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Participatory Breeding in Rice

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Introduction

Rice is the staple food of the population of eastern India, and is grown in a wide range of environments ranging from upland areas, with little moisture, to situations where the water is 3-4 meters deep. In rainfed lowlands, floods and drought singly or in combination, are the major abiotic stresses. While the other regions of the country have achieved a rapid growth in agriculture, this region has lagged behind. The green revolution has had little impact on the 15 m ha of rice in the lowland ecosystem in eastern India. However, it is now becoming increasingly clear that this vast area can contribute greatly to solving the present and future agricultural problems in India if there is a better application of available technology.

Bihar is a typical eastern state, with a large proportion of land (5.4 m ha) under rice, which has an average productivity of only 1.2 t ha^{-1}. More than half of the rice area is rainfed lowland, including flood-prone ecosystems, which are characterised by low productivity obtained under traditional systems of cultivation. Despite scientists' claims to have developed appropriate high-yielding varieties (HYVs), both at a national and a state level, their adoption is negligible. Farmers prefer their own cultivars which are highly adapted to the varying adverse conditions prevalent in the region. These local cultivars have passed through innumerable generations of selection and have evolved mechanisms to adjust to the harsh environment. There is no doubt that HYVs perform better when conditions are at their optimum, but they virtually fail when conditions are adverse. In this situation, the higher stability of traditional cultivars is preferred by farmers.

In this paper, we compare HYVs with the traditional landraces that farmers grow, and which represent a diverse genetic resource. A participatory approach has been used for varietal selection in rainfed lowland and flood-prone ecosystems in the existing farming systems.

The Present System of Varietal Development

The All India Crop Improvement Projects and State Agricultural Universities have a mandate to breed and release new varieties and popularise them along with an appropriate package of practices. The breeder produces a large number of pure-breeding lines from crosses at a research station that are evaluated in initial variety evaluation trials. The best few are promoted to advanced trials and a small number of promising entries are retained for further testing. Based on their overall yield performance across years and other desirable traits, an entry is identified for release. At this stage, it may be tested in minikit trials on farmers' fields by the State Department of Agriculture. When a variety is finally released it is, therefore, largely on the basis of its overall yield performance.

The cultivars, developed through this process, have mostly been adopted by farmers in risk-free, homogeneous, and irrigated conditions, i.e., in environments where the green revolution took place. However, for risk-prone, rainfed lowland and deep-water ecosystems the appropriateness of this process appears to be highly doubtful. Rarely, if ever, has a variety developed through this procedure been specifically adapted to harsh environments. Despite this, new varieties continue to be selected on the basis of their overall mean performance across diverse locations. Further, it is rarely considered that farmers' field conditions and agro-ecological zones are often quite different from those represented by the experimental stations where the improved varieties are developed and tested. The farmers' fields conditions often include highly changeable water regimes, no insect-pest control, and no soil amendments. Consequently, improved varieties do not manifest their genetic superiority over local varieties when grown under farmers' field conditions (Maurya *et. al.,* 1988, Saran *et. al.,* 1990). These basic factors bring about a situation where farmers have more confidence in local cultivars than in HYVs.

Pattern of Adoption of Local Cultivars in Bihar

The popular local cultivars predominantly grown in the different regions of the rainfed lowlands of Bihar differ greatly (Table 13.1). A set of cultivars is popular in each region, and no variety is predominately grown in all regions. Farmers select the cultivar type for a specific location using their prior experience of the location and the available cultivars. Regional adaptability is very obvious as their choice is based mainly on the average water regime of the location, the time of seeding and planting. We may examine the pattern of requirements in a typical *Chaur* (low-lying land depression, mostly circular in nature) situation (Fig. 13.1). Given that water depths are greater at the centre than the periphery, farmers select cultivars that adapt to the expected water depth at any particular part of the *Chaur.* Short duration varieties, even HYVs, are sown at the periphery; progressing inwards they plant photosensitive tall cultivars which can withstand 40-100 cm of water depth and in the centre they grow floating rice varieties. One can visualise the pattern of water depth in the *Chaur* from the varietal adaptation pattern. However, in low rainfall years such as 1992, farmers may change varietal succession by planting medium duration varieties instead of photosensitive tall types.

