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Rice-based cropping systems

for enhancing productivity of food grains in India: decadal experience of AICRP

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While most rice is grown in the kharif *(wet-season, roughly July-December), rice is also grown in the* rabi *(dry-season, roughly January-June) in many states of India. Approximately 55% of India's rice crop is irrigated, up from about 45% in 1990; the fraction of rice area that is irrigated varies by state from <50% irrigated in Madhya Pradesh, Maharashtra, and Bihar, to >90% in Punjab, Tamil Nadu, Andhra Pradesh, and Haryana. Existing All India Coordinated Rice Improvement Project at Indian Institute of Rice Research, Hyderabad provides sufficient information on the decadal changes in the cropping systems research, further to quantify and reach a future novel research strategy to enhance productivity of rice based cropping systems.*

Key words: Cropping systems, Foodgrains, Productivity, Rice

RICE-based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops. Intercropping of rice and other compatible crops is also widely practised in many regions. Rice-based cropping system is a major cropping system practised in India, which include the rotation of crops involving cereals, pulses, oilseeds, cotton, sugarcane, green manures, vegetable, etc. Various rice-based cropping systems have been reported from different parts of India ranging from rice-rice-rice to rice followed by different cereals, pulses, oilseeds, vegetables and fibre crops. Rice-based cropping systems may include lowland and upland crops. So far, most people have been focusing on individual crops disregarding the fact that each crop is only a component of a cropping system. In rice growing areas, several crop combinations (cropping systems) are in practice based on agro-ecological conditions, market and domestic needs and facilities available with farmers. Some of the most prominent ones are being discussed.

Mixed varietal cropping of rice : System of mixing seed of early rice with late maturing deep water rice is being practices in West Bengal to avoid total crop loss at the event of flood. The seed of both the types of mixed in 1:1 ratio and has given higher yield than sole cropping of either type. Similarly, growing of a mixture of autumn and winter varieties in 3:1 ratio in Tamil Nadu and Kerala is frequently in practice. However, under normal conditions, it has created problems in performing agricultural operations like harvesting, deciding fertilizer doses etc.

Intercropping rice with other crops: It is a common practice under upland conditions in north and north-eastern part of the country to grow rice intercropped with blackgram, greengram, sesame, maize, finger millet or other minor millets. The ratio of rice and intercrop is preferred to be 3-4:1.

Relay/paira/utera cropping: The seed of succeeding crops like lentil, gram, pea, lathyrus, berseem, linseed etc. is sown broadcast in maturing rice crop. This practice saves time; money (to be spent on land preparation etc.) and utilizes residual fertility. This practice is common in both upland and lowland rice culture.

Sequential cropping in rice: Sequential cropping refers to the crops grown as preceding or succeeding with rice as shown below.

Rice-based cropping systems research under AICRIP in last decade

Rice-cereal based cropping system: Rice, maize, and wheat are major cereals contributing to food security and income in South Asia. These crops are grown either as a monoculture or in rotations in tropical and sub-tropical environments of South Asia. In the irrigated and favourable rainfed lowland areas, rice-rice (R-R), rice-

Table 1. Rice-based cropping system under (AICRIP)

Irrigated conditions	Upland condition	Rice under integrated farming system
Rice-Rice-Rice	Rice-Chickpea	Rice-Fish-Poultry
Rice-Rice-Cereal	Rice-Lentil	Rice-Fish-Duckery
Rice-Rice-Pulses	Rice-Mustard/Linseed	
Rice-Wheat-Pulse	Rice-Barley	
Rice-Toria-Wheat	Rice-Wheat	
Rice-Wheat	Rice-Pea	
Rice-Mustard		

wheat (R-W), and rice-maize (R-M) are the predominant cropping systems Table 1. Rice-rice is common in tropical climate with distinct dry and wet seasons such as in South India, and in sub-tropical areas with mild cool winter climate such as in Bangladesh, Eastern India, and Eastern Nepal. The rice-wheat system of India are important for food security of the country, and for the livelihoods of the many millions of farming families and others employed in aspects of the value chain. Most of the R-W area is located on the Indo-Gangetic Plains (IGP), with 10 Mha in India, 2 Mha in Pakistan, 0.5 Mha each in Nepal and Bangladesh. The two small north-west Indian states of Punjab and Haryana, located mostly in the Indus basin, provide about half the rice and 85% of the wheat procured by the Indian government. Multi-locational trials on rice-wheat systems under AICRIP showed that transplanting method was found to be superior over direct seeded method and application of organics + farmyard manure and micro-nutrients enhanced system productivity at most of the locations.

