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Comparing farmers and breeders rankings in varietal selection for low-input environments: A case study of rainfed rice in eastern India

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Summary

A number of breeding institutions developed a project to assess importance of participatory plant breeding approaches for rainfed rice improvement in eastern India. The results of the first two years of participatory varietal selection are reported here. The objective was to evaluate the respective effects of participation of farmers in varietal evaluation and decentralization of varietal testing from breeding stations to farmers' fields on varietal ranking. Fields representing various hydrological situations were chosen in two to three villages at four rainfed lowland sites and one upland site. Sets of 15 to 25 varieties were tested both in farmers' fields and on-station in 1997 and 1998 and ranked by both farmers and breeders. The effect of participation was judged by comparing the rankings attributed by farmers and breeders to a given set of material in a given trial. The effect of decentralization was determined through comparisons between individual breeders' rankings across trials. Farmers' rankings were not randomly allocated, but agreement within the farmers' group was not always very strong. Except at one site, concordance among breeders' ranking was high, but, because of the limited number of breeders involved, it was seldom significant. In about two-thirds of the trials, there was a good agreement between farmers' and breeders' mean rankings. The consensus was particularly strong when severe constraints induced contrasting behavior in the genotypes. The decentralization effect appeared to be moderate, but variations due to a breeder effect were recorded. The part of genotype by environment interactions for grain yield due to location within one site and year was evaluated through various methods, showing more effect of G × E interactions at some sites than at others. Crossover interactions inducing changes in ranks represented a limited part of the yearly G × E interactions at all sites. Both farmer participation and decentralization of varietal testing in farmers' field would help in best matching the varieties to the needs, although their combined contribution would be more useful in some sites than in others.

Introduction

Rainfed rice is an important crop for the eastern states of India (Assam, West Bengal, Bihar, Orissa, and the eastern parts of Uttar Pradesh and Madhya Pradesh). It is grown on 23 million hectares and is a significant component of the income of an estimated 450 million people. A characteristic of rainfed rice in this region is a large year-to-year fluctuation in production because of unreliable monsoon (Hossain & Laborte, 1996). Drought, floods, or both, at different stages of plant growth can severely affect the crop. Partly because of the high agroecological risks of crop failure, farmers are discouraged from applying chemical fertilizers and input levels in the dominant production systems are low. As a result, regional yields are low: from 0.6 to 1.5 t/ha for rainfed upland rice to 0.9 to 2.4 t/ha for rainfed lowland rice against 3.2 t/ha for irrigated rice (Garrity et al., 1996).

The adoption rate of improved varieties is low in rainfed environments when compared with the irrigated environment (Kshirsagar & Pandey, 1995). Poor adoption may be caused by limited access to new varieties, as shown by Joshi & Witcombe (1995) or poor environmental adaptation of improved varieties. If the main constraint to adoption is limited access, the mechanisms by which varieties are released and disseminated should be improved. If the problem is the poor adaptation of modern varieties, then the breeding strategies used need to be re-examined.

Breeding programs for rainfed rice share two features: farmer participation in the process is limited and selection is undertaken mainly on a few research stations.

Farmer participation is not common in goal setting. Farmers are rarely consulted systematically on their selection criteria, or on the trade-off they apply between traits. Participation is not widespread in the rest of the breeding process either. Farmers' participation usually occurs in the last steps of the scheme, through the evaluation of a limited number of pre-released material in farmers' fields, generally under scientists' management. Rice is a self-pollinated crop and most varieties released for rainfed environments are pure lines. Consequently, in the pre-release trials, variability within lines is nil while that between lines can be quite limited if the number of varieties tested is low, leaving little room for farmers to express their preferences. Moreover, results of on-farm trials are seldom taken into consideration in official varietal release procedures (Virk, 1998).