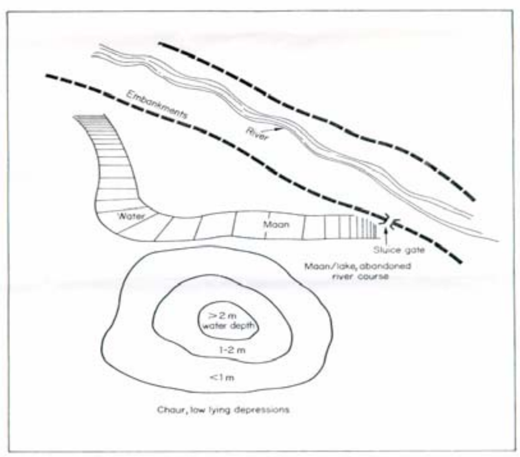

Fig. 13.1 Types of deep-water areas in Bihar

Table 13.1 Some important features of traditional photo-sensitive rice cultivars popular in Bihar

Name of traditional cultivars	Flowering time	Area of adoption	Adaptability	Special features
Laldhari Kessore, Selha, Jhiggasar, Hathia Jhulan, Chengule, Kelasar, T 141, No. 52, Jalansar	All of October	South Bihar (plains of Bhagalpur region)	Regional	All adapted to late planting. Hathia Jhulan has strong stems and broad leaves.
Katarni, Kamod, Dehradun, Tulsimanjari	Mid October to early November	South Bihar (plains of Bhagalpur region)	Regional	Adapted to late planting. Fine grain, highly tolerant to cold at flowering, and drought tolerant
Bakol, Bakoi, Jaswa, BR 34Q, Herankel, Kalamkathi	All of October	North Bihar (plain of Muzaffarpur region)	Wide	Jaswa has good quality. Bakol is most predominant, being cultivated in many districts of north Bihar
Dhusari, Bakol, Kasaunjh, Parwapankh, Akalbir, Malida	Al of October	North Bihar (plain of Darbhanga / Kosi region)	Regional	Kasaunjh has short stature, tolerance to soil deficiencies, disease and pests, and cold tolerance at flowering

Grain yield is not the sole criterion of varietal selection by the farmers. The variety must fit into their cropping system, meet household requirements and adapt to management practices which farmers can afford to apply without much difficulty. In rainfed lowland areas, local varieties invariably face drought and/or flood and, they must, therefore, have an inherent ability to adapt to such situations. Numerous national demonstrations conducted in the rainfed lowland areas have shown that higher yields could be achieved by HYVs, yet, on a practical basis, no farmers grew them the following year. The reasons for their rejection possibly arise from:

- seeding and planting dates in the trials that farmers may not be able to follow in practise;
- higher levels of management in the trials than on farmers' fields;
- availability of irrigation water for the trials, and
- the use by extension staff of higher levels of applied inputs in demonstration plots than on farmers' fields, in order to make the demonstration look impressive.

From 1989 to 1994, we studied these issues in a cluster of four representative villages.

Targeting the Environment

In low-lying areas the water regime is extremely variable: there may be no water on higher ground but water stagnation in lower areas. Because of this, it is difficult to predict the water depth that rice plants will encounter in lowlands. In rainfed lowland/deep-water ecosystems the situation is further complicated by yearly variations in rainfall patterns that cause floods or drought, and types of land depression. This makes it difficult to specify the conditions for which varieties are being bred. If HYVs show high yields in lowland environments, it is often because they are grown in good climatic conditions and appropriate water depths. Local landraces, on the other hand, are adapted to variable conditions. They possess adaptation to late sowing and planting, tolerance to droughts or floods, or both, and tolerance to extremes of temperature, especially cold.

We therefore approached the problem of environmental variation by starting from the varietal choices made by farmers themselves. Farmers grow a range of varieties chosen to match the highly diverse lowland ecosystem environment. Individual varieties must have sufficient plasticity to adjust to environmental variation. For example, 'Bakol', a landrace is grown in *Chauri* (lowland) as a transplanted crop and is direct sown in *Chaur* (deep-water). When there is a likelihood of floods, it is direct sown and when there is less chance of flooding it is transplanted. Hence, varieties having a narrow range of adaptability, tend to perform poorly in such environments.

