *Mahanzaya.*



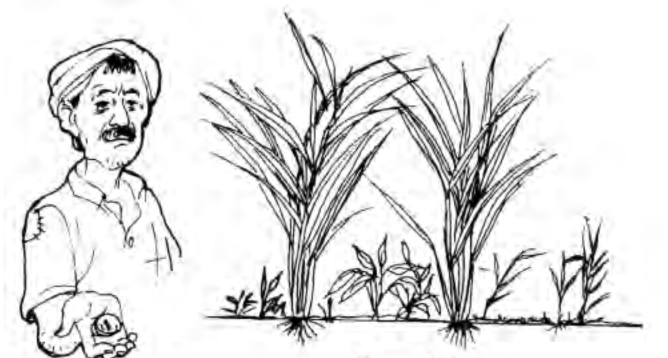
Prepared by:
G.N. Mishra

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

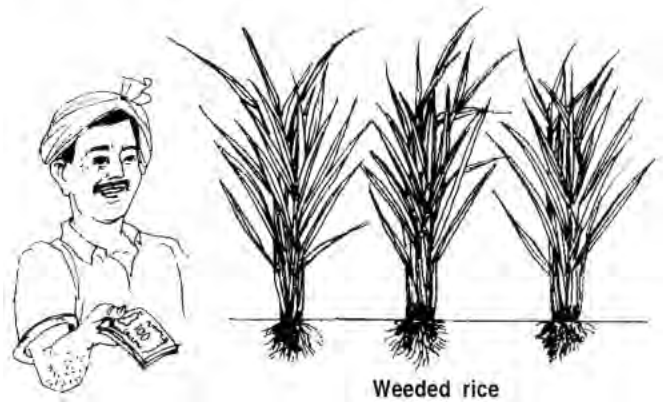
Cost Effectiveness of Weed Management for Rice

For improved rice varieties, yield loss due to weeds is a major factor affecting the economics of rice production. Usually, in calculating the economics of weed management, only the cost of labour and herbicides is taken into account. But the cost-effectiveness is greatly influenced by several other factors such as cultural practices, such as crop rotation, intercropping which has a crop with potential to smother weeds, summer ploughing, efficient water and nutrient management and use of a weed-suppressing variety. Indirect long-term gains affecting health and environmental safety of humans, livestock and other forms of life have to be considered.

In subsistence farming with traditional varieties, weed control is not always beneficial as yields are otherwise low. Moreover, these cultivars are naturally competitive against weeds while comparatively improved rice cultivars are more susceptible to weeds. Therefore, weed control is mandatory and is a remunerative practice which gives higher returns.


Unweeded rice

One has to understand the economics of weed control before adopting any weed management practice. Information is also needed about the **right stage** of weed control, i.e., **critical period** for weed control, its **necessity** and **level** required.


Weeded rice

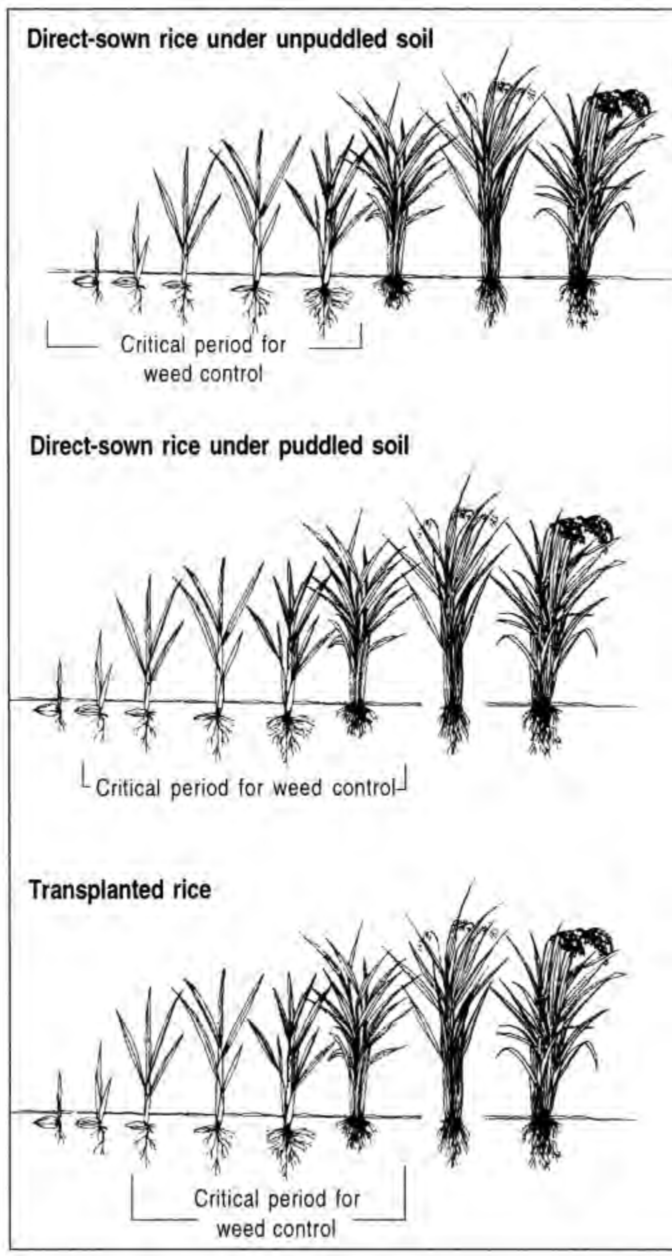
Critical period

The crop stage and duration of the critical period depend on factors such as weed flora, growth

Weeds cause significant yield reduction. The extent of yield losses ranges between 15-20% in transplanted rice, 30-35% in direct-seeded lowland rice and 50-90% in upland rice.

characteristics of rice and weeds, cultural practices and environmental factors. Normally, in direct-seeded rice under unpuddled conditions, weed control has to be done during the initial 40 to 45 days after sowing. Under puddled conditions, whether direct-seeded or transplanted, there is not much competition during the first 10 to 15 days of crop establishment. The crop is sensitive to weeds from the tillering stage until the heading stage.

Weed problems are more serious in uplands than in other ecosystems. Upland soil favours faster weed growth and crop-weed competition starts soon after the emergence of rice. In the initial stage of weeds, it is, difficult to distinguish several grassy weeds from rice seedlings. This helps weeds in escaping the attention of farmers, to the detriment of rice.



Necessity of weed control

A quick survey of the field will suggest whether weeds are present at the level that needs control. The mere presence of weeds does not make weed control mandatory. In recent years, scientists have been developing economic threshold levels of weeds. Even in the absence of such recommendations, farmers can use their own judgement, based on experience, to determine whether weeding is required even at low levels of infestation.

Level/intensity of weed control

This can be determined by making an economic analysis of gains from the adoption of weed control measures. Identification of constituents of cost and benefit of weed control is very important.

Methods of weed control

Manual weeding

It is an age-old and widely used practice, though it is time-consuming and often cumbersome. It is economical in situations where wages of labour are low or when labour is available in abundance or when family members work in the fields. In addition, manual weeding is desirable in situations where chemical or mechanical weed control is ineffective. Further, manual weeding can be used as a supplement to other types of weed management practices.

Mechanical weed control

Although mechanical weeding is economical, its scope is sometimes limited. It does not work in situations where the physical condition of the soil does not favour the use of tools or when rice is broadcast-seeded or transplanted randomly.

Chemical weed control

Increased cropping intensity, diversion of the labour force from agriculture to other enterprises and the rising trend of wages of agricultural workers have forced farmers into using herbicides. Scarcity of water for puddling has resulted in the replacement of transplanting by direct seeding. In such situations, the weed problem is more acute. Use of herbicides is more cost-effective than manual weeding. However, the large-scale use of herbicides can have a negative effect on employment, environment and health. So, herbicides should only be used as a supplement to other weed control practices.

Integrated method of weed control

The integrated method of weed control involves the use of more than one method of weed control. A combination of chemical and manual weeding is one example of integrated weed management practice. Another example in rainfed lowlands is the use of the traditional cross plough in a standing crop of direct-seeded rice as a component of beushening combined with hand weeding and gap tilling. This is more cost-effective than two hand weedings.

When water availability is low and labour costs are low, use manual weeding.

When water availability is low and labour costs are high, use herbicides.

When water availability is high and labour costs are high, use herbicides.

When water availability is high and labour costs are low, combine manual weeding and herbicide use.

Measurement of cost-effectiveness

Several terms are commonly used to express cost-effectiveness. These are highest yield, highest gross benefit, highest net return, etc. But these parameters do not give the correct picture. To correctly measure cost-effectiveness, the following steps should be taken.

- Know all the variable costs of the individual weed management practices. Costs of labour, herbicide and hire charge of machinery/tools (self or rental) are considered as variable costs.
- Price of herbicide should be obtained from the local source from where farmers commonly purchase agricultural inputs. Wages of labour should also be the locally prevailing rates. Even if family labour is engaged, it should be treated as hired labour for measuring cost-effectiveness.
- Add all types of variable costs to get the total variable cost. For example, it is Rs. 1011/ha in the farmers' practice of one hand weeding (T_1) and Rs. 2074/ha in two hand weedings (T_2).
- Know the adjusted economic yield. Adjusted yield is obtained by suitable correction towards expected yield difference in the experimental plot and farmers' field. If yield at the research station is 1.70 t/ha and 3.67 t/ha in T_1 and T_2, respectively, but farmers get 15% less yield, the adjusted yield in T_1 and T_2 will be 1.68 and 3.30 t/ha, respectively.
- Know the field price by deducting the cost of transport, storage, etc., from the rate of produce in the local market. If farmers sell rice at Rs. 5/kg, but spend Rs. 0.50 on various items, the field price will be Rs. 4.50/kg.
- Calculate gross benefit with the help of adjusted yield and field price of produce. It works out to Rs. 7574/ha and Rs. 14864/ha for T_1 and T_2, respectively.
- Calculate net benefit by the difference of gross benefit and total variable cost. It works out to Rs. 6563 and Rs. 12790 for T_1 and T_2, respectively.
- Compute marginal benefit-cost ratio (MBCR).

$$\textbf{MBCR} = \frac{\text{Change in gross benefit due to treatment in question versus control treatment}}{\text{Change in variable cost due to treatment in question versus control treatment}}$$

$$\textbf{MBCR} = \frac{\text{Rs. 14864 } (T_2) - \text{Rs. 7574 } (T_1)}{\text{Rs. 2074 } (T_2) - \text{Rs. 1011 } (T_1)} = \frac{7290}{1063} = \mathbf{6.86}$$

Any new treatment/practice should be considered for further analysis only when the MBCR is 2.0 or more. Otherwise, discard the new treatment in question.

¢ Compute marginal rate of return (MRR) and express it in percent.
Here, the MRR is 586%, which means that for every Rs. 1 farmers invest, they will get back Rs. 1 plus Rs 5.86 more if they adopt T2.

$$\textbf{MRR} = \frac{\text{Change in net benefit due to new practice versus control treatment}}{\text{Change in total variable cost due to treatment in question versus control treatment}} \times 100$$

$$\textbf{MRR} = \frac{\text{Rs. } 12790\ (T_2) - \text{Rs. } 6563\ (T_1)}{\text{Rs. } 2074\ (T_2) - \text{Rs. } 1011\ (T_1)} \times 100 = \frac{6227}{1063} \times 100 = \textbf{586\%}$$

- Calculate capital cost, which includes interest on capital and various expenses involved in arranging money. This is also expressed in percent and added to 20 for work incentive to farmers. If the capital cost for the period of credit taken is 30%, after adding 20% it becomes 50%.
- For acceptance of technology, the MRR must be higher than the capital cost. In the present example, farmers can consider T_1 as a replacement of their T_1.

Yardstick for acceptance of technology

Apart from direct economic gain from any weed management practice, its indirect impact should also be considered. Any practice which will have an influence on reducing weed problems in the future, due to reduced propagation rate, environmental and health safety, etc., should be given priority when there is a choice among several approaches having identical weed control efficiency. Groundwater pollution, reduction of the vertebrate population in surface water systems and the long-term disruption of the species equilibrium in the rice ecosystem are environmental factors for consideration. Eye, skin, pulmonary and neurological problems are significantly associated with frequent exposure to pesticides.

Accept and recommend those weed management practices which are technically sound, economically viable and ecologically friendly.

Prepared by:
G.N.Mishra and R.D. Vaishya

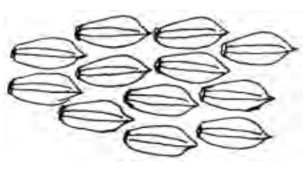
Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Pest, Disease and Rat Management

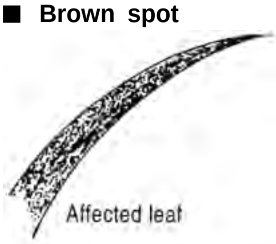
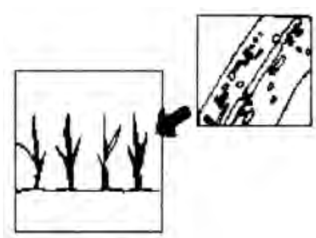
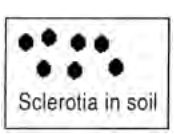
Pest Control Alternatives for the Rainfed Rice Ecosystem

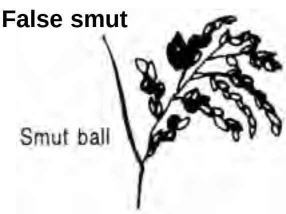
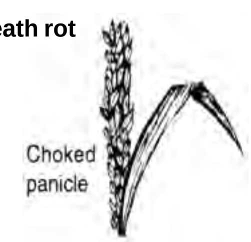
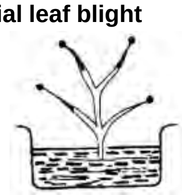
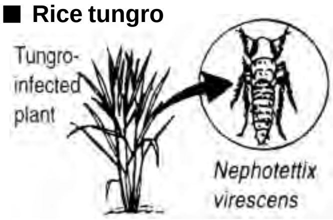
Pests grow faster under high-moisture conditions and in an environment of flourishing weeds. Under rainfed conditions, pests multiply fast. Because poor farmers own low-quality lands and cannot afford pesticides and fungicides, they have to resort to alternative measures that are indigenous and environment-friendly.