The high genotype by environment (G × E) interactions that characterize rice in rainfed environments call for a multi-location approach to breeding with definition of the target population of environments and consideration of key constraints in each target areas (Wade et al., 1996). In India, rainfed rice varietal improvement involves multiple actors from the public sector (rice research institutions and universities) and is decentralized down to the state level. Breeding programs are mainly conducted on regional research stations, which, however, generally represent only a part of the target environments. The management of the fields at stations, with at least moderate input use (generally the level recommended by extension services), tends to reinforce this lack of representativeness by creating situations relatively uncommon in farmers' fields, where chemical fertilizer use is low.

The public rice breeding programs are all structured on the basis of hydrological characterization. Rainfed rice is subdivided into rainfed lowland rice – which is grown in bunded fields that are flooded during at least part of the crop cycle, generally with alternating anaerobic and aerobic conditions –, and upland rice – which is grown under aerobic conditions in unbunded fields without standing water –. The rainfed lowland ecosystem is further divided into three major subecosystems: drought-prone, drought- and submergence-prone, and submergence-prone ecologies. All these situations can commonly be found in a single watershed. A decreasing degree of risk of drought but an increasing risk of submergence and late water recession are observed for fields located from the top to the bottom of the topo-sequence. The position of the field in the topo-sequence defines the timing of submergence and height of the water table which, in turn, determines the maturity group, and, therefore, degree of photoperiod sensitivity, plant height, and type of resistance to abiotic stresses needed for the variety. The ideotypes for the various hydrological situations are separate breeding targets. The main agroecological variations are taken care of in the definition of the goals of breeding programs. However, the various needs of farmers (food for various occasions and preparations that require different grain types, straw used as forage for cattle or for thatching), degree of market integration (subsistence versus commercial orientation), and their various production strategies and objectives are seldom formally taken into consideration.

A participatory plant breeding project for rainfed rice was developed by eastern India breeding institutions in collaboration with the International Rice Research Institute (IRRI) to assess whether farmers' participation in one or more steps of the breeding process can substantially increase the suitability of modern rice varieties for rainfed environments. This project consists of two complementary components, respectively dealing with the plant breeding and socio-economic aspects.

The overall objective of the plant breeding component is to develop and evaluate a methodology for participatory improvement of rainfed rice. The objectives of the socio-economic component are 1) to establish a farmers' typology based on socio-economic variables assumed to be important in the varietal choice process like market integration, importance of rice for the household, wealth, gender, cast, education, etc. to guide establishment of breeding goals and their possible differentiation for various farmers' groups 2) to elicit farmers' selection criteria and their reactions to a range of cultivars and breeding lines. The project involves farmers and scientists (breeders and social scientists) working in a participatory mode.

A detailed description of both components of the project is given in Courtois et al. (2000). There were three main points we had in mind when designing the breeding component. First, the breeders' mandate is to deliver products for a range of farmers or for a geographical area broader than areas touched by most participatory plant breeding projects. Except in regions with limited diversity or projects with a very good coverage of the target environment and audiences, this 'scale' issue would arise because the degree of commitment of farmers and breeders possible with a unique participatory project may not be conceivable when extending the project to many sites. To permit a scaling up as easy as possible, we need to define the breeding operations for which participation is most necessary. Farmers' participation in goal and selection criteria settings and/or selection by farmers within well-chosen pre-released varieties (participatory varietal selection or PVS following the nomenclature developed by Witcombe et al., 1996) may be enough to increase the rate of adoption. Then farmers' participation in the breeding process itself (termed participatory plant breeding or PPB), which is one degree of complexity further, may not be necessary. This is why we decided to concentrate on a PVS component first.

The benefits from involving farmers in a breeding program can arise from the decentralization of varietal testing in farmers' fields, as well as from participation of farmers in the definitions and application of selection criteria. These two types of benefits are not mutually exclusive and may re-enforce each other. The testing of the same material both on-station and in farmers' fields and its evaluation/selection by both breeders and farmers should allow us to separate the effects of decentralization per se from the effects of farmers' participation as stressed by Cecarelli et al. (1997) and Witcombe (1997). The effect of participation is judged by comparing the ranking of varieties by farmers and breeders at the same locations. The effect of decentralization is determined by comparing the breeders' rankings of the lines in experiment station trials and farmer field trials. This framework was used for the PVS component of this project.