R-M systems exist in all climate ranging from tropical to sub-tropical to warm temperates. Rice-maize systems, however, are less extensive as compared to R-W or R-R, if total area under these cereal systems is considered. Higher productivity with sustainability remains the major concern of any crop planning. Any system which requires less input and contributes more is considered to be the efficient. In recent years, oilseeds and legumes are receiving more attention owing to limited production and higher prices. Inclusion of these crops in the sequence changes the economics of the cropping system. There is a closer relationship between cropping system productivity, economics, energy and environment. Different rice-based crop rotations were evaluated at 13 locations to economize the nutrient recommendation, enhancing nutrient use efficiency, soil-health and sustain productivity. The result showed that rice-maize rotation (Table 2) produced the highest rice equivalent yield (10.2 tonne/ha) and gross monetary returns (₹ 59,110/ha).

Table 2. System productivity and gross return of different rice based cropping system

Cropping systems	REY (tonne/ha)	Gross return (₹/ha)
Rice-rice	7.8	45,124
Rice-wheat	8.4	48,882
Rice-maize	10.2	59,110
Rice-pulse	8.5	49,152
Rice-oilseed	7.0	40,472

REY, Rice equivalent yield

Nutrient management strategy for rice-based cropping system: In developing countries such as India, the most important challenge is to provide sufficient food for the growing population at affordable prices from inelastic land areas. The application of agro-chemicals resulted in a many-fold increase in agriculture production but at the cost of soil health. For the present level of production, the estimated nitrogen–phosphorus–potassium removal is about 28 metric tonne, resulting in a negative balance of about 10 metric tonnes. To fulfill such a negative balance of fertilizers, there is an urgent need to identify suitable integrated plant nutrient systems for different crops and cropping systems. Rice–wheat cropping system is an important cropping system of northern India. In rice–wheat cropping systems, green manuring has proved a feasible and reliable practice to improve the productivity and soil fertility as well. It is worthwhile to mention that although organic manures ameliorate the physical, chemical and biological properties of the soils, they cannot substitute chemical fertilizers because of the low amount of plant nutrients present in them and because their bulky nature involves high transport cost. Thus, we can not wholly and solely depend upon manures for increasing the yield of the rice–wheat cropping system. The main bio-fertilizers which can be used as supplement to chemical fertilizers are blue-green algae and *Azolla* for rice. Blue-green algae are capable of fixing atmospheric nitrogen, particularly under puddled rice soils, contributing about 50–100 kg N/ha. They also produce growth-promoting substances. In simple terms, Integrated Nutrient Management system refers to a balanced use of chemical fertilizers in combination with organic manures, crop residues, bio-fertilizers and other biological sources. Multi-locational trials conducted at different parts of the country revealed that rice-based cropping systems performed better under green manure and farmyard manure applied plots than those of without organic manure applied plots. Similarly, nutrient management in different seasons also plays an important role in productivity of a system (Table 3).

Micronutrient plays a major role in enhancing the productivity of any cropping system. The experiment revealed that addition of micro-nutrients substantially improved rice grain yields in sandy loam soils of Kanpur and addition of organic matter during previous *kharif* had positive residual effect in succeeding wheat crop productivity and recorded additional higher grain yield either with soil or spray application of micro-nutrients.

Conservation agriculture: Various forms of conservation agriculture are now being practised in over 157 million ha globally but mostly in large mechanized farms in rainfed and supplementary irrigation areas. There is much less application of conservation agriculture in rice-based systems which support predominantly smallholder farms.

Table 3. Productivity of rice-based cropping system under seasonal nutrient management

Treatments	Rice-rice	Rice-wheat	Rice-maize	Rice-pulse	Rice-oilseed
Control	8.54	4.67	7.3	5.56	5.53
50% RFD (K)	7.20	6.10	9.12	7.84	6.80
100% RFD (K)	7.56	8.88	10.19	8.81	7.61
150% RFD (K)	7.78	9.27	10.47	9.26	8.19
50% RFD (K and R)	7.97	7.39	10.48	8.52	7.12
100% RFD (K and R)	8.74	11.14	11.80	9.68	8.65
150% RFD (K and R)	9.06	11.6	12.01	10.21	9.05

RFD

Table 4. Impacts of conservation agriculture on productivity of rice-based cropping systems

Treatments	Rice-rice	Rice-linseed
Conventional tillage with hybrid	13.15	10.0
Conventional tillage with high yield variety	12.54	9.08
Zero tillage with hybrid	8.96	7.74
Zero tillage with high-yield variety	8.19	7.15
Minimum tillage with hybrid	10.07	9.02
Minimum tillage with hybrid	9.50	8.19

Conventional tilled rice-rice system produced the highest system productivity compared to other tillage management practices (Table 4). Similarly, rice-linseed system also produced the highest system productivity than other tillage management practices. It is concluded that reduced tillage negatively affected the rice-based cropping system than conventional tillage practices.