Healthy rice crop under rainfed conditions in eastern India

■ Disease-free seed 	■ Treatment of seedlings with turmeric and asafoetida 
■ Seed treatment 	■ Green manuring and basal dose before planting 
■ Sowing on healthy soil 	■ Foliar spraying of fertilisers and micronutrients at maximum tittering stage 
■ Nursery treatment 	■ Pre-flowering sprays reduce pests, diseases and weeds 

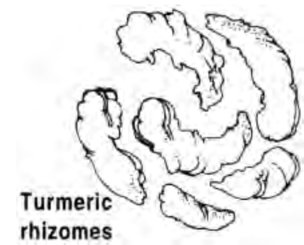
Alternative pest control measures

	Symptoms	Control measure
Diseases affecting leaf blade		
■ **Blast** 	Spots appear as distinct large, indefinite spindle-shaped with grey center and brown margin (hill terrain and rainfed upland).	Seed treatment with 100 g turmeric powder + 10 g sodium bicarbonate for 10 kg seed
■ **Brown spot** 	Small, oval or oblong with brown or straw center and dark reddish brown margins (all ecosystems, especially in nutrient-deficient ecosystem).	Apply 60 kg nitrogen/tha
■ **Sheath blight** 	Greenish grey irregular lesions with dark line on margins, cobra-type lesions are large and develop indefinitely on older plants (upland, semi-deep and waterlogged).	Apply farmyard manure at 3 cartloads/ha and foliar spray with 100 g turmeric powder and 10 g sodium bicarbonate in 10 liters water. Use 500-800 liters water/ha.
■ **Bacterial blight** 	Leaves with undulated yellowish white or golden yellow dry margins back from tip and curling, mid-rib intact (rainfed upland, medium land and lowland in epidemic form).	Seed treatment with 100 g turmeric powder + 10 g sodium bicarbonate, followed by foliar spray with cow dung slurry (2 kg/ 10 liters water).
Diseases affecting stem and sheath		
■ **Sheath blight** 	Sheath with large greenish grey or dark-edged whitish lesions, which are oval, oblong or irregular and necrotic. Small white or brown globular bodies loosely attached to the surface (rainfed upland, medium land and lowland in epidemic form).	Apply farmyard manure at 3 cartloads/ha or biological control with *Trichoderma viridis* and *Bacillus subtilis,* 500 g powder/ha.
■ **Foot rot**	Leaves and leaf sheath dry out, lower nodes become discolored and sometimes develop adventitious roots. Pink bloom on sheath above water level (hills, drought areas).	Biological control with *Trichoderma viridis/ T. harzinium,* 500 g powder/ha.

	Symptoms	Control measure
Diseases affecting grains		
■ **Blast**	Grain partially chaffy and brittle or unfilled. Panicles show white appearance (hills and terrain).	Foliar spray with 100 g turmeric powder, 10 g sodium bicarbonate in 10 liters water, 500-800 liters/ha.
■ **Brown spot**	Dark brown or black oval or oblong spots on the glumes or whole surface of the grain (drought and eroded soil).	Apply 60 kg nitrogen/ha.
■ **False smut** 	Grain completely replaced by large spherical yellowish or orange body, which changes to powdery mass later (lowland and deepwater).	Seed treatment with turmeric powder and sodium bicarbonate, 100 g/kg of seed.
■ **Stem rot** 	Whole plant starts rotting from water level up to panicle. Plant is covered with mustard-like bodies which transform into cylindrical rods covered with white mycelium (lowland).	Deep ploughing and burning of stubble in the field after harvest.
■ **Sheath rot** 	Oblong or irregular lesions with brown margins and grey centers, or greyish brown on leaf sheath, especially covering the panicles. The panicles remain within the sheath or only partially emerged. White powdery fungal growth inside the rotten sheath (all ecosystems).	Seed treatment with 100 g turmeric powder + 1 g asafoetida + 10 g sodium bicarbonate.
Diseases affecting entire plant		
■ **Bacterial leaf blight** 	Transplanted seedling showing bluish color with incurled central leaf. Plants rot completely, starting from the outer leaves. If these plants are cut and immersed in water, bacterial drops (ooze) appear at the cut ends (all ecosystems).	Foliar spray with 2 kg fresh cowdung in 10 liters water.
■ **Rice tungro** 	Brownish yellow in colour and severe to mild stunting, reduced tillering (all ecosystems).	Soil application of 20 kg neem cake or foliar application of 1% neem oil spray or spray asofoetida + sodium bicarbonate.
■ **Ufra**	Ufra nematode affects entire plant, especially panicle (lowland in Assam).	Turmeric powder spray and soil application, 20 kg neem cake/ha in deepwater conditions. Grow field-tolerant varieties such as *Bazal 165* and several Rayada cultivars.

Turmeric treatment for seed-borne diseases

Turmeric (*Curcuma longa* L.) has long been used as a germicidal ingredient. The powder of the dried rhizome of turmeric is an effective fungicide used as a systemic seed dresser.



Turmeric belongs to the family Zinziberaceae. It grows well under diverse agro-climatic conditions in wastelands, drought-prone areas, and garden or orchard shade. Once the rhizomes are planted, they grow year after year. Besides the essential oil, turmeric powder also contains other chemicals such as 0.6% difeluroloyl methane, $C_{21}H_{20}O_6$ and sesquiterpenes, of which $C_{13}H_2O$ is the main active ingredient. When a small quantity of sodium bicarbonate is added to turmeric powder, the ingredient easily enters the seed and plant system, making it more potent to the fungal and bacterial population.

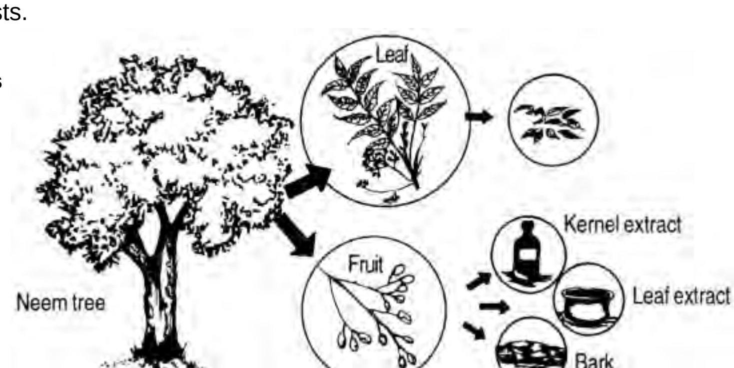
Farmers can safely use turmeric powder as a fungicide and bactericide as it is non-hazardous, cheap and ecologically friendly. For treating 10 kg paddy seed, dress it with 100 g turmeric powder and 10 g sodium bicarbonate. A pinch of asafoetida (not more than 1 g) will make it more effective as a foliar spray.

Neem - a farmer's friend

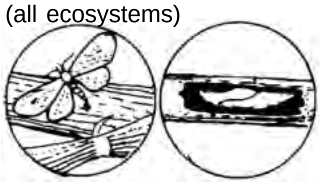
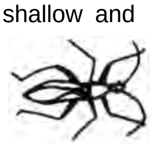
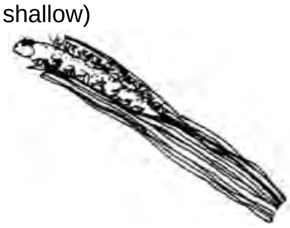
Neem (*Azadiracta indica*) is commonly found in all parts of India as it grows on all types of soil. All parts of this tree have valuable properties. Neem cake works as a fertiliser as it increases nitrogen recovery from 28% to 47%. Neem-coated urea is well known for its slow release of nitrogen to the crop.

Neem is effective as an antifeedant, growth retarder, repellent and toxicant. In rice, neem oil, neem seed, kernel extract and neem cake extract control brown planthopper, green leafhopper, leaffolder and gall midge. It is also used to treat seeds at 1 g/kg of seed, and to check storage pests.

Neem tree parts and pesticides from neem



Pest control in rainfed upland rice

Name of pest	Damage	Control measures
Stem borers (all ecosystems) 	Bore into stem, causing deadheart at tillering stage and chaffy white earhead at panicle formation stage. Serious problem from November onwards. Worst pest of summer paddy.	Early planting, pheromone traps of different types or *Bacillus* sp. or nuclear polyhedrosis virus, predators and parasitoids; internal feeders; caterpillars.
Leafhoppers and planthoppers (shallow and intermediate system) 	Sap-sucking insect. Numerous green, white and brown jassids puncture leaves and sheaths and suck sap. Leaves become browny yellow and dry from the tips. Plants look sickly and stunted. Brown and white-backed planthoppers congregate around the lower part of stem and suck sap, causing leaf yellowing and drying. Plants dry in circular patches, known as hopperburn. Transmit virus diseases.	Lower parts of plants must be thoroughly covered for effective planthopper control. Monitoring is important for planthopper management. Apply 100 kg neem cake/ha at puddling for planthopper control.
Leaf roller (shallow and irrigated) 	Leaf-eating insect. Green caterpillars fold and stick leaves sideways or from tip downwards, remain inside and feed on green matter; leaves look whitish.	Foliar spray of cow dung slurry or only 0.1% asafoetida suspension.
Gundhi bug (upland, shallow and irrigated) 	Grain-sucking insect. Adult and young stinkbugs puncture and suck milky grains, causing several chaffy white grains in the earhead.	Grow tolerant varieties, foliar spray with 1% neem product (nimidine). Grow *Cajanus cajan* on bund.
Rice hispa (shallow - Assam, Bihar, West Bengal, Orissa coastal) 	Leaf-feeding insect. Adults eat green leaf and white parallel lines appear. Larvae feed inside the leaves.	Dip a rope in kerosene oil and run it through the field. Hispa will drop in water and die.
Caseworm (intermediate and shallow) 	Leaf-eating insect. Caterpillars cut leaf tops, make tubular cases hanging from leaves, remain inside and feed on green tissues of leaves. Fields look whitish.	The cases can be destroyed by moving a rope on the crop and collecting them at one point from the water and destroying the larvae.
Termites (drought areas)	Attack young plants, feed on roots and underground parts, causing wilting and death of the plants. Severe in well-drained light soils.	Before sowing, apply 20 kg karanj cake or neem cake in soil and *Lantana camara* plant ash.

Gall midge fly

Rice gall midge

Rice gall midge (GM), *Orseolia oryzae* (Wood-Mason) (Cecidomyiidae: Diptera), earlier called *Cecidomyia oryzae* and *Pachydiplosis oryzae,* causes severe damage during the tillering stage of the crop. Yield loss from rice GM damage varies from 3% to 70%. The maggot-like larva feeds inside developing tillers, causing their base to swell as galls.

Reasons for outbreaks of gall midge

- Early monsoon showers following a dry spell
- Continuous cloudy weather associated with intermittent rains
- High relative humidity
- Late planting

The increased incidence of gall midge in recent years can be attributed to the following reasons:

- Spread of high-yielding susceptible varieties
- Continuous cropping
- High nitrogen application
- Closer plant spacings

Bamboo trap

Gall midge in light trap

It is well established that adult midges are attracted to light and this behaviour can be used to monitor their activity. Females are mostly trapped under the mercury light. This demonstrates the potential of using light traps with different kinds of light and light intensities.

Bamboo traps with a 250-W infra-red lamp attract the maximum number of midges, followed by 40-W incandescent light. The black-light invisible light trap attract larger numbers of midges. The peak catch of midges occurs between 10 and 11 p.m.

The light trap catches were correlated with different weather parameters. In general, early rains with moderate temperature followed by heavy rain, overcast cloudy weather and drizzle were conducive to midge incidence.

Predators of gall midge

Three carabid predators, *Casonides* sp., *Nabis capsiformis* Germar and *Ophionia indica* Thumb were found to prey upon larval, pupal and adult stages, while a mite, *Amblyseius* sp., was predatory on eggs.

Parasitoids as biocontrol agents

The egg-larval parasitoids, *Platygaster oryzae* Cameron (Platygasteridae: Hymenoptera), are highly effective in reducing the population of gall midge in nature. The occurrence of this parasitoid is higher in the successive rice crop. The adult parasitoid is black or yellowish brown and measures about 1 mm. Resistant varieties are Shakti, Heera, Neela and Shaktiman.

Conclusions

Some agricultural techniques for inducing resistance to pests and diseases in the rice crop follow:

- Remove the alternate and collateral hosts and weeds from bunds and grow *Cajanus* on bunds.
- Deep summer plough to keep the soil free from pathogens such as sclerotia and insect eggs.
- Use turmeric powder along with sodium bicarbonate for seed treatment.
- Apply rice husks at two cartloads/ha and 20 kg neem cake during puddling.
- Use green manure with *Sesbania aculeata* or *S. rostrata* and plough before planting.
- Use neem cake and neem oil to control soil-borne diseases and pests.
- Use fresh cow dung slurry to control bacterial blight, tungro, brown spot and brown planthopper.
- Use asafoetida 0.1% water emulsion as a foliar spray to control fungal and bacterial diseases.
- Store paddy at 12% moisture content to reduce mycotoxin-developing fungi.

Prepared by:
S. Gangopadhyay

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Insect Pest Management

Pests are one of the major constraints to growing a healthy rice crop in rainfed areas in eastern India. With the evolution of modern varieties, pests in the fields are increasing. Losses in grain yield from insect pests vary from 5% to 15%, depending on the location and moisture regime. The appearance of pests and the resulting damage and loss depend on components such as variety, environment (macro- and micro-climate), soil type, temperature, moisture and agronomic and water management practices.

Managing major pests

All pests do not occur at the same time in the same ago-climatic condition. These methods may be adopted where these pests appear year after year.

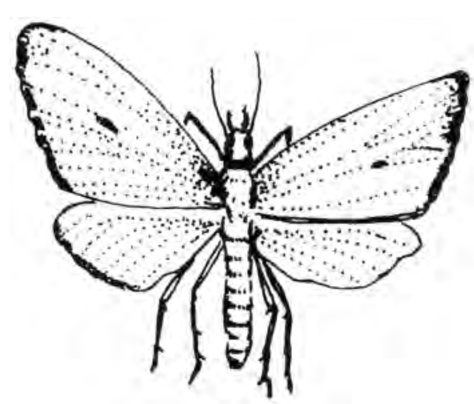
Integrated rice-pest management

This is managing insects, weeds and rodents at populations below the economic injury level by using a combination of two or more control methods such as biological and chemical control.

Control measures for insect pests

Yellow stem borer

- Summer ploughing and destroying stubble.
- Apply granular insecticides such as:
  - Lindane 6G at 20 kg/ha;
  - Carbofuran 3G in soil in nurseries at 2.5 g/sq m or 25 kg/ha;
  - Phorate 10G at l0kg/ha:
  - Phosphamidon 85EC at 300 ml/ ha;
  - Dimethoate 30EC at 1.0l/ha;
  - Monocrotophos 36EC at 1.0l/ha;
  - Quinolphos 25EC at 1.0-1.25l/ha; or
  - Fenitrothion 50EC at 1.0l/ha at economic threshold level (ETL) of 5% deadheart; or one egg mass/ one adult/sq m crop area.