The last point is that, in these partly subsistence-oriented systems, post-harvest traits such as grain cooking quality and taste are factors that strongly influence the degree of adoption and duration of use of varieties. These traits are not always well correlated with the physico-chemical properties assessed in the laboratory. A component involving milling, cooking and tasting of the varieties by farmers was therefore included in the overall project. This component could not be carried out at the same time as field evaluations because of the need to store the paddy for a few months before it stabilizes its properties. The results of these complementary tests and their relationships with field performances can be found in Singh et al. (2000).

This paper presents the first two years of results of PVS of the project and compares the ranking of sets of varieties among farmers, among breeders and between farmers and breeders based on field performances. It also compares the breeders' ranking across sites to assess the effects of decentralization of varietal evaluation into farmers' field and links it with a preliminary assessment of the importance of G × E interactions for the sites of the project.

Materials and methods

Sites and participants

The results reported here involve two main rice ecosystems (Table 1) and five different sites (Table 2), all considered low input environments. A 'site' includes a breeding station and its satellite villages and is named after the main nearby city. Hazaribagh, Bihar, where the Central Rainfed Upland Rice Research Station (CRURRS) is located, was the site chosen

Table 1. Institutions involved in the PVS trials and main target ecosystem

Center	Station	Ecosystem
CRURRS	Hazaribag, Bihar	upland, drought prone
NDAUT	Faizabad, Uttar Pradesh	rainfed lowland, shallow drought and submergence prone
IGAU	Raipur, Madhya Pradesh	rainfed lowland, shallow drought prone
CRRI	Cuttack, Orissa	rainfed lowland, submergence prone
OUAT	Bhubaneswar, Orissa	rainfed lowland, submergence prone

Table 2. Main characteristics of the villages involved in the farmer participatory breeding program for rainfed rice, eastern India (from Courtois et al., 2000)

Site*	Village	Agroecology	Extent of adoption of modern varieties (%)	Distance from market (km)	Other relevant socioeconomic factors
Hazaribagh	Chichi	Forest	20	13	40% literacy
	Handio	Forest	90	25	90% literacy
	Khorahar	Open	10	33	25% literacy
Faizabad	Sariyawan	Drought prone	55	2	High population density, mixed castes
	Mungeshpur	Drought prone	50	3	High population density, mixed castes
	Basalatpur	Submergence prone	<20	5	Low population density, mixed castes
Raipur	Tarpongi	Drought prone	40–50	5	Mixed castes, resource poor
	Saguni	Drought prone	40–50	5	Mixed castes, resource poor
Cuttack	Samantarapur	Submergence prone	10–20	2	Mixed society, resource poor
	Kolar	Submergence prone	10–20	6	Mixed society, resource poor
Bhubaneswar	Kothar	Submergence prone	10–20	10	Mixed society, resource poor

* Named after the nearby city.

to represent the upland ecosystem. For the rainfed lowland ecosystem, the site selection was based on the environmental characterization carried out in the shuttle breeding program (Sarkarung, 1995), covering different rice environments. Raipur, Madhya Pradesh, where the Indira Gandhi Agricultural University (IGAU) is located, represented the ‘shallow drought-prone’ environment; Faizabad, Uttar Pradesh, where the Narendra Deva University for Agriculture and Technology (NDAUT) is based, the ‘shallow drought- and submergence-prone’ environment; and Cuttack and Bhubaneswar, Orissa, where the Central Rice Research Institute (CRRI), and the Orissa University of Agriculture and Technology (OUAT) are located respectively, the ‘coastal submergence-prone’ areas of the state. Breeding stations are present in all five sites but, for the ecology represented by the CRRI-OUAT sites, the CRRI station was chosen as a reference and OUAT conducted only trials in farmers’ fields. One to three breeders per site participated in the project.

In each site, two to three villages, with one to three fields per village, were selected to conduct the trials. The bases for village selection were the dominant agroecological conditions, especially hydrology, the extent of adoption of modern varieties, the distance to the market, and other social and ethnic factors (Table 2). The basis for field selection was the representativeness of targeted agroecological conditions in terms of hydrology.