The Need for Participatory Research

When organised agricultural research started, emphasis was placed on increasing production by producing reliable irrigation and the applications of purchased inputs such as chemical fertilisers. There were initial gains from this strategy. However, when yield levels did not increase beyond a certain level, even when inputs were increased, yield barriers were investigated. A dramatic increase in yield was achieved with the green revolution of the 1960s in the Indian sub-continent with the introduction of non-lodging, photo-insensitive, semi-dwarf and dwarf varieties. Even for deep-water ecosystems, semi-dwarf plant types which had elongation ability were advocated. While in irrigated homogenous environments it worked well, this approach did not bring about any improvement in the problematic rainfed ecologies. More recently, it is has been realised that it is crucial to involve the client-farmers as partners in the research process. Farmers, can provide valuable information on the type of constraints usually encountered in their locality and the varietal characteristics needed to overcome them. Farmers can be involved in the varietal selection process for the region and varieties identified through this process will be highly adapted to the area. Farmer participatory varietal selection discussed in this paper is especially relevant to the predominantly rainfed lowland ecology of Bihar.

Intervention and trial design

Two types of on-farm trials were planned, on-farm research trials and on-farm trials. In the on-farm research trials, promising materials generated at research stations were evaluated to identify the ones with location specificity. These trials had a large number of entries but were conducted on few sites. The best few entries selected on the basis of their performance were then included in the on-farm trials conducted on a large number of sites. Farmers were partners in the planning and execution of these trials which were designed to enable semi-literate farmers to understand their implications.

On-farm research trials

Twelve élite rice genotypes differing in maturity and plant height, along with a local cultivar 'Bakol' were tested in on-farm research trials at 18 sites from 1989 to 1994 (Table 13.2). The trial sites, one in each village, were selected in cooperation with farmers and the trials were conducted under farmers' management practices. The trials were laid out in a randomised complete block design with three replications, and the plot size varied from 24 to 30 m^2. The objectives of the on-farm research trials were to:

- offer alternative choices of varieties to farmers, and
- verify the performance of improved genotypes under farmers' conditions in comparison to the research station trials.

Evaluations, jointly with farmers, were arranged at the post-flowering period and a few entries, possessing high yield and early maturity, were selected for the next stage of evaluation, the on-farm trials. This multi-stage process of rice varietal evaluation from on-station trials, to on-farm research trials, to on-farm trials continued until 1994. Two cultivars, namely 'Sudha' and 'TCA 48' in a photosensitive group comparable with the local variety Bakol and one variety 'Rajshree' in an early-maturing group were identified during the first year. They were selected to be included in the on-farm trials and were also retained in the on-farm research trials as controls (Table 13.2).

Table 13.2 Performance of rice varieties in on-farm research trials from 1989 to 1994 under the rainfed lowland ecosystem condition of Bihar, India.

Variety	Duration (days)	Height (cm)	Average grain yield (kg ha^{-1}) 1989	1990	1991	1992†	1993	1994
TCA 48	185	155	2445	2345	3912	1836	3240	2680
PSR 1209-2-3-2	150	140	-	-	-	-	3200	3350
TCA-214	190	150	2039	-	-	-	-	-
Sudha	185	147	2358	2514	3418	1662	2630	2344
Rajshree	145	130	2840	2737	4215	1772	3160	2604
Mansarowar	155	95	2004	-	-	-	-	
IET 7591	156	135	2139	2215	-	1334	2275	2968
SBR 3013	165	120	2245	2380	-	-	-	-
IET 7552	170	130	2168	1915	-	558	2386	
TCA 84-3	150	145	-	-	3146	1694	2837	2466
SBR 1119-13-3-1	148	165	-	-	3736	1007	2938	2791
SBR 38-50-2-4	136	140	-	-	3415	508	-	-
Bakol (Local)	175	160	2135	1832	3118	1262	2424	1779
LSD at 5%	6.2	6.3	18.5	19.4	15.3	14.8	10.3	9.3
No of sites			3	3	4	2	3	3

† Severe drought year

On-farm trials

The trial design was simple: the test variety was grown with the local check in a 500-1000 m^2 area under farmer management practices at sites that, although not very uniform, were mostly on the peripheral portion of the *Chaur*. The variety Rajshree was evaluated in 54 on-farm trials conducted from 1990 to 1992 (Table 13.3). Its performance in comparison to the local cultivar was outstanding. In the drought years of 1990 and 1991, it did remarkably better than the long duration local landrace Bakol which faced severe drought in September-October, while Rajshree, because of its early maturity, was virtually unaffected.