Climate resilient management practices

Indian agriculture faces the dual challenge of feeding more than a billion people in a changing climatic and economic scenario. Agriculture is the main source of livelihood for almost 60% of the country's total population. The impacts of climate change on agriculture will be severely felt in India. It has been projected that under the scenario of a 2.5^{0}C to 4.9^{0}C temperature rise, rice yields will drop by 32-40% and wheat yields by 41 to 52%. As Indian agriculture is highly dependent on specific climatic conditions, the research on the impact of climate change on agriculture in general and rice production in specific is a high priority in India. There is an urgent need to focus on climate resilient input management practices for improving use efficiency and sustaining the rice and rice-based cropping systems across the country. To address the issues of sustainability of food production on account of changing climate, a combination of water and nutrient management practices were tested aimed at water and nitrogen saving in rice and rice-based cropping system. For this purpose, an experiment was done during *kharif* 2013. The study indicated that non-puddled rice crop establishment is promising at Coimbatore and at other locations and it can be made as productive as transplanted rice with resorting to split application of N, use of biofertilizers to substitute 50% N and crop residue retention at most of the locations. Further, non-puddled rice didn't influence the grain yields of *rabi* crops except at Coimbatore. Climate resilient management practices (Split application of fertilizer + biofertilizer + crop residue retention) are more promising than conventional practices (Fig. 1).

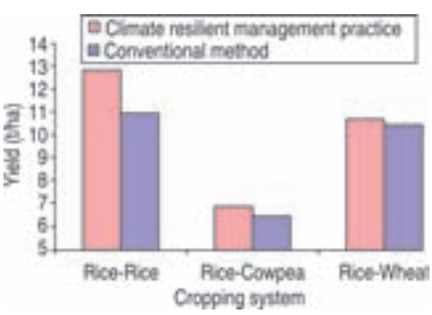

Fig. 1. Climate resilient management practices in rice-based cropping systems

FUTURE STRATEGY

1. Intensify crops in rice-based production systems by increasing the number of crops grown on the same land each year following the main rice crop. Crop intensification may be achieved by using shorter season varieties, improving on-farm water and soil fertility management (e.g. water-harvesting practices, minimum tillage, supplementary irrigation), and introducing rotation crops.
2. Boost yields by improving the efficiency of water and nutrient use. The entry point for yield enhancement is to improve the crop water-use efficiency of both irrigated and dryland components of rice-based systems. Water productivity gains will need to be underpinned by sustainable soil fertility. This will necessitate targeted research to develop site-specific nutrient management systems, including more efficient use of fertilizers, soil ameliorants, green and animal manures, and residues. Tailoring agronomic practices (e.g. weed management, planting methods) to local conditions will further enhance water and nutrient efficiency.
3. Improve livestock production by integrating animals more effectively with rice-based cropping systems. Livestock production is highly dependent upon feed sourced from crops – grains and tubers, stover, green forage, and processing by-products – together with weeds within and beside crops. The transformation of poor farmers from livestock keepers to active market-oriented producers will require improvements in livestock reproduction and nutrition coupled with better access to markets.
4. Strengthen policy settings by improving understanding of the linkages with, and impacts on, food security. Food security is affected by the mix of policy settings at local to international scales. Achieving more productive and sustainable rice-based cropping systems will necessitate better understanding of and

integration across formal and informal policies, especially in the arenas of agricultural industry and trade, land and water resources management, agricultural extension systems, and marketing systems for rice and related products.

5. Build capacity of individuals and institutions by establishing effective collaborative relationships and facilitating knowledge sharing. Effective and lasting results for food security will depend upon developing strong in country capacity for framing, conducting and extending R&D. This capacity extends from individual researchers to the broader institutional arrangements. The principal mechanism for capacity building is through partnering of agricultural research institutions, universities, Krishi Vigyan Kendras, state agriculture departments and all other agriculture related functionaries in country to jointly deliver a model for sustainable enhancement of productivity of rice-based cropping system in India.

SUMMARY

Rice is a dominant crop; about 20% of global total human food calories are supplied by rice. More than 150 million ha were sown with rice in 2002, 90% of that in Asia. Demand for rice in Asia is projected to increase by 70% over the next 30 years. At ~45 million ha, India has the largest national area of rice cropping . Much of this rice area is multi-cropped, and cropping patterns are very diverse. These varied cropping systems occur across a varied environment (e.g. weather, soils, topography), so quantitative assessment of a number of the 'outputs' of agriculture (e.g., crop yield, water use, soil erosion, nutrient leaching, greenhouse gas emissions) will benefit from detailed study of cropping systems and environmental variables.

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