The number of farmers involved in the varietal evaluation was between 4 and 8 per village except in Hazaribag where it was slightly higher (Table 3). Farmers were chosen based primarily on their willingness to participate in the project. The socio-economics characteristics of these farmers were recorded in the framework of large socio-economic surveys which were carried out in between the cropping seasons. However, the limited number of farmers involved in the field evaluation did not allow disaggregation of the results according to socio-economic factors in most sites. Few women participated in the field experiments: for cultural reasons, they more seldom volunteered to participate in the project; in some areas of Bihar, women belonging to the main cast do not participate in field work.

Experimental designs

For each site, 15 to 25 lines or varieties were chosen by the breeders from the elite material of the breeding programs for the specific hydrological conditions of the fields. They were evaluated together with the varieties most commonly grown by farmers in parallel on-station and in farmers' fields. The sets differed for each ecosystem. The lines were evaluated by a group of farmers and a group of breeders in the 1997 and 1998 wet seasons, except at OUAT, where the experiment started in 1998. The lines that performed poorly in 1997 were replaced by more promising lines in 1998. In each site, the participating farmers of a given village evaluated all trials conducted in the village and, when they were available at the right time, the station one as well. The breeders evaluated all trials of all villages, and the station one.

The trials were unreplicated CRD in farmers' fields and replicated RCBD at stations. On the station in Raipur, however, the trial was unreplicated because beushening was practiced as in farmers' field. Beushening is a widespread farmer cultivation method of weed control through ploughing one month after dry seeding (Singh et al., 1994). The ploughing asks for the lay-out of large plots.

Farmers were encouraged to use their normal management practices although a bias was often observed toward a use of more inputs than normal in these trials. Breeders' standard practices were used at stations.

Farmers and breeders ranked the various lines at two to three key phenological periods (early tillering stage, flowering, and maturity) from best liked to least liked based on their personal sets of selection criteria. In addition, breeders recorded duration, height, yield components and yield, and reaction to pests, diseases and abiotic stresses in most trials. Besides the rankings, farmers commented on the characteristics they liked or disliked in the varieties and the reasons underlying their rankings. These 'open-format' results are still in the process of analysis.

Statistical analyses

Concordance among farmers' or breeders' rankings

Since multiple rankings were involved, the Kendall coefficient of concordance (W) was used to compare the concordance among rankings as described in Siegel (1956). W was computed as $W = s/((1/12)k^2(N^3-N)-kT)$, with s for sum of squares of the observed deviations from the mean, k for number of rankings, N for number of varieties ranked, and T a correction factor used when ties were observed. Tied varieties were assigned the average rank they would have been assigned had no ties occurred and T was computed as $T = \Sigma(t^3-t)/12$, with t being the number of observations tied for a given rank. Farmers and breeders often ranked only part of the varieties, i.e. those varieties they considered the best ones. The varieties that were not ranked were considered as tied and treated as indicated above. In a few cases, farmers evaluated the material together and gave it exactly the same rankings. These could not be considered as independent rankings and only one of them was included in the analysis. The null hypothesis for W (W=0) is that the rankings are randomly attributed. This hypothesis was tested by calculating $\chi^2 = k(N-1)W$ and comparing its value with the critical value of a Chi square with N-1 degree of freedom. A W value of 1 indicates unanimity among all rankers.

Comparison between farmers' and breeders' rankings

The farmers' rankings were averaged as well as the breeders' ones. These means were, then, ranked and the two sets of final ranks were compared using Spearman coefficient of correlation.