Yellow stem borer

Gall midge

- Summer ploughing.
- Timely sowing/transplanting.
- Grow location-specific resistant varieties such as Shaktiman, Vikram, Falguna, Mahamaya, Daya, Rajendradhan, Dhanyalakshmi, Pratap, Samalei, CR-57, Surekha, etc.
- Judicious use of nitrogen.
- Eight to ten days before transplanting, apply phorate 10G at 10 kg/ha or carbofuran 3G at 25 kg/ha in nursery beds or seedling dip of nursery with 0.02% chlorpyriphos for 8-10 hours. In the transplanted crop, spray the same insecticides as for stem borer at an estimated threshold level of 5% silver shoots.

Gall midge

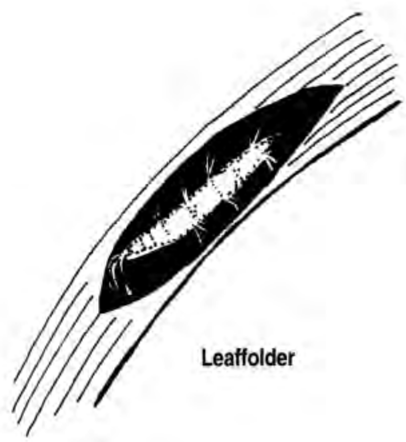
Brown planthopper and white-backed planthopper

- Timely planting.
- Judicious use of nitrogen fertiliser.
- Grow tolerant varieties such as Uday, Krishnaveni, Chaitanya, Vikram or Sarasa.
- Use light trap.
- When insects reach the estimated threshold level of 10/hill, spray the crop with monocrotophos 36EC at 0.75 1/ha, carbaryl 50WP at 2.5 kg/ha, chlorpyriphos 25EC at 1.0 1/ha or Asataf (acephate) 75 SP at 0.625 kg/ ha.

Planthopper

Leaffolder

- Burn stubble and straw.
- Balance use of fertilisers.
- Spray monocrotophos 36EC, chlorpyriphos 25EC, quinolphos 25EC or endosulphan 35EC at 0.75-1.25 1/ha depending on crop growth at the estimated threshold level of one leaf/hill.



Leaffolder

Rice hispa

Rice hispa

- Use mechanical control with kerosene-dipped rope.
- Spray endosulphan 35EC at 1.0l/ha, quinolphos 25EC at 1.25l/ha or monocrotophos 36EC at 1.0l/ha at ETL of one damaged leaf/hill.

Armyworm and climbing cutworm

Armyworm and climbing cutworm

- Do not allow the field to be dried.
- Keep the water impounded at flowering stage.
- At ETL of one to two damaged leaves/sq m crop area, spray the crop alternatively with carbaryl 50EC at 2.5 kg/ha or malathion 50EC at 1.125l/ha or dust the crop with methyl parathion 1.5% or malathion 5% at 25 kg/ha.

Gundhi bug

Gundhi bug

- Trim bunds and keep field weed-free.
- Do summer ploughing.
- Grow pigeonpea on bunds.
- At the estimated threshold level of two to three nymphs or adults/hill, dust the crop with carbaryl 4%, malathion 5%, phenthoate 2%, methyl parathion 1.5% or quinolphos 1.5% at 25-37.5 kg/ha.

General recommendations

- Use varieties with multiple resistance in pest-endemic areas such as Sunahsha, Shaktiman, Lalat, Rasmi, Samlei, IR36, Swarnadhan, Mahamaya, Rajdhan, Vikramarya and Nidhi.
- Do not destroy natural enemies such as predators and parasitoids; use selective pesticides.
- Do not destroy useful fungi, bacteria and viruses; use selective fungicides.
- Do not use more than the recommended dose of nitrogen to avoid severity of pests and diseases.
- Do summer ploughing.
- Give emphasis to biopesticides.

Prepared by:
J. P. Chaudhary and **S. Gangopadhyay**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Disease Management Strategies

In nature, the rice crop is infected by more than one disease. Losses in grain yield from diseases vary from 12% to 15% depending on location and moisture regime. Often, diseases such as blast, sheath blight, sheath rot and brown spot tend to appear at the same time. Except for brown spot, all diseases are favoured by a similar set of conditions such as high nitrogen and phosphorus, low potassium and high plant density and canopy, etc.

The intensity of these diseases is likely to increase when high-yielding varieties are adopted or used more and when fertiliser use increases in rainfed areas. The incidence of certain diseases also predisposes crops to other diseases. Many pathogens survive in rice straw and several weeds in rice fields also host pathogens.

Rice residue disposal and proper field sanitation influence the level of overwintering or oversummering inoculum and reduce foci for secondary infection. Rice tungro virus incidence increases with increased plant spacing. Some cultural practices (e.g., proper spacing, early sowing, balanced fertiliser application, etc.) and fungicides (e.g., mancozeb, carbendazim, ediphenphos) are effective against multiple diseases. Some varieties show multiple disease resistance. It is therefore desirable to integrate several strategies for integrated disease management.

Disease control measures

Brown spot

(caused by *Bipolaris oryzae*)
Brown spot manifests itself as a seedling blight or a foliar and glume disease of the mature plant. Infection reduces the number of grains per panicle and kernel weight. The disease is primarily seed-borne and is aggravated by poor soil fertility conditions.

Symptoms
The presence of uniform oval or round dark spots, which may be larger, up to 1 cm long.

Brown spot

Brown spot is more an indicator of nutritional or physiological disorder than a pathological disease. An epidemic of the disease in Bengal in 1942 resulted in a yield loss of 40-90% and was largely responsible for the infamous Bengal famine of 1943.

Control measures

- Apply appropriate nutrients to the soil and prevent water stress. Use resistant cultivars in areas where soil abnormalities are not easily corrected.
- For seedling disease, use seed treatment with organomercurials, dithane M-45 or vitavax.
- Use a recommended dose of nitrogen and other fertilisers. Do not allow the field to be nutrient-deficient.
- Use a foliar spray of mancozeb at 2 kg/ha or aureofungin at 50 g/ha at ETL.

Blast is a serious problem in rainfed upland rice. Crop management greatly affects the disease. Losses are the greatest under intensive, high-input rice cultivation.

Blast

(caused by *Pyricularia grisea*)

Blast is a constraint to adopting new production technologies. Higher application of nitrogenous fertilisers and soils with less silica content increase blast incidence. Two phases of the disease are most pronounced: leaf blast and neck blast.

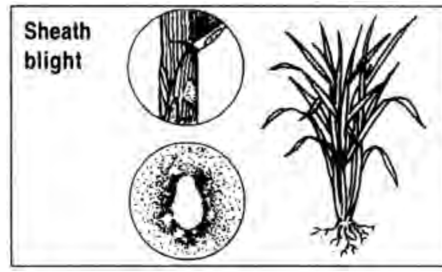
Symptoms

Small, bluish water-soaked lesions appear on leaves and soon become several centimeters long and spindle- or eye-shaped. Lesions are produced on all parts of the shoot. Infection at the panicle neck node or neck blast is the most destructive symptom. The pathogen surviving in crop residue is the primary source of infection.

Control measures

- Grow resistant varieties such as IR64, Rasi, Tulsi, HPPU-741, Swarnadhan, Vikas and Neela.
- Do not use more than the recommended dose of nitrogen.
- Destroy alternate and collateral hosts.
- Use a seed treatment with a safe fungicide such as thiram, bavistin SD and turmeric powder in the ratio of 1:300.
- Use a foliar spray of fungorene 0.05% (or 500 g/ha), hinosan 1% bavistin 0.05% and kitazin 0.05% (at 500 ml/ha) or carbendazim at 500 g/ha for neck blast at ETL of three eye spots/leaf or three broken necks/hill.

Sheath blight
(caused by *Rhizoctonia solani*)



The fungal pathogen has a wide host range, attacking other crops after or before rice. Many weeds in the ricefields also host the pathogen. Fruiting bodies (sclerotia) of the fungus remain in the soil and serve as the primary inoculum for disease initiation.

The disease is favoured by high nitrogen and phosphorus and high plant density. In general, modern cultivars lack resistance against sheath blight. Losses occur because of poorly filled grains, increased lodging and reduced ratoon production.

Symptoms

Spots or lesions of greenish grey, elliptical or oval and about 1 cm form mostly on the leaf sheath. The spots first appear near the waterline in fields. Infections spread rapidly under low sunlight, high humidity and high temperatures between 28 and 32°C.

Control measures

- Apply green manures such as dhaincha and sunhemp to reduce primary inoculum and disease severity.
- Sanitise the field properly.
- Balance the application of fertilisers.
- Do not use long rotation without a non-host crop.
- Foliar application of chemicals such as carbendazim, vitavax and topsin M (0.5 kg a.i./ha) reduces disease under field conditions. Two fungicide applications are necessary.
- Use resistant varieties, if available.
- Use crop rotation with legumes.
- Seed treatment with 100 g turmeric powder and 1 g asafoetida powder/10 g sodium bicarbonate followed by foliar spray of captafol 80% at 1.5 kg/ha or carboxin 500 g/ha or benomyl 500 g/ha at ETL of three cobra spots on the leaf sheath in three tillers of three random plants.
- Use available biocontrol agents for soil treatment (500 g/ha), such as *Trichoderma viridis* or *T. harzianum* alone or in combination with green manure.

False smut
(caused by *Ustilaginoidea virens*)

The disease has become important with the introduction of high-yielding varieties.

Symptoms

The rice kernels are replaced by globose, velvety spore balls (sclerotia), 1-5 cm in diameter, which burst out from between glumes. Low maximum temperature accompanied by high relative humidity at flowering and also high nitrogen favour the disease.

Control measures

- Follow sanitation practices by manually removing spore balls before harvesting.
- Apply balanced nitrogen.
- Use varieties that are moderately resistant such as Bala, Kaveri and Hamsa.
- Apply mancozeb using a spray at heading.

This is now a major disease with the introduction of modern varieties.

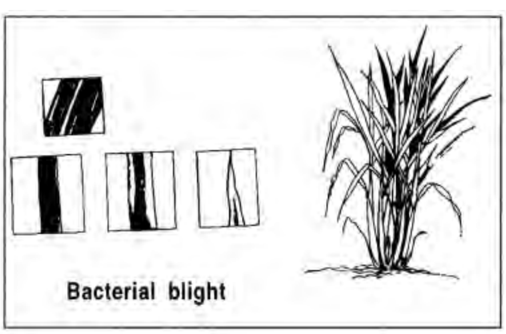
Sheath rot (caused by *Sarocladium oryzae*)

Symptoms

Rot occurs on the uppermost leaf sheaths enclosing the young panicles. These panicles remain in the sheath or emerge only partially. Panicles that have not emerged tend to rot.

Control measures

- Plant rice early to avoid infection.
- Plant resistant or moderately resistant varieties under rainfed lowland systems, such as NC492 and CR1030.
- Use a spray application of carbendazim at tillering and boot leaf stage.



Bacterial blight
(caused by *Xanthomonas campestris* pv. *oryzae*)

Infected plants produce fewer and lighter grains and the grains are of poor quality. Kresek can lead to total crop failure. Infected rice seeds can carry the bacterium until the following crop season, but the disease originates mainly from other sources such as straw, stubble, volunteer plants, ratoons, wild rice or susceptible weeds. The disease results from high temperatures, high rates of nitrogenous fertilisers and phosphorus and potassium deficiency.

Symptoms

The disease has two phases of infection:

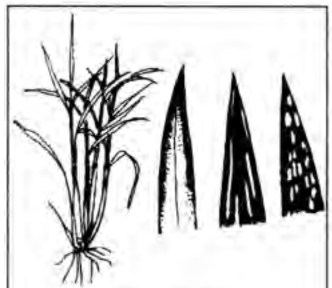
1. Elongated white lesions on the leaves (leaf blight) and
2. Systemic infection that wilts the entire young plant (kresek).

Control measures

- Use resistant varieties such as NC492 and CR1030 under rainfed lowland conditions.
- Balance fertiliser application and split the application of nitrogen.
- Plow infected plant debris, self-sown plants and ratoons.
- Use bleaching powder in the field water at 5 kg/ha.
- Use seed treatment at a ratio of 1:l000 plantamycine or tetracycline to seed.
- Use a foliar spray of streptocycline at 15 g/300 1 of water, agromycine 100 at 75 g/500 1 of water, plantamycine at 750 g/500 1 of water or cowdung slurry at 1 kg/5 1 of water (600 1 slurry/ha).
- Grow tolerant varieties such as Ajaya and PR-111 in endemic areas.

Rice tungro

This is caused by the rice tungro bacilliform virus and rice tungro spherical virus. Plants infected at seedling stage show a 10-40% reduction in yield. The viruses are transmitted by the rice green leafhopper *(Nephotettix virescens).* The incidence of tungro disease correlates with the population of insect vectors. Both viruses persist in rice and several weed hosts. Ratoons from overwintered, infected rice stubble serve as virus reservoirs.



Rice tungro

Symptoms

Typical symptoms are stunting of plants and yellow or yellow-orange discolouration of the leaves. Yellowing starts from the tip of the leaf and may extend to the lower part of the leaf blade. Infected plants usually have fewer tillers than healthy plants.

Control measures

- Suppress the insect population in seedbeds by using insecticides or adjusting planting dates.
- Plant resistant cultivars. Rice tungro virus-resistant or moderately resistant varieties that have gained acceptance are CNM539 and CNM540 in West Bengal and IET7970 and Janaki in Bihar. Variety Mahsuri is moderately susceptible.
- Manage the vector through safe and non-resurgence insecticides using both foliar spray (monocrotophos) and furadan granule application with urea in moist soil in the ratio of 1:300.
- Conduct vector surveillance and monitor the migration of the vector from surrounding areas/regions.

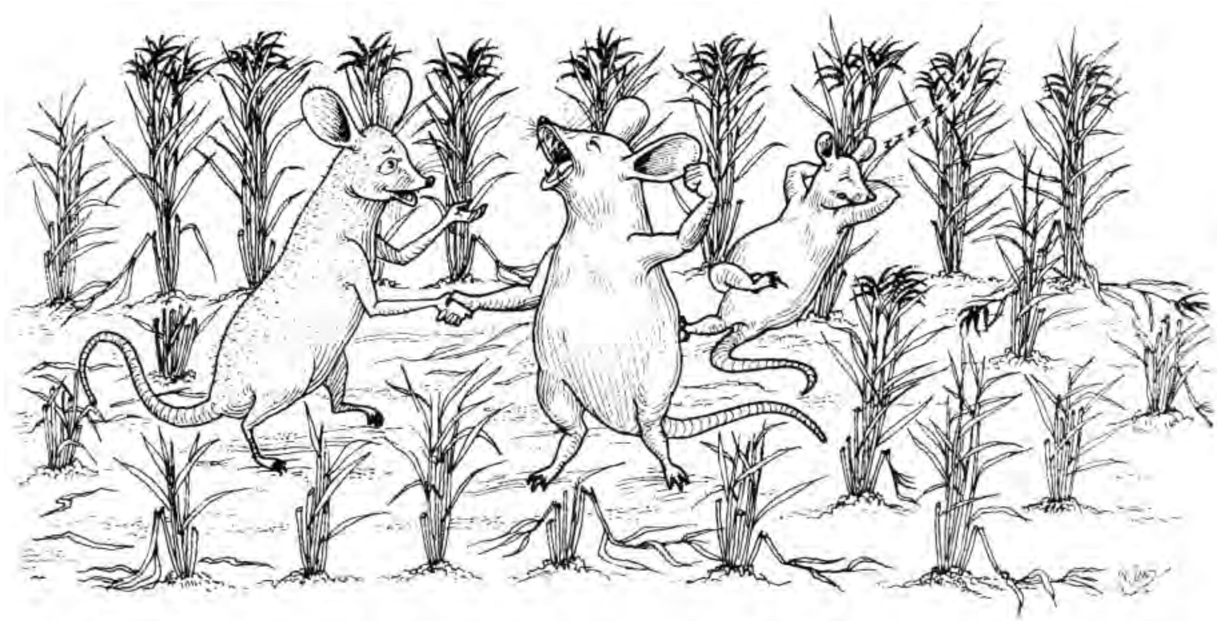
Prepared by:
J. Kurnar and **U. S. Singh**

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Rat Population Dynamics and Management

Rodents are gnawing animals and include rats, mice, squirrels, porcupines, hares, hedgehogs, etc. Of these, rats are a major problem to farmers and their crops.