Table 13.3 Grain yield of Rajshree in on-farm trials conducted under lowlands/shallow deep-water ecosystems of Bihar, India

	1990			1991			1992		
	No	Yield (kg ha^{-1})		No	Yield (kg ha^{-1})		No	Yield (kg ha^{-1})	
Village	sites	Rajshree	Bakol	sites	Rajshree	Bakol	sites	Rajshree	Bakol
Choudhary tola	3	2536	2132	3	2646	1945	7	3048	1436
Dhobgama	4	3615	1638	9	3817	1639	4	3140	1238
Bakhtiyarpur	3	3415	2241	4	3618	1932	3	3845	1537
Gwalatola	2	3517	1948	9	4435	1614	3	3937	1008

Sudha was also compared in transplanted conditions against Bakol at 18 locations over three years. It did fairly well in comparison to the local check (Bakol) but that was due to the drought in 1991, it also suffered like Bakol. However, it did have superior grain quality. TCA 48 was subsequently found to be better both under transplanted and direct sown conditions (data not shown). It performed significantly better than Bakol under drought, and was also found to be suitable for delayed sowing and planting. It has now been released as 'Vaidehi' (Thakur *et. al.*,1994).

Implications
The data from on-farm trials imply that it would be beneficial to establish a two way linkage between on-farm and on-station research. The rainfed lowlands (which constitutes more than 50% of the rice area in the Bihar state) are clearly illustrate how research priories at research stations bear little relevance to the farm situation at state and national levels. Dwarf varieties, responsive to fertiliser application with record yields under trial conditions are released, but are unadapted to the adverse conditions which exist in farmers' fields. The varieties 'Mansarowar' and 'Salivahan' were released centrally but failed in our on-farm research trials (Table 13.2). Rajshree, a tall variety succeeded because it is adapted to late sowing and is drought tolerant. Though released on the basis of its stable yield in research station trials, it shows adaptation to adverse situations as it is a spontaneous mutant from a farmers' variety. Similarly, the variety TCA 48 released as Vaidehi, is a selection from local germplasm. Rajshree which matures nearly a month earlier than the local variety, shows how varieties of short duration can be produced, as envisaged by Choudhary (1982). Duration, and to some extent tolerance to submergence and drought are assessed on-station, but adaptation to delayed sowing and planting, which is the most important problem, is rarely assessed in the selection process. At the Eastern India Lowland Breeders' Workshop, held at Bhubaneshwar, the author reported his experiences, on working in farmers' fields, and this led to the implementation of screening trials in the eastern Indian states for late sowing and planting (Thakur and Mishra, 1992).

Varietal Release Methodology

Rainfed ecosystems have various niches that vary from region to region, and in each region farmers grow different varieties. A limited number of varieties, therefore, are insufficient. The release of numerous varieties, rather than a few, has been recommended previously (Jain and Banerjee, 1982), and the varietal release procedures need to be reformed, at least for risk-prone environments, along these lines.

Pure-line selection from variable landraces though abandoned, still has relevance in these ecologies. The varieties 'Jaladhi I' and 'Savita' in West Bengal, 'Kamini' and Vaidehi in Bihar have been released recently and have gained popularity in their respective regions. This breeding methodology was suggested after reviewing the results of the hybridisation programme (Thakur and Mishra, 1992; Thakur, 1995). Compared with hybridisation procedures, it can create an impact on production in a much shorter period of time. However, hybridisation does have longer term applications and must involve locally adapted germplasm and selection from the segregating generations that takes into account the dynamism of rainfed environments. For instance, in the last four years North Bihar, which used to be flood prone, has now become largely drought prone, because of a decrease in precipitation levels. Thus farmers who were previously using long-duration cultivars started searching for medium-duration varieties for the middle part of low-lying *Chaur* lands.

The solution lies in appropriate breeding strategies, in a systems context, and with the active participation of farmers. There is now an awareness that HYVs are not the solutions to all problems. Innovative farmers' techniques, their indigenous knowledge, and their active participation in technology generation are essential. Participatory approaches, advocated earlier, have now been found useful in identifying farmer-preferred cultivars (Thakur and Singh, 1992; Thakur *et. al.*, 1993, Joshi and Witcombe, 1995; Loevinsohn and Sperling, 1995).

Concerted efforts are required to integrate participatory approaches in breeding programmes, and release procedures need to be reformed in response to the results of farmer participatory intervention. These changes in organisation, methodology and policy are perquisites for the development of adaptable technologies for harsh environments.