Among mammals, rats are highly adjustable and can adapt themselves to new environments and new foods and can mix with the new members of a community with remarkable swiftness.



In some regions of India, useful studies on the population density of rats in an ecological zone have been carried out. These studies were conducted for brief periods of one or two years, however, and more work is required to determine population cycles, food habits, reproduction, home range, activity, behaviour patterns, adaptability, etc., before scientists can suggest sound strategies for rat management.

Rats attack crops at night

To know the intensity of the rat population and rate of opening of rat holes per day, observations were conducted at the ricefields of Sakra village and Kaul Rice Research Station, Haryana. At Sakra, 363 holes of *Mus* species and 32 holes of *Bandicota bengalensis* species were plugged and observed. On the other hand, 344 holes of Mus species and 84 holes of *B. bengalensis* species were plugged and observed at Kaul.

Population fluctuation of rats

Although house rats are most common rats, little information is available on their population fluctuation. The following is one study on their population and the data.

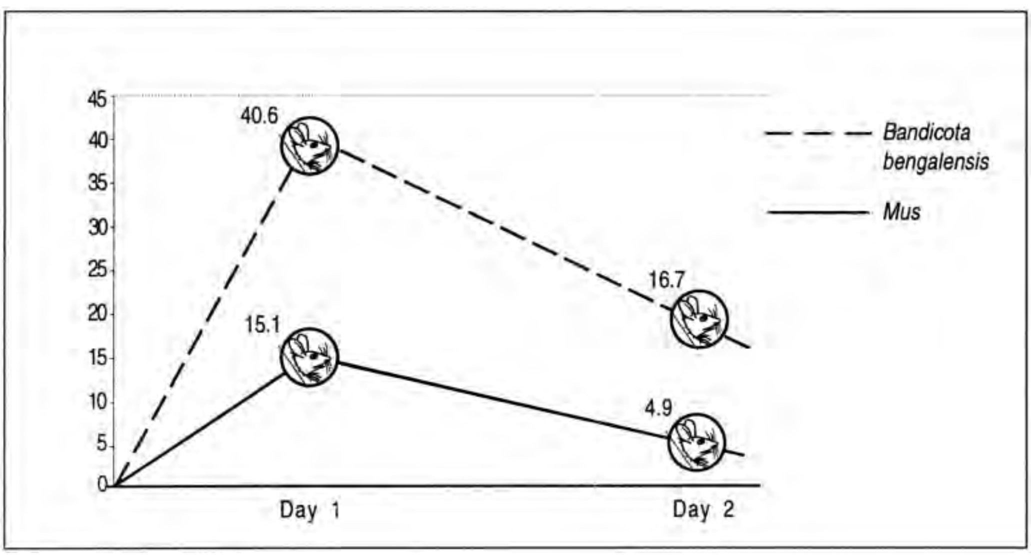
Uttar Pradesh

- 624-1,335 rats per village (average 1,057)
- 5.7-15.6 rats per house (average 9.8)
- 0.86-1.76 rats per person (average 1.29)

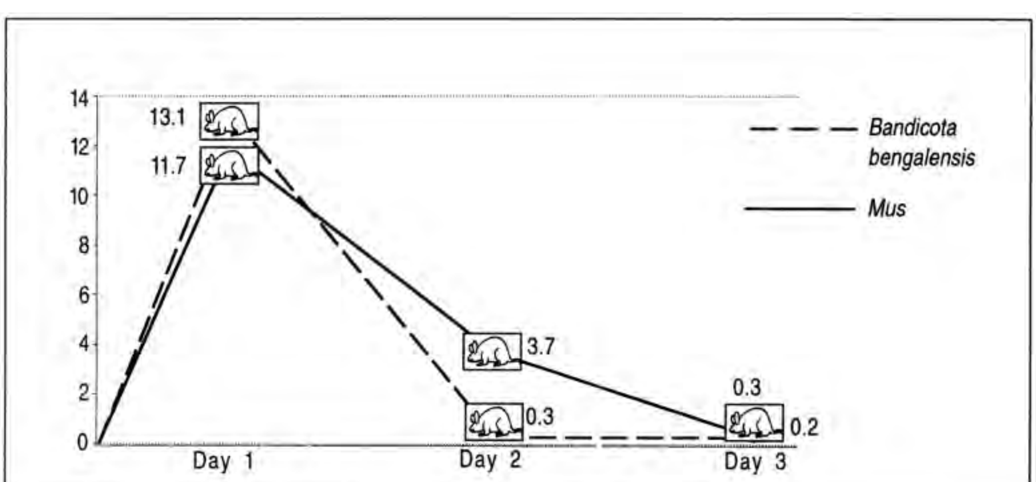
Villages near N.D. University

- 985-1,300 rats per village (average 1,171)
- 20-32.8 rats per house (average 28.6)
- 1.81-3.54 rats per person (average 2.98)

Percentage of rat holes opened per day (Sakra village)



Percentage of rat holes opened per day (Kaul Rice Research Station)



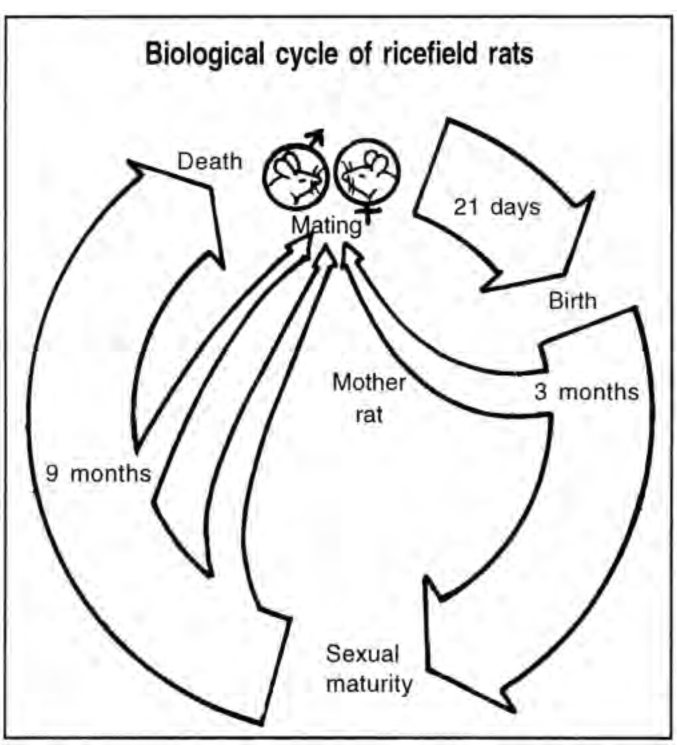
Damage to crops

- Seedbed damage is caused by the consumption of seeds by rats or by the destruction of young seedlings.
- Rats cut or pull up recently transplanted seedlings. The result is missing hills.
- Rats cut or bend older tillers to reach the developing panicles.
- Damaged tillers are cut near the base at a 45° angle.
- Damage is usually low during the vegetative stage, increasing rapidly after the flowering stage. Rat damage in the field is not visible from a distance until more than 15% of the tillers are cut.
- Rat damage is done more to the staggered crop than to the methodically transplanted crop.
- A weed-free ricefield will provide less shelter to rats and therefore less favoured rat habitat, ultimately resulting in less crop damage.

Rat management

Factors relating to rat management and rat population dynamics follow,

- Rats can live for one year or longer.
- Females can reproduce up to four times a year, averaging six rats/litter.
- Even if the total rat population drops to a lower level of 5-10% from its original level, this low population is sufficient to make the population reach its original level within a year or so.
- It is therefore necessary to plan and execute control operations every season after harvest.



Common rat control practices

- Trapping
- Biologicalcontrol
- Predation
- Anti-fertility agents
- Diseases
- Environmental control methods
- Chemicals
  - Of these practices, chemicals have been the most successful, especially under field conditions. Among chemicals, zinc phosphide, a slaty coloured powder, is the most commonly used because of its effectiveness and local availability.

Rat control campaign

Individual efforts to control rats have not been effective. Rat control must therefore be undertaken on a community basis using a campaign approach.

Day 1

Planning

- Survey and map area of rat campaign.
- Decide the date and timing of operations.
- Disseminate information to the farming community.
- Estimate manpower.
- Assign duties to operational squads – two squads.

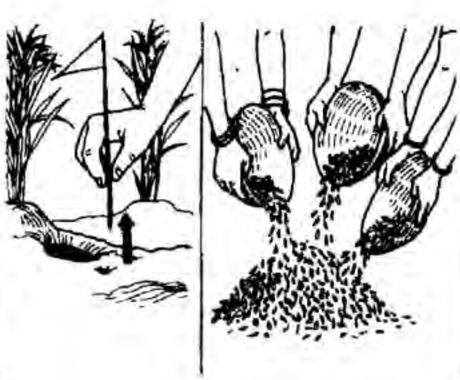
Day 2

Identification, bunting and mud plastering

- First squad identifies rat holes and marks them with bunting.
- Second squad follows and plasters the holes with mud.
- After one area is covered, the process continues in other areas.

Days 3-5

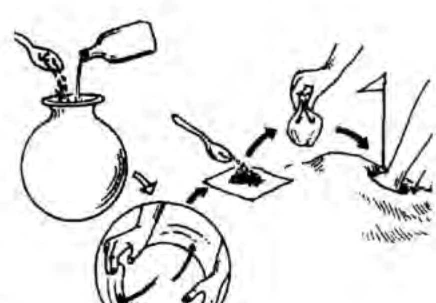
- Search for live holes where rats live.
- Remove bunting from dead holes.
- Collect healthy rice grains from contributing farmers.



Days 6-7

Pre-baiting and baiting

- Mix grains with 2% edible oil in an abandoned container.
- Put the oil-mixed grain (1 teaspoon) into small, loose paper packets.
- Place the packets in the live holes.

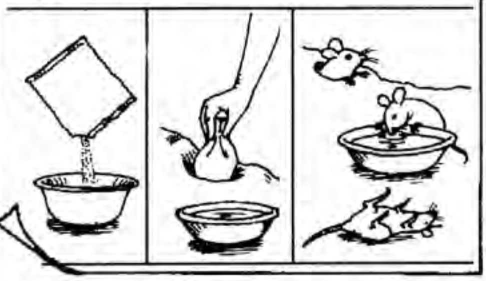


Day 8

- Repeat the process of the second day.

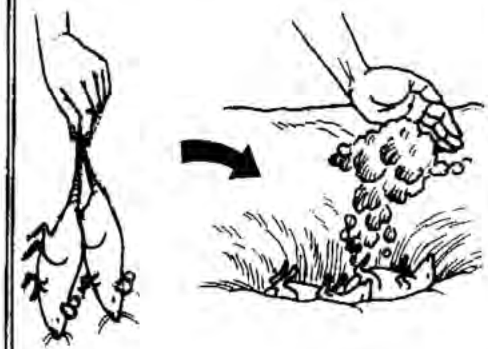
Application of chemical to baits

- Mix 2-2.5% zinc phosphide with oil-mixed grains and put them in paper packets.
- Place the packets in the live rat holes and keep water close to the area.
- Most rats will be found dead near the water.
- Once the rats consume the poison, they get restless and die within 2½-3 hours.



Day 9

Collect dead rats and bury them.



Day 10

Plaster already opened holes with mud.

Days 11-12

Observe opened holes.

Day 13

Fumigate with aluminum phosphide.

Prepared by:
Ram Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Insecticide Use, Precautions and Insect Resistance

What are pesticides and insecticides?

Pesticides are the chemical compounds used to:

- control pests (insects and diseases of plants);
- minimise weeds;
- kill pests and microorganisms that spoil agricultural products; and
- control parasites and vectors of dangerous diseases of humans and animals.

Insecticides, on the other hand, are the chemicals used particularly for protecting plants and animals from harmful insects.

Initially, indigenous plant products such as *Acorus calmus* L. and neem; wood preservatives such as coaltar and creosote; chrysallic acid, carbonic acid; sanitary fluids – phenyl and crude oil emulsions; fish oil resin soaps, Bordeaux mixture, lime, arsenic, copper salts and many others were used.

When and how to use pesticide control measures

Users should possess knowledge of the pests that have to be controlled, the physical properties of insecticides and the influence of weather and plant growth on their effectiveness. Pesticides should be used only when the pests occur above economic threshold or economic injury levels. This will not only reduce the cost of control measures but also reduce pesticide-related pollution.

When to avoid pesticide control

- Avoid prophylactic measures and repetitions of the same' insecticides against the same pest.
- If natural enemies are high, insecticidal control is not necessary.
- Avoid application when wind velocity is high to avoid excessive drifting and also when the population and activities of non-target organisms, such as honeybees, etc., are high.

Chemical formulations

The successful use of pesticides depends not on their toxicity alone but also, to a considerable extent, on the form of pesticides. The formulation determines how a pesticide is used. The pesticides normally used to control insect pests are available as powders (dust), granules, solutions, emulsifiable concentrates, ultra-low-volume concentrates and as aerosols and fumigants. Some of these pesticides are also available as poison baits, insecticide soaps, paints and insecticide papers.

Merits and demerits of insecticide control

Merits

- Pesticides are the only practical control measure at the expected threshold level.
- Increases farmers' income.
- Without pesticide, many commonly used quality food products could not have been produced commercially.
- Pesticides are useful for protecting health and property.

Demerits

- Many insect and mite species have developed resistance to insecticides and acaricides.
- Provides temporary reduction of pest population, which often resurges, necessitating repeated application.
- Outbreak of secondary pests, resulting from the destruction of natural enemies.
- Undesirable effects on non-target organisms, such as honeybees, fish, wild animals, etc.
- Residue hazards for crop and direct hazards during operation.

The problem of insect resistance to insecticides

It is a biological property of an organism to withstand the poisoning action of a pesticide. A resistant organism functions, develops and reproduces normally in a medium containing a poison.

Various kinds of resistance

NATURAL RESISTANCE: This kind of resistance appears and exists independently of the use of chemical means.

Specific	It is due to the biological feature of a definite species and can be successfully controlled by selecting the appropriate pesticide.
Sexual	In most cases, the females of the species have higher resistance. This is overcome by choosing relevant doses.
Phase or stage	This is the phase/stage of development of the insect. Larval and adult stages of insects are the most sensitive to insecticides. High resistance is a feature of egg and pupal stages.
Seasonal, temporary and age	The resistance within a single stage (phase) of development changes depending on age, time of day and year (season). Proper choice of insecticide and strict observance of the optimal periods are the best ways to control this resistance.

SPECIFIC (ACQUIRED) RESISTANCE: It signifies the ability of a harmful insect to survive and reproduce in the presence of an insecticide that previously suppressed its development.

Individual	This kind of resistance is encountered rarely and is due to the activity of narrowly specialised enzymes decomposing toxic substances.
Group	This is the resistance of insects/pests belonging to the same group to two or more insecticides with a similar structure and mechanism of action. Resistance is due to: ■ slower penetration of the poison and faster excretion; ■ rapid detoxification of an insecticide because of higher activity of the enzymes or appearance of specific enzymes; ■ a different penetrability of the shell of nerve cords; and ■ increased lipid contents in the body of the resistant insects.
Cross	This is resistance to two or more insecticides of different groups in both the chemical structure and mechanism of action that appear after the use of one pesticide.

Insecticide resistance prejudices the usefulness of insecticides in future pest control programs.

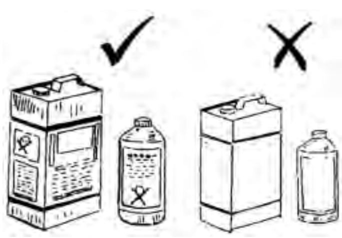
Precautions in handling pesticides

Pesticides, if used without proper knowledge and caution, can be dangerous. One must follow instructions on safety in storage, transportation and use of pesticides and also the methodological instructions on the use of individual toxicants.

BEFORE APPLICATION

DOs

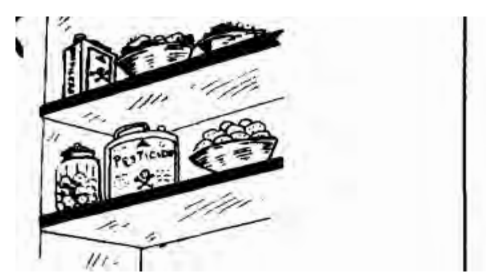
- Keep pesticides in labelled containers only.
- Read the label carefully and follow the manufacturer's directions and precautions.
- Store pesticides in a cool, safe, locked and dry place and out of reach of children, unauthorised persons and pets.
- Children, pregnant women and people with mental health problems must not be allowed to handle pesticides.
- All pesticide containers should be adequately labelled to identify the content, the nature of the material and precautions to be observed.



- When purchasing pesticides, ask for receipts to reduce the chances of spurious quality.
- Purchase insecticides in their sealed original packet.
- Verify expiry date before purchase.
- Before handling pesticide containers and pesticide application machines, clean water, soap and towel should be kept ready for washing the hands after preparation and for use in case of accidental contamination to other parts of the body.

DON'Ts

- Store pesticides near foodstuffs or medicines.
- Purchase pesticides sold in unmarked packages or open packages to avoid getting adulterated ones.



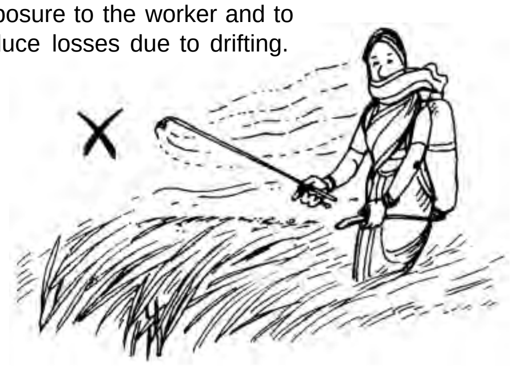
DURING APPLICATION

DOs

- Wear the necessary protective clothing and devices.

- The preparation and mixing of spray solutions from concentrated pesticide: should be undertaken in deep containers with long-handled mixing devices to prevent splashing and to allow stirring from a standing position without using the hands.

- Apply insecticides only in their recommended concentrations/doses.
- Apply insecticides along the direction of the wind to reduce insecticide contact with the applicator's body.
- Application of pesticide should be postponed if wind velocity is high to reduce pesticide exposure to the worker and to reduce losses due to drifting.



- In case of pesticide poisoning, apply first-aid and call a physician immediately.
- Operators handling dangerous pesticides should be periodically checked by a physician.
- Wash hands thoroughly with soap and clean water whenever the sprayer or duster is used.

DON'Ts

- Tear open the pesticide bags or cut them with a knife.
- Blow, suck or apply mouth to any sprinkler, nozzle or other spraying equipment.
- Apply insecticide in the field on an empty stomach.
- Apply pesticide for more than eight hours a day.

AFTER APPLICATION

DOs

- Contaminated effluents from washing of equipment and mixing vessels must be disposed of by scattering over barren land or burying in the ground.
- Use separate working clothes. They should be washed and changed as frequently as possible.

DON'Ts

- Use empty containers of pesticides for alternative purposes. (Destroy used containers and bury them deep into the soil, away from ponds, lakes, rivers, etc., to avoid pollution and poisoning.)
- Use insecticide-treated seeds, grains, paddy straw, etc., for feeding cattle, pets, birds, fish or other animals.
- Harvest crops from insecticide-treated fields until the recommended safety interval period has passed.
- Wash insecticidal application equipment or any kind of insecticide in those water tanks, ponds, etc., used for fish culture, washing clothes or drinking by humans or animals.

First-aid precautions

Swallowed poison

If one swallows pesticides/poison, give 1 teaspoonful (15 g) of common salt mixed in a glass of warm water for vomiting and repeat until the vomit is clear. To induce vomiting, gently touch the throat with a finger or with the blunt end of a spoon. If the patient is already vomiting, do not add salt but give plenty of warm water and then follow the directions suggested. After emptying the stomach, give milk or egg, which absorbs poison. Do not induce vomiting if the patient is in a coma.

Inhaled poison

In case of poison being inhaled, carry the patient to an open space and loosen all clothing. Give artificial breathing if breathing is irregular or has stopped. Care must be taken to see that the patient is kept warm by wrapping a blanket around him/her.

Skin contamination

- Apply a stream of water on the contiminated area while removing clothing.
- Clean the skin thoroughly with soap and water.
- Rapid washing is most important for reducing extent of injury.

Eye contamination

- Wash the eyes gently with a stream of running water immediately.
- Consult a physician as soon as possible.

Prepared by:
J. P. Chaudhary

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Effects of Pesticides on Humans and the Environment

The use of chemicals in pest and disease management has evolved dramatically during the past four to five decades. While they have contributed significantly to the success in increasing crop production, indiscriminate use of these chemicals may cause risk to people and the environment. The dilemma of pesticide use is that they do so much good and also cause so much harm.

A complete stop in the use of pesticides might result in a 25-30% drop in crop and livestock production. Therefore, it becomes important to use these chemicals judiciously. This can be done by studying their distribution pattern and persistence in hosts, i.e., plants, animals, fish, food products and the environment.

Agrochemical poisoning

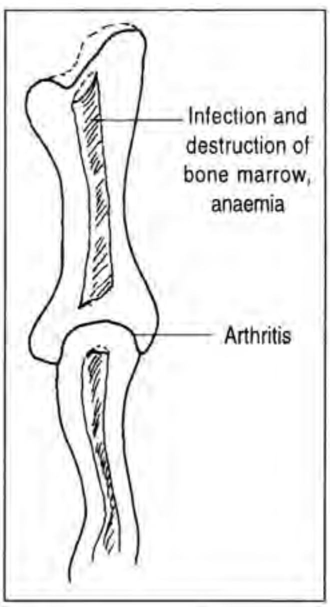
Recently, due to extensive *boro* rice cultivation in West Bengal, pumping of groundwater even from the aquifer region has posed a problem of arsenic contamination in drinking water (200 ppm) causing night blindness, crippled children and male infertility. Probably by 2005, the arsenic concentration will be so high that the underground water will be unfit for drinking.

In recent years, a concern has been expressed about the hazards of excessive use of agrochemicals. Interest has increased in alternative technologies which reduce or even eliminate the use of agrochemicals while relying more and more on various natural processes and organic materials to get good yields, thereby also maintaining long-term fertility of land.

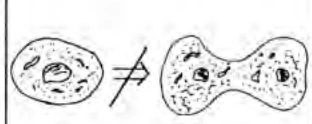
Pesticide hazards in human health

Due to pesticide use, new virulent pathotypes and biotypes are developing that cause loss even to resistant plant varieties and valuable germplasm and are also destroying natural predators. Insecticide, fungicide and herbicide applications to foliage and soil cause symptoms and human diseases such as:

- burning sensation of buccal cavity;
- gastroenteritis and diarrhoea;
- nausea;
- destruction of bone marrow;
- suppression of mitosis and diploid embryonic lung cells;

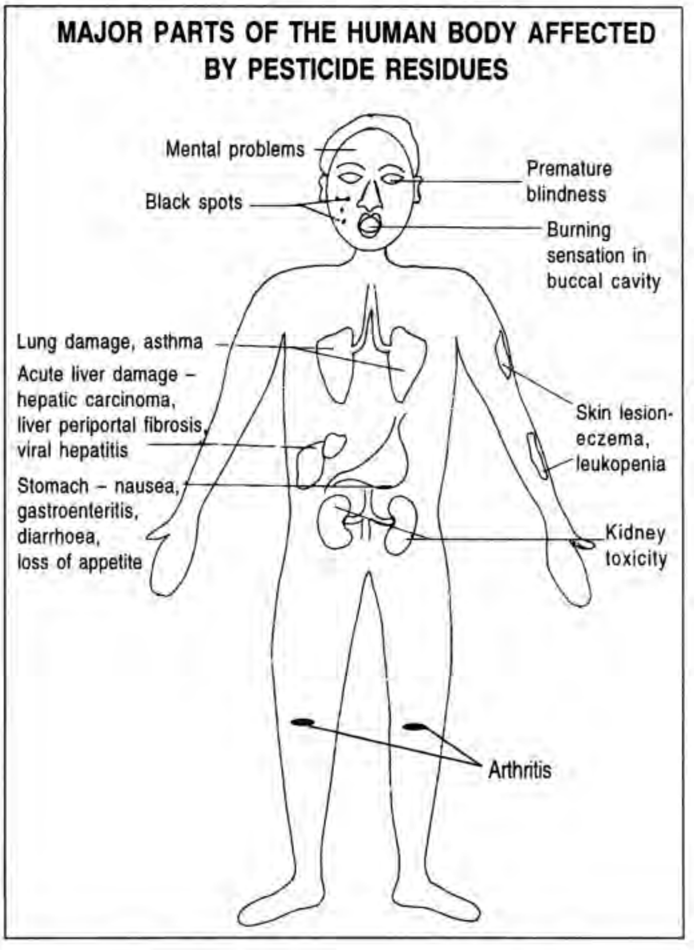


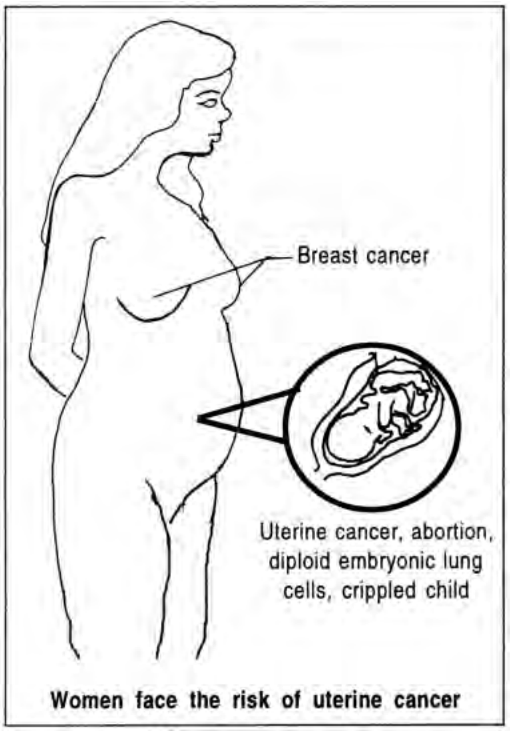
Nausea induced by pesticides



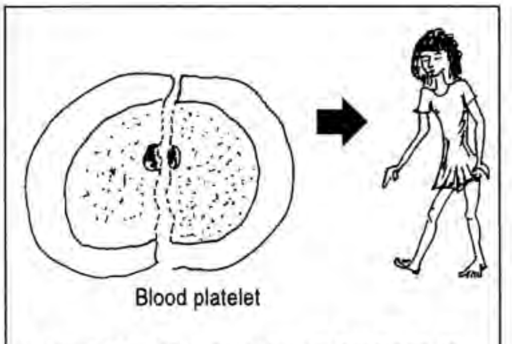
Suppression of mitosis (cell division) by pesticide residues

- hepatic carcinoma;
- acute liver damage;
- toxicity in kidney cells;
- inhibition of protein synthesis;
- anorexia (loss of appetite);
- viral hepatitis - cytotoxicity;
- nuclear and cytoplasmic destruction;
- eczema and necrotic lesions and black spots on face;
- leukopenia;
- anaemia and breakage on blood platelets;
- miscarriages; and
- uterine cancer.





Women face the risk of uterine cancer



Pesticide residues produce breakage in blood platelets, retarding growth

Chromosomal aberrations due to pesticides

- Residues induce cell damage in the immune system.
- Sperm count decreases and the sperm heads develop abnormalities.
- Residues induce cytogenetic damage in the immune system and mitosis.

In human beings, who are at the peak of the food chain, pesticide residues enter the body, almost daily. Frequent consumption of fruits and vegetables rich in vitamins is advised to minimise the cytogenetic toxicity of pesticides like xenobiotics. Fats and oils, on the other hand, increase the frequency of pesticide-induced toxicity, and their use should therefore be avoided.

Carcinogenic effect

- Pesticide-treated products may cause breast and uterine cancer, arthritis, asthma, a crippled child, liver cancer, premature blindness, imbalances of sex hormones causing infertility and miscarriage disruption of brain functioning and mental problems.
- Consumption of contaminated feeds and fodders may cause sickness and death of livestock and fish.

Fish contamination by pesticides

Lindane gets stored preferentially in lipids (fish oil) and can accumulate when ingested with different food items. It causes:

- phagocytosis;
- breathlessness;
- number of B lymphocytes increases in the head and kidneys;
- blood-increasing lysozyme level (reduces blood formation); and
- celluloplasmine activity in plasma (drying of cells).

Nitrification inhibition

Nitrification, the process of conversion of the ammoniacal form of nitrogen into available nitrate by bacteria, is inhibited due to non-degradation of pesticides in the soil. In the nitrification inhibition test, chlorinated phenols exhibited an elevated toxicity to nitrifying bacteria.

The nitrifying bacteria cannot multiply because of toxicity and fail to form nodules which help in nitrogen fixation for crops. These chemicals also check the multiplication and colonisation of blue-green algae.

Genetic alteration in plants due to pesticides

Pesticides could be cytotoxic or mutagenic to plants. Plant studies showed that the cellular mechanisms for DNA replication and repair involve a complex set of enzymes and gene-controlled biological reactions. These reactions are altered by pesticides in different ways. Not only genetic damage of different types is possible but also each type may be accompanied by a variety of mechanisms. Some herbicides develop structural abnormalities in plant chromosomes, resulting in severe physiological disturbances.

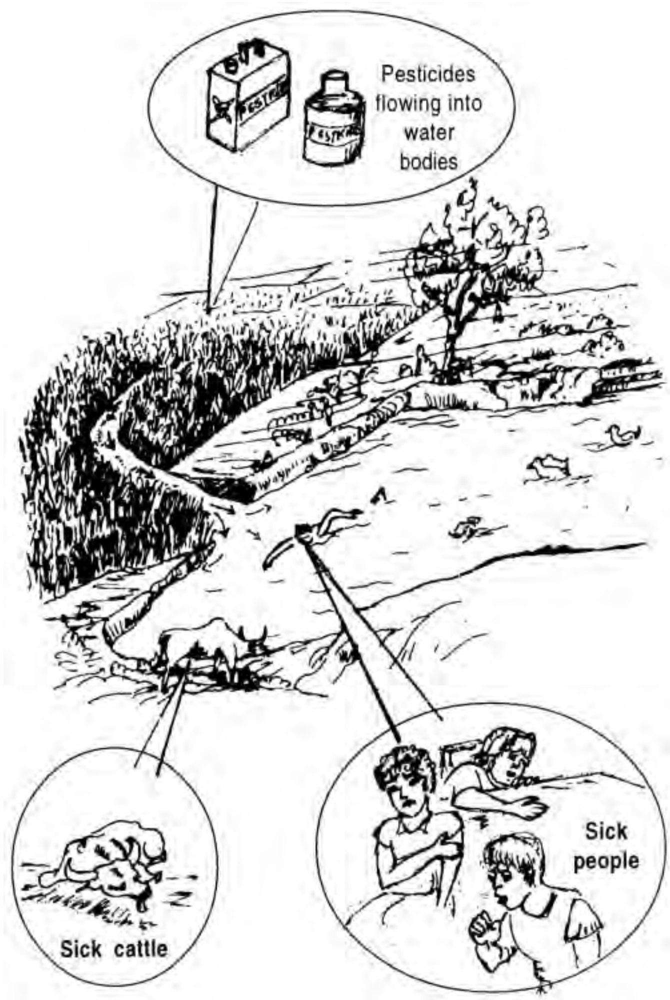
Soil and water pollution

Plants are essential components that produce oxygen and organic matter on which most other life forms depend for food and shelter. Plants are essential in the process of nutrient cycling. The adverse effect of pesticides can directly disturb the structure and function of an ecosystem. Some herbicides can even harm non-targeted plants. Pesticide-mixed effluents may be practically non-toxic to fish, etc., but can injure and kill aquatic vegetation when discharged into water.

Water pollution

Pesticide residues frequently found in irrigation and drinking water are as follows:

Metal-based	Non-metal-based
■ Copper	■ Phenol
■ Zinc	■ Styrene
■ Mercury	■ Chloroform
■ Arsenic	■ Ammonium chlqride
■ Cyanide	
■ Dodecyl benzene	■ Sodium lauryl sulfate
■ Cadmium	
■ Chromium	■ Sulfonic acid
	■ Benzene
	■ DDT compounds
	■ Ammonia
	■ Diethylamine



Chemicals contaminate groundwater through leaching into the soil and pondwater from plants and soils. Such polluted water causes interference in the intracellular and exo- or endoenzymic activity in the bacteria and causes' toxicity in mammals.

Banned pesticides

The following pesticides are banned in India as per notification of the Government of India letter no. 8-20/97-CIR II dated August 19, 1997.

- Aldrin
- Dieldrin
- Calcium cyanide
- Chlordane
- Copper aceto arsenite
- Dibro mochloro-propans (DC CP)
- Endrin
- Ethyl mercury chloride
- Ethyl parathion
- Heptachlor
- Menazon
- Nicotine sulphate manufactured in India for export

Nitrofon
Paraquat dimethyl sulfate
Pentachloro-nitrobenzene (PCNB)
Pentachloro-phenol (PCP)
Phenyl mercury acetate (PMA)
Sodium methane arsonate (SMA)
Tetradifon
Toxaphene
BHC

Besides arsenic, nitrite poisoning which comes to the groundwater from urea fertiliser has posed a direct threat to human lives.

- Urea is converted to nitrate.
- Nitrate is converted to nitrite and this nitrite comes to the drinking water to an extent of 1000 ppm, causing acute problems in human beings such as child blindness, hepatic ulcer, uterine and breast cancer, drying of bone marrow and cirrhosis of liver.
- Not only pesticides but also agrochemicals may pollute the drinking water, in both villages and towns, particularly for poor people with low protein intake who are prone to these types of problems. This problem can be mitigated by oxidation of , nitrite-contaminated drinking water through multilayer algal groups or three layers of lime in overhead tanks.

Integrated pest management (IPM) - an eco-friendly approach

One scientific approach to counter pesticide hazards is the use of IPM. It is the integration of cultural and mechanical methods, use of natural products, behavioural approaches, conservation and augmentation of biological agents and need-based chemicals.

Cultural practices on IPM

- Use healthy seeds.
- Grow resistant/tolerant varieties.
- Use summer deep ploughing.
- Destroy crop residues.
- Follow proper sowing time and method.
- Use crop rotations to check pest growth.
- Maintain optimum plant density.
- Follow inter-cropping.
- Grow trap crops and carrier crops.
- Avoid excessive irrigation and fertilisation.
- Use water-logging in summer season to kill soil-borne pests and pathogens.

Mechanical practices on IPM

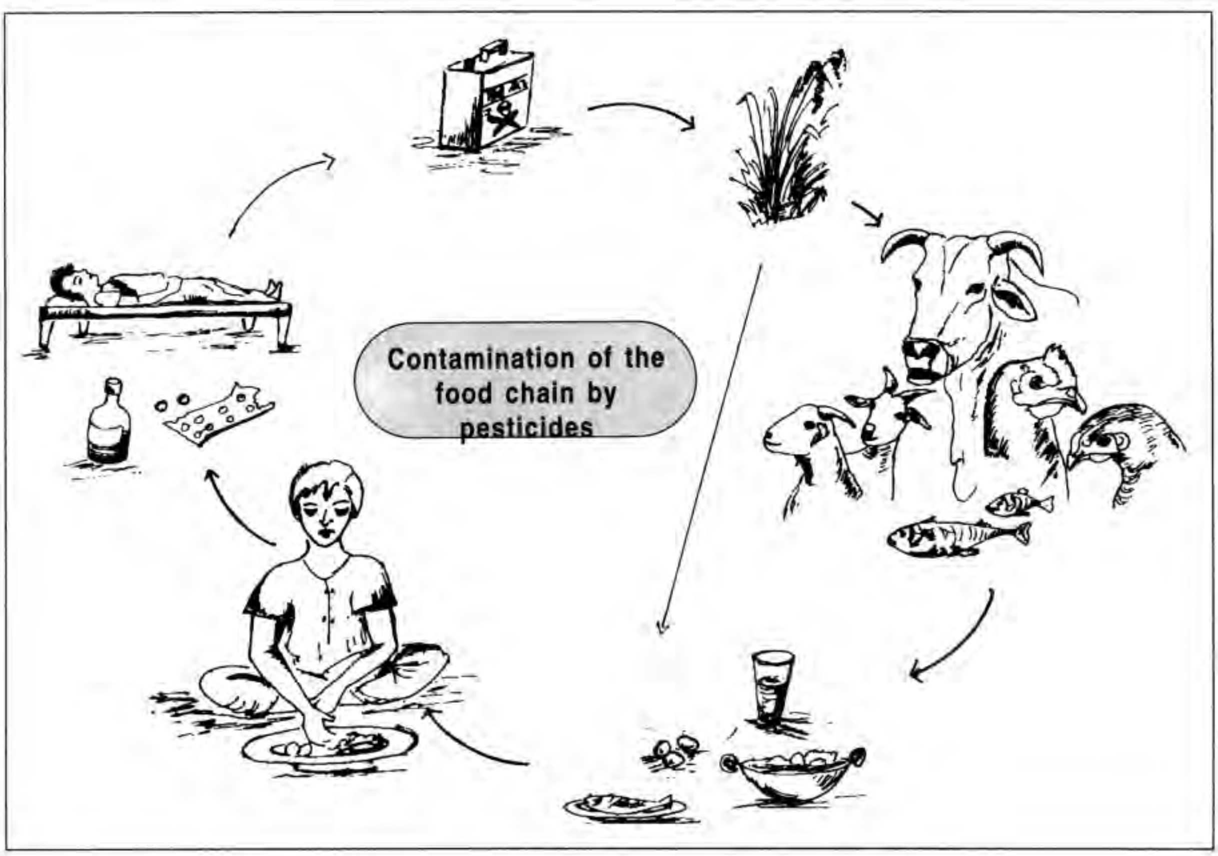
- Hand-pick egg masses and destroy.
- Collect early instars of larvae and grubs.
- Destroy disease-/pest-affected parts.

Behavioural practices on IPM

- Use light traps, pheromone traps and bright yellow strip stickers.
- Trap moths and adults and monitor their population.

Eco-safe pest management

The adoption of modern agricultural technologies has resulted in serious problems of pesticide resistance in major pests, resurgence in minor pests, environmental pollution and pesticide residues in food grain, fruits, vegetables, milk, meat, eggs, etc. A rational, integrated approach at the farmers level is needed so that pesticides, while controlling pests, do not pose any health hazard.



Presented by:
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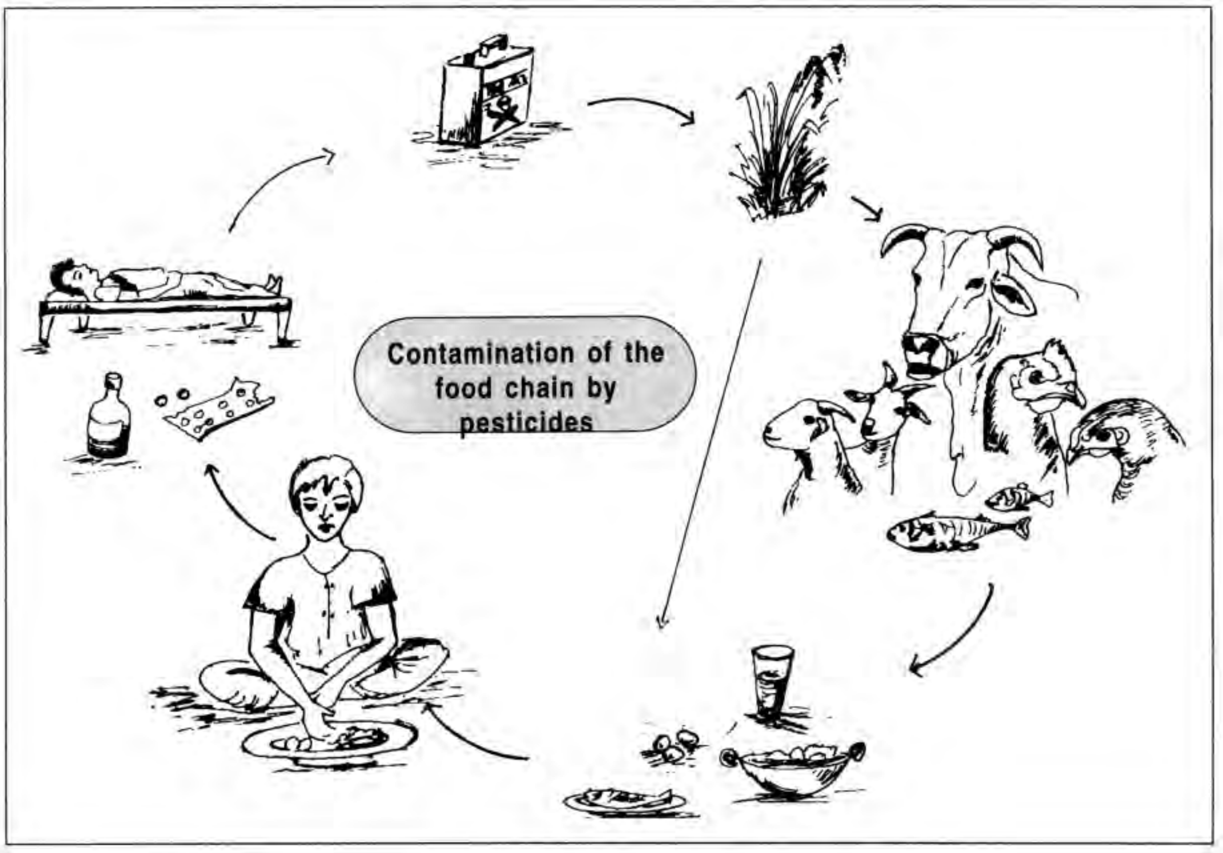

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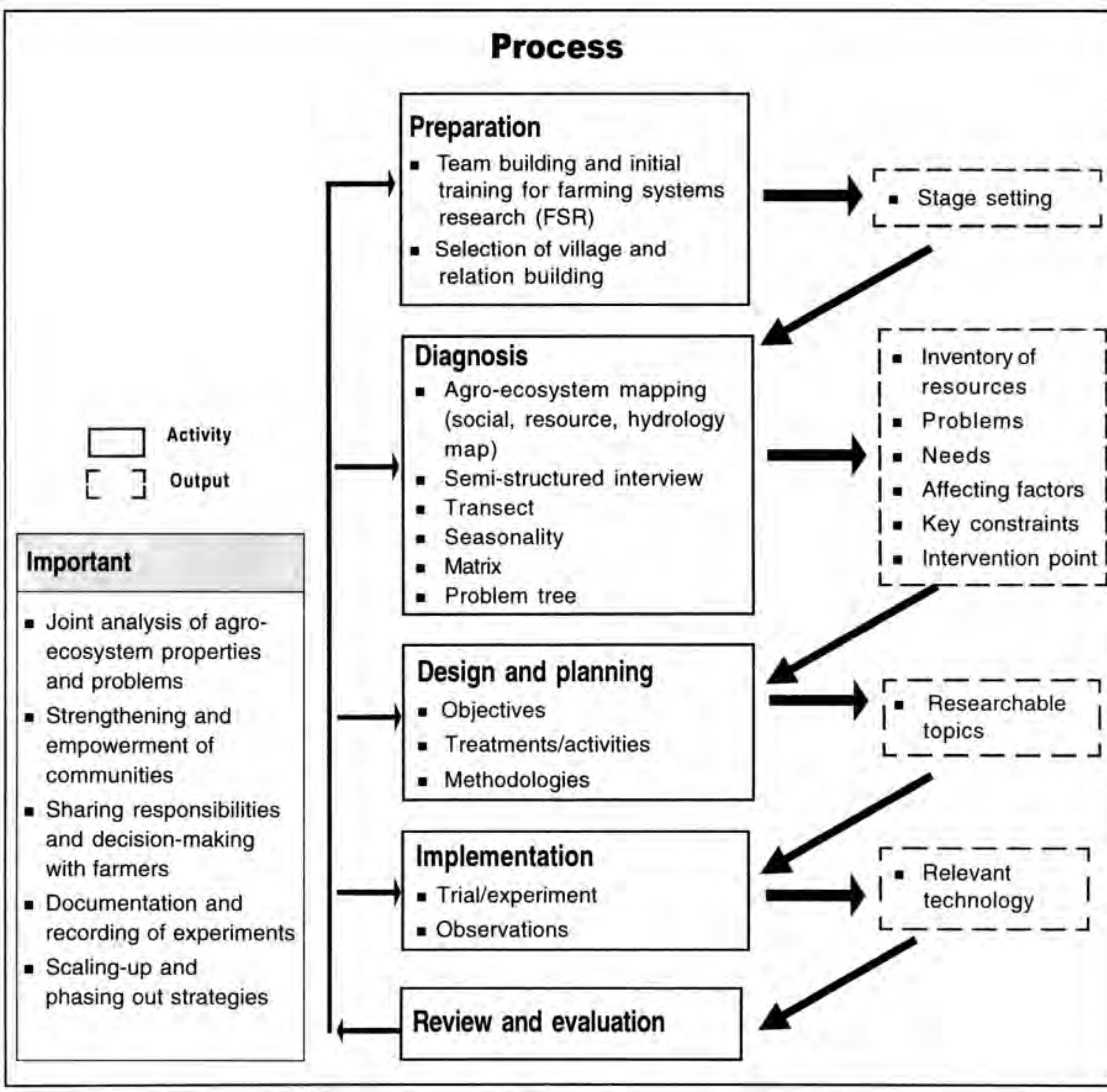
Participatory Farming Systems Technology Development

Participatory Technology Development in Rainfed Rice-Based Farming Systems of Eastern India

Rice farming in eastern India is complex, diverse and risk-prone. By the early 1980s it was realised that the development of technologies for rainfed areas should take a different research approach from the conventional on-station research type for the irrigated homogeneous areas. On-farm research within the context of farming systems was emphasised starting in 1983-1984, as part of the Eastern India Farming Systems Research project.



This initial effort to develop farmer-centered research methods involved the use of multi-disciplinary teams, setting the stage for the use of participatory methods in research. Further methodology testing was undertaken in collaboration with the International Fund for Agricultural Development (IFAD)- and the International Rice Research Institute (IRRI)-supported rainfed rice project. This led to a remarkable increase in the use of this approach in the technology development process for the rainfed regions of eastern India. All the participating centres applied these measures throughout the course of research and technology synthesis. More than a hundred case studies are available.

This section provides an overview of the framework for participatory technology development used and highlights two cases where the involvement; of farmers influenced the research objective or its outcome.

Basket of participatory tools and techniques used in the participatory research

Participatory tools

Mapping
Location specificity of resources, target people and place for technology adaptation and dissemination, trial site and farmer cooperators, evaluation

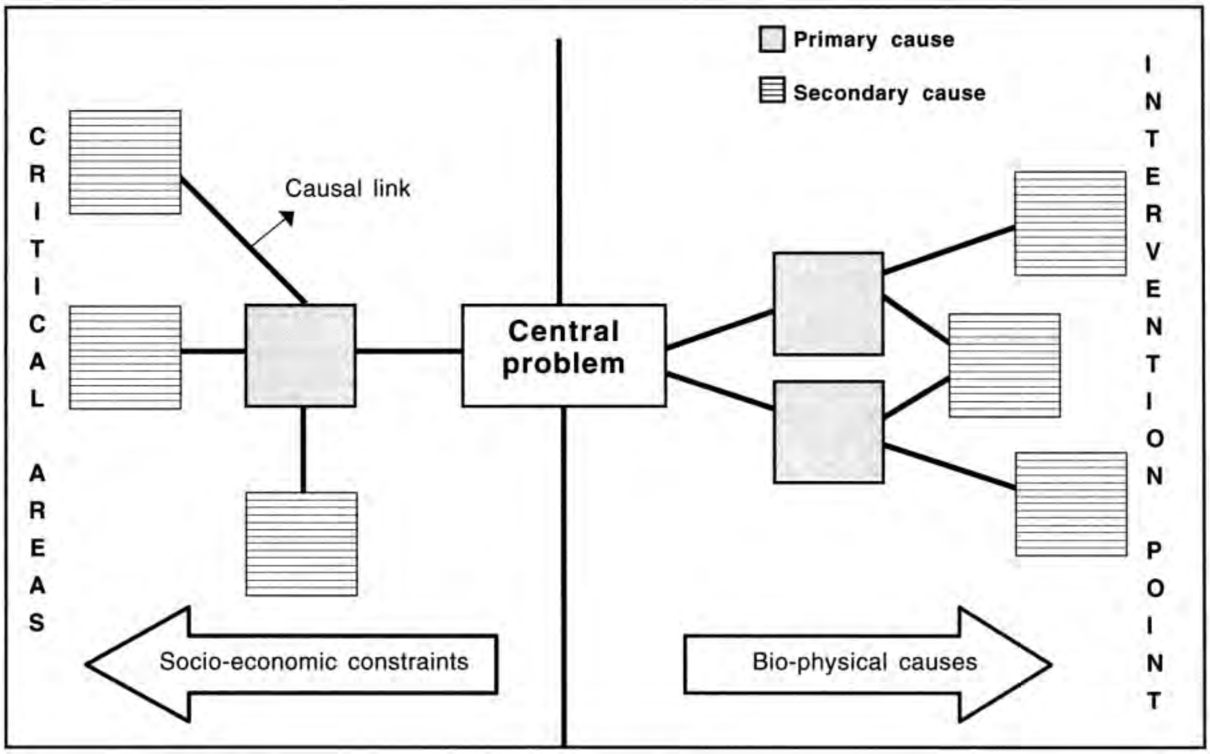
Transect
Land type, enterprise, socio-economic parameters, problems and opportunities

Seasonality
Time-related information and analysis

Problem tree
Cause analysis and intervention point

Matrix
Prioritisation of problems and options

Farmers' problem tree



Conclusion

- Participatory on-farm research in difficult environments is a feasible research management approach.
- Based on the FSR approach, all the participating institutions have developed different technological options to suit farmers' needs.
- Though modest, the technologies, have significantly helped in increasing on-farm productivity, meeting household needs and generating income.
- The Eastern India-FSR project has also, in many ways, contributed to bringing about attitudinal changes in favour of participatory research approaches among institutions, such as NDUAT, Faizabad; ARI, Patna; RKM, Narendrapur; and the Indian Council of Agricultural Research (ICAR).
- The Eastern India-FSR still needs to internalise/institutionalise itself in the research planning processes.

CASE STUDY
Weeding research

In view of the pressing weed problem in the uplands, an on-farm experiment was conducted by row seeding of a high early vigour rice variety (RR167-982) at Hario village of Hazaribagh. It was expected to suppress the weed population and make weeding easier in rows, thereby minimising weeding drudgery for women. This decision was made in consultation with the male members of the household and on the basis of favourable on-station results.

The experiment was laid out with four replications in the village. In spite of providing a hand hoe, the women did not weed the fields in three out of four replications almost up to six weeks after sowing. Therefore, the researchers weeded the field to collect the experimental data and, as expected, this treatment provided the best yields.

The reason for non-weeding given by males was that the females were busy in some other operations, but the females reasoned differently. They used to weed the rice field after it was lightly harrowed *(tevai)* by the male members so that they could easily pull and collect the weeds manually. In the new system, the weeding involved hoeing as an additional burden to the women, which required more time and efforts. Moreover, inter-row space was heavily covered by weeds that belied the promised potential benefit of the technology itself.

Upon further probing, the women had this to say, ".... Despite knowing that weeding is our work, you did not consult us; had you consulted us in the beginning, we would not let you conduct this experiment....The RR982 is a good variety and in the future we will consider this in our *tevai* system of rice cropping...."

In the same experiment, realising the higher rice yields from another variety, RR165-160, the males favoured adoption of this variety. However, the females were concerned about its low straw yield due to its short size. They are also worried about grazing problems due to its longer maturity duration than the local varieties as it would raise the burden of fodder collection for them.

With the new weeding technique, the hoe replaced the plough and the women are doing the job of men (who used to use animal power). Also, the new variety replaced the traditional one and increased the work burden of women. These changes disrupted the social interaction in weeding and crop care; thus, the technologies were socially incompatible, though economically viable.

Case Study
Intercropping research

Intercropping technology of pigeonpea with rice was found to be productively promising for uplands in the on-station research at Hazaribagh. It provided 0.4 t/ha of pigeonpea grain yield and increased cropping intensity by 36%. The 0.6 t/ha decrease in rice yield was more than compensated by the high-value pigeonpea, and this technology provided additional income of $70.00/ha.

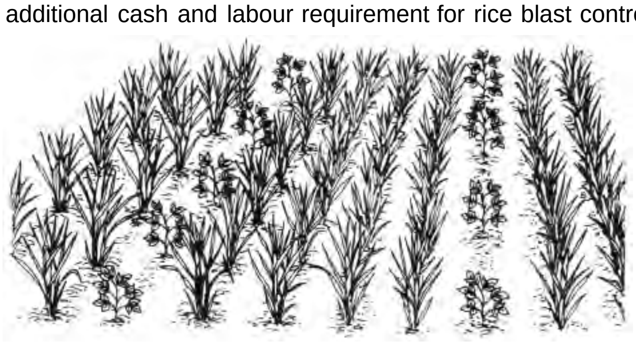
It was considered best suited for drought-prone conditions with a built-in compensation provision for rice crop failures by the high-value pulse. Therefore, several on-farm trials were conducted to introduce this technology in Nagwan village covering 5 ha in different parcels. The trial crop performed at par with the on-station results. Impressed with its performance, the farmers tried for a year but abandoned the practice the following year.

Underlying reasons given by the farmers were that there was a further decrease in rice yield than the pigeonpea could compensate for. They did not consider the pigeonpea yield as a compensation for the loss in rice yield, as rice was socially more valued than pigeonpea. Moreover, the pigeonpea remained in the field longer after the rice harvest and was destroyed by grazing animals. Conventionally, the post-rice fields were meant for grazing throughout the Hazaribagh uplands.

However, farmers suggested that should they be provided with a short-duration pigeonpea variety maturing together with rice, they would still try out the intercropping technology with wider row spacing. If short-duration varieties of pigeonpea are unavailable, some of them suggested an alternative strategy to plant pigeonpea earlier than rice to match up their maturity. They also suggested that if they were to plant rice + pigeonpea in a contiguous area it would protect the crop from grazing animals.

Subsequent research on rice + pigeonpea intercrop indicated increased blast incidence in rice brought about by increased humidity due to pigeonpea stands. The blast disease incidence was higher in the village than at the station. Failure in specifying to farmers the rice variety used in the experiment and in thoroughly checking the associated disease incidence partly contributed to this.

The farmers' suggestion of using wider row spacing seems quite logical as it would decrease the buildup of humidity. It appeared that farmers' reluctance to adopt the new technology was their concern about the additional cash and labour requirement for rice blast control.



Prepared by:
A. Kumar, J. Gonsalves and V. P. Singh

Sourcebook produced by the International Rice Research Institute (IRRI) and the International Institute of Rural Reconstruction (IIRR).

Annexes

Participants

Kumar Ajay
Rice Agronomist
Rajendra Agricultural University
Agricultural Research Institute
Mithapur, Patna, 800001
Bihar, India
☎ (91-612) 351 501; 220 804 (res)

Hemendra Chandra Bhattacharya
Agronomist
Regional Agricultural Research Station
Assam Agricultural University
Regional Agricultural Research Station
Titabar, Jorhat - 785630
Assam, India
☎ (91-3771) 484 53
(91-3771) 376 320919; 376 320939

Gupta Diwan Chandra
Director, Agricultural Statistics and Crop Insurance
Government of U.P
Krishi Bhawan 226001
Lucknow, !India.
☎ (91 -522) 272 984; 282 914; 371 407 (res) 328 145 (res)
(91 -522) 272 984

Subhendu Deb Chatterjee
Managing Director
West Bengal State Seed Corporation
Government of West Bengal
4, Gangadhar Babu Lane
Calcutta 700012, India
☎ (91-33) 225 9311; 237 4369; 236 7859; 359 7530
(91-33) 237 5591

Jwala Prasad Chaudhary
Former Professor and Head, Department of Entomology
Haryana Agricultural University
6/167 Shiva Colony, PO. Purani Basti
District Basti - 272002 (U.P), India
☎ (91 -55) 428 4458

Raj Kumar Chowdhury
Project Coordinator, National Seed Project
Indian Council of Agricultural Research
Seed Science Technology Building
ICAR, New Delhi - 11 001 2, India
☎ (91-11) 578 1908
(91-11) 578 1908

Srijib Gangopadhyay
Principal Scientist
Central Rice Research Institute
Cuttack - 753006
Orissa, India
☎ (91-671) 642 445 to 446 (ext. 293); 44548 (res.)
(91-671) 641 744

Julian F. Gonsalves
Vice President for Program
IIRR
Y.C. James Yen Center, Biga
Silang, Cavite 41 18, Philippines
☎ (63-46) 414 2417
(63-46) 41 4 2420
ovp-iirr@cav.pworld.net.ph

Anand Parkash Gupta
Senior Soil Chemist
Department of Soil Science
CCS Haryana Agricultural University
Hisar 125004, India
☎ (91-1 662) 377 20 to 26 (ext. 4278)
(91-1662) 349 52
hau@hau.hry.nic.in

Humayun Kabir
Regional Office for Asia
International Institute of Rural Reconstruction (IIRR)
Y.C. James Yen Center, Biga
Silang, Cavite 4118, Philippines
☎ (63-46) 414 2417
(63-463 414 2420
roa-iirr@cav.pworld.net.ph

Saha Nirmal Kanti
Additional Director of Agriculture
Government of West Bengal
17, S.P Mukherjee Road, Calcutta 700025
West Bengal, India
☎ (91-33) 476 1492; 475 4072; 475 3375
(91-33) 475 5674; 337 0231 ; 321 6783

Praduman Kumar
Head and Principal Scientist
Division of Agricultural Economics
Indian Agriculture Research Institute
New Delhi, India
☎ (91-11) 578 7501

Girisha Nandan Mishra
Senior Scientist, Agronomy
Central Rainfed Upland Rice Research Station
P.O. Bcx 48, Hazaribag (Bihar) 825301
India
☎ (91-6546) 222 63; 264 54
(91-6546) 236 97

Sarat Kumar Mohanty
Principal Scientist
Division of Soil Science and Microbiology
Central Rice Research Institute
Cuttack 753006
Orissa, India
☎ (91-671) 642 445 (ext. 21 3)
(91-671) 641 744
crri@x400.nic.gw.nic.in

Jamal Perez Noor
Administrative Officer
International Rice Research Institute (IRRI)
C-18 Friends Colony (East)
New Delhi, India
☎ (91-11) 692 6290; 692 5070
(91-11) 692 3122
irri@vsnl.com

Kameshwari Prasad
Principal Scientist and Officer-in-Charge
Central Rainfed Upland Rice Research Station
Post Box 48, Hazaribag - 825301 (Bihar)
India
☎ (91-6546) 222 63
(91-6546) 236 97

Jafran Keshari Roy
Joint Director (Retired)
Central Rice Research Institute
Cuttack 753006
71, Surya Nagar, Bhubaneswar — 751003
India
☎ (91-671) 416 897

Ram Kumar Sahu
Rice Breeder
Indira Gandhi Agricultural University (IGAU)
Krishak Nagar
Raipur 492012, India
☎ (91-771) 424 481126; 771 421072
(91-771) 424 532

Nalini Kanta Sarma
Senior Scientist
Regional Agricultural Research Station
Assam Agricultural University
North Lakhimpur, P.O. Garumuria
Assam 787001, India
(91-3752) 227 14; 427 60
(91-376) 320 919; (3752) 221 96; 428 82
A-LAKHIM@X400.nicgw.nic.in

A.S.R.A.S. Sastri
Associate Director of Research
Indira Gandhi Agricultural University
Krishak Nagar, Raipur (M.P.) 492012
India
(91-771) 427 217; 429 506 (res)
(91-771) 424 532
ad@zrcmpo1.mp.nic.in

Abha Singh
Social Scientist
Narendra Deva University of Agriculture and Technology (NDUAT)
Faizabad, INDIA
or L/31 Neel Vihar Colony
P.O. Ram Nagar Colony
Faizabad, U.P 224001, India
(91-5278) 463 93
(91-5278) 455 16

Amrendra N. Singh
Scientist
Remote Sensing Application Centre, U.P.
Sector "G", Janakipuram, Kursi Road
Lucknow - 226021
India
(91-522) 363002; 361453
(91-0522) 363002
ansingh@lw1.vsnl.net.in

Gajendra Singh
Agronomist
Narendra Deva University of Agriculture and Technology (NDUAT)
Crop Research Station, Ghaghra-ghat
P.O. - Jarwal Road
Bahraich, U.P, 271901, India
(91-5252) 35747

Giri Raj Singh
Professor
Narendra Deva University of Agriculture and Technology (NDUAT)
Faizabad, India
(91-5270) 623 32
(91-5270) 620 23

Om Prakash Singh
Professor (Agronomy)
Narendra Deva University of Agriculture and Technology (NDUAT)
A-923/4 Indira Nagar
Lucknow, U.P., India

Ram Singh
Professor and Head of Fisheries
Narendra Deva University of Agriculture and Technology
Faizabad (U.P.)
India
(91-5270) 62117

R. K. Singh
International Rice Research Institute (IRRI)
C-18 Friends Colony (East)
New Delhi, India
(91-11) 692 6290; 692 5070
(91-11) 692 31 22
irri@vsnl.com

Rama Kant Singh
Senior Soil Scientist
Central Rainfed Upland Rice Research Station
PO. Box 48, Hazaribag - 825301
Bihar, India
(91-6546) 222 63
(91-6546) 23697

V.P. Singh
Agronomist
International Rice Research Institute (IRRI)
Los Baños, Laguna
Philippines
(63-2) 845 0563; 844 3351 to 53
(63-2) 891 1292, 845 0606
V.P.Singh@cgiar.org

Prakash Chandra Srivastava
Associate Professor
Department of Soil Science, College of Agriculture
G.B. Plant University of Agriculture and Technology
Pantnagar - 263145, India
☎ (91-5944) 337 10; 339 45

R.D. Vaishya
Professor of Agronomy (Weed Science)
Narendra Deva University of Agriculture and Technology (NDUAT)
Kumarganj 224229
Faizabad, U.P., india
☎ (91-5270) 623 22

Mansha Ram Varma
Professor, Agricultural Engineering
Narendra Deva University of Agriculture and Technology
Narendra Nagar, Kumarganz 224229
Faizabad U.P.
India
☎ (91-5270) 623 63
📠 (91-5270) 620 23

D.S. Yadav
Professor of Agronomy
Narendra Deva University of Agriculture and Technology (NDUAT)
Kumarganj - 224229
Faizabad, India
☎ (91-5270) 621 64
📠 (91-5270) 620 23

Management team

IRRI

V. P. Singh
Agronomist
International Rice Research Institute (IRRI)
Los Baños, Laguna
Philippines
☎ (63-2) 845 0563; 844 3351 to 53
(63-2) 891 1292, 845 0606
V.P.Singh@cgiar.org

R. K. Singh
International Rice Research Institute (IRRI)
C-18 Friends Colony (East)
New Delhi, India
☎ (91-11) 692 6290; 692 5070
(91-11) 692 3122
irri@vsnl.com

Jamal Perez Noor
Administrative Officer
International Rice Research Institute (IRRI)
C-18 Friends Colony (East)
New Delhi, India
☎ (91-11) 692 6290; 692 5070
(91 -11) 692 31 22
irri@vsnl.com

IIRR

Julian F. Gonsalves
Vice President for Program
IIRR
Y.C. James Yen Center, Biga
Silang, Cavite 4118, Philippines
☎ (63-46) 414 2417
(63-46) 414 2420
ovp-iirr@cav.pworld.net.ph

Joy R. Rivaca-Caminade
Head, Publications Unit
International Institute of Rural Reconstruction
Y.C. James Yen Center, Biga, Silang 4118
Cavite, PHILIPPINES
☎ (63-46) 414 2417
(63-46) 414 2420
pub-iirr@cav.pworld.net.ph

Subrata Rana
International Institute of Rural Reconstruction (IIRR)
India Camp Office
32/H Doctor Bagan Lane, Serampore-3
Pin. 712 203, West Bengal, India
☎ (91-33) 483 8197; 652 3455
(91-33) 662 3796 (attn. 652 3455)
srana@cal2.vsnl.net.in; subratarana@hotmail.ccm

Humayun Kabir
Regional Office for Asia
International Institute or Rural Reconstruction (IIRR)
Y.C. James Yen Center, Biga
Silang, Cavite 4118, Philippines
☎ (63-46) 414 2417
(63-46) 41 4 2420
roa-iirr@cav.pworld.net.ph

Production staff

Editors

Nilam Ashra
Editor/VSO Volunteer
International Institute of Rural Reconstruction (M)
Y.C. James Yen Center, Biga
Silang 4118, Cavite, Philippines
☎ (63-46) 414 2417
(63-46) 414 2420
n ashra@hotmail.com

Amba Jamir
Coordinator
The Missing Link, Society for Environment and Communication
"Jawan Bazar", Aongza Ward
Mokokchung - 798 601, Nagaland, India
☎ (91-369) 23389
thelink@gw1.vsnl.net.in

Melanie Priya Kumar
Editorial Consultant
L-4 University Teachers' Quarters
lnana Bharati, Bangalore - 560056, India
☎ (91-80) 321 1059
(91-80) 321 1059
mpkao@hotmail.com

Prahlad Narain Mathur (Chief Editor)
Scientist
16B/AN, Shalimar Bagh
New Delhi 11 0052, India
☎ (91-11) 571 0685; 747 7439

Jean Pandian
Journalist
The Times of India
No. 7, Bahadur Shah Zafar Marg
Times House, New Delhi, India
☎ (91-11) 331 2277; 694 5148
jean - pandian@hotmail.com

Sheila Vijayakumar
Assistant Managing Editor
Asian Agri-History Foundation
47 ICRISAT Colony –1, Brig. Sayeed Road
Secunderbad - 500 026, India
☎ (91-40) 775 5774
(91-40) 775 0630
ylnahf@hdl.vsnl.net.in

Technical Editors

Julian Gonsalves
Vice President for Program
International Institute of Rural Reconstruction (IIRR)
Y.C. James Yen Center, Biga
Silang, Cavite 4118, Philippines
☎ (63-46) 414 2417
(63-46) 414 2420
ovp-iirr@cav.pworld.net.ph

Prahlad Narain Mathur
Scientist
16B/AN, Shalimar Bagh
New Delhi 11 0052, India
☎ (91 -11) 571 0685; 747 7439

V.P. Singh
Agronomist
International Rice Research Institute (IRRI)
Los Banos, Laguna, Philippines
☎ (63-2) 845 0563; 844 3351 to 53
(63-2) 891 1292,845 0606
V.PSingh@cgiar.org

R. K. Singh
International Rice Research Institute (IRRI)
C-18 Friends Colony (East)
New Delhi, India
☎ (91-11) 692 6290; 692 5070
(91-11) 692 31 22
irri@vsnl.com

Artists

Shreeparna Ghosal
Lecturer
Vidyasagar College for Women
39 Shankar Ghose Lane
Calcutta, India
or 80/1/2 Kankulia Road
Calcutta - 700029, India
☎ (91-33) 241 8887; 440 4710;
473 7539

Lepden Jamir
Senior Artist
Department of Agriculture
Project Operations Unit
Nagaland Environment Protection and
Development (NEPED) Project
14, Old Ministers Hill, Post Box 231
Kohima - 787 001, Nagaland
or Le'Colle n Home Gallery
Lower A'gri Colony
Nagaland, Kohima, India
☎ (91-370) 22 410; 24 294

Vijay Kumar
Design Expo
F-211, Friends Tower (2nd floor)
Opp. Jwala Heri Market
Paschim Vihar, New Delhi - 110 063
or 342, Pocket II, Paschini Puri
New Delhi - 110063, India
☎ (91-11) 557 0923, 543 3561
📠 (91-11) 557 0923

Manab Paul
5/C/2A Telipara Lane
Dhakuria, Calcutta - 700 031, India
☎ (91-33) 415 7048

A.V. Prasanth
Artist
306-A UNA Apartments, Patparganj
I.P Extension (Behind Mother Diary)
Delhi - 110 092, India
☎ (91-11) 272 7621

Bharat Raj
Design Expo
F-211, Friends Tower (2nd floor)
Opp. Jwala Heri Market
Paschim Vihar, New Delhi - 110 063
or 342, Pocket II, Paschini Puri
New Delhi - 110063, India
☎ (91-11) 557 0923; 543 3561
📠 (91-11) 557 0923

Vishal Sharma
H-No. 91, Natthanpur Street
P.O. Nehru Gram
Dehradun 248001
U.P. India
☎ (91-135) 672 070

Desktop Publishing Staff

Sanjay Chaudhary
Village Danda Lakhond
P.O. Gujara, Sahastra Dhara Road
Dehradun, India
☎ (91-135) 607 340

Sumit Dutta
Imagicos Inc.
Y9, Sivanath Bhavan, Gariahat Road
Calcutta - 700029, India
☎ (91-33) 440 8528; 440 2593
📠 (91-33) 4408 528
✉ paku@giascla.vsnl.net.in

Vikas Kumar
T-57, A Railway Colony
Dehradun, U.P., India
☎ (91-135) 672 070

Abdul Gaffar
460, Sector - 23
NIT, Faridabad - 121 005, India
☎ (91-129) 423 664

Pradipto Ghosal
PMS Express Service
80/1/2, Kankulia Road, Calcutta 700029
West Bengal, India
(91-33) 440 4710

Evangeline Montoya
(Materials Production Coordinator)
Desktop Publishing Associate
International Institute of Rural Reconstruction
Y.C. James Yen Center
Biga, Silang 4118
Cavite, Philippines
(63-46) 414 2417
(63-46) 414 2420
pub-iirr@cav.pworld.net.ph

P. Nageswara Rao
Creative Services
#109, Pancom Business Centre, Ameerpet
Hyderabad 500073, India
(91-40) 375 1462; 375 1335

Computers and Support Staff

Rajiv Dimri
Canon Machine Operator
c/o Print Systems
64, Krishna Street
Dehradun - 248001
U.P., India

Monish Kamboj
Computer Care Center
423, Khurbura
Dehradun, India
(91-135) 721 718; 724 382
(91-135) 727 379; 650 944

Vivek Sharma
Computer Care Center
423, Khurbura
Dehradun, India
(91-135) 721 718; 724 382
(91-135) 727 379; 650 944

Lita Katimbang
International Rice Research Institute (IRRI)
Los Baños, Laguna, Philippines
(63-2) 845 0563; 844 3351 to 53
(63-2) 891 1292, 845 0606
lkatimbang@cgiar.org

Workshop Coordinators

Joy R. Rivaca-Caminade
Head, Publications Unit
International Institute of Rural Reconstruction
Y.C. James Yen Center
Silang 4118, Cavite, Philippines
(63-46) 414 2417
(63-46) 414 2420
pub-iirr@cav.pworld.net.ph

Subrata Rana
International Institute of Rural Reconstruction
India Camp Office
32/H Doctor Bagan Lane, Serampore-3
Pin. 712 203, West Bengal, India
(91-33) 483 8197; 652 3455
(91-33) 662 3796 (attn. 652 3455)
srana@cal2.vsnl.net.in;
subratarana@hotmail.com

POST-PRODUCTION STAFF

Editors
Nilam Ashra
Joy Rivaca-Caminade
Amba Jamir
V. P. Singh
R. K. Singh

Artists
Manab Paul
A.V. Prasanth

Copy editor
Bill Hardy
Editor
International Rice Research Institute (IRRI)
Los Baños, Laguna, Philippines
(63-2) 845 0563; 844 3351 to 53
(63-2) 891 1292, 845 0606
bhardy@cgiar.org

Desktop Publishing Staff
Vikas Kurnar
Abdul Gaffar
Evangeline Montoya

PRITHVI PRINT