Table 3. Comparisons between ranks attributed by farmers and breeders at different growth stages in the PVS trials, eastern India, 1997–98

Site	Trial location	Year	Field	Stage	No var.	No F.	No B.	Agreement among farmers W	Agreement among breeders W	Correlation between farmers'/ breeders' rankings r
CRURRS										
Hazaribag	Station	97	1	V	15	36	–	0.22**	–	–
		97	1	M	15	15	2	0.33**	0.81	0.83**
	Chichi	97	1	V	14	10	–	0.46**	–	–
		97	1	M	14	15	2	0.40**	0.70	0.27
	Handio	97	1	V	15	10	–	0.42**	–	–
		97	1	M	15	15	2	0.35**	0.45	0.58*
	Korahar	97	1	V	14	12	–	0.25**	–	–
		97	1	M	14	15	2	0.16**	0.69	0.09
	Station	98	1	F	16	24	2	0.46**	0.89*	0.96**
		98	1	M	16	18	2	0.57**	0.92*	0.63**
	Chichi	98	1	F	16	24	2	0.34**	0.76	0.74**
		98	1	M	16	10	2	0.79**	0.72	0.73**
	Handio	98	1	F	16	6	2	0.58**	0.81	0.68**
		98	1	M	16	7	2	0.88**	0.81	0.56*
	Korahar	98	1	F	16	18	2	0.47**	0.75	0.89**
		98	1	M	16	9	2	0.50**	0.88	0.87**
NDUAT										
Faizabad	Station	97	1	M	15	6	3	0.68**	0.76**	0.79*
	Munghespur	97	1	M	15	5	3	0.82**	0.63*	0.78**
		97	2	M	15	5	3	0.80**	0.73**	0.76**
		97	3	M	15	5	3	0.81**	0.64*	0.76**
	Sariyawan	97	1	M	15	5	3	0.77**	0.76**	0.86**
		97	2	M	15	5	3	0.85**	0.69*	0.83**
		97	3	M	15	5	3	0.76**	0.71**	0.68**
	Basalatpur	97	1	M	15	5	3	0.87**	0.36	0.11
		97	2	M	15	5	3	0.84**	0.51	0.54*
	Station	98	1	M	13	4	3	0.59*	0.37	0.11
	Munghespur	98	1	M	13	4	3	0.80**	0.53	0.59*
		98	2	M	13	4	3	0.80**	0.61*	0.85**
	Sariyawan	98	1	M	13	4	3	0.79**	0.57	0.99**
		98	2	M	13	4	3	0.75**	0.42	0.18
	Basalatpur	98	1	M	13	4	3	0.81**	0.26	0.43
		98	2	M	13	4	3	0.84**	0.40	0.18

Table 3. Continued

Site	Trial location	Year	Field	Stage	No var.	No F.	No B.	Agreement among farmers W	Agreement among breeders W	Correlation between farmers'/ breeders' rankings r
IGAU										
Raipur	Station	97	1	F	16	8	1	0.34**	–	–0.20
		97	1	M	16	8	1	0.51**	–	0.11
	Tarpongi	97	1	F	16	5	–	0.51**	–	–
		97	1	M	16	4	2	0.55**	0.47	0.13
		97	2	F	16	5	–	0.50**	–	–
		97	2	M	16	7	2	0.34**	0.53	–0.03
	Saguni	97	1	F	16	7	–	0.30**	–	–
		97	1	M	16	6	2	0.44**	0.30	–0.18
		97	2	F	16	5	–	0.79**	–	–
		97	2	M	16	5	2	0.54**	0.56	–0.06
	Station	98	1 (M)	F	16	8	2	0.32**	0.77	0.16
		98	1 (M)	M	16	6	2	0.26	0.60	0.50*
		98	2 (L)	F	16	8	2	0.31**	0.54	–0.04
		98	2 (L)	M	16	6	2	0.67**	0.70	0.28
	Tarpongi	98	1 (M)	F	16	5	1	0.55**	–	0.46
		98	1 (M)	M	16	4	1	0.30	–	0.20
		98	2 (L)	CROP FAILURE						
	Saguni	98	1 (L)	F	16	4	1	0.56**	–	0.07
		98	1 (L)	M	16	4	1	0.59**	–	0.02
	Khairkhoont	98	1 (L)	F	16	6	1	0.38**	–	0.51*
		98	1 (L)	M	16	4	1	0.44*	–	–0.01
CRRI										
Cuttack	Station	97	1	F	11	5	2	0.98**	0.98*	0.96**
		97	1	M	11	5	2	0.96**	0.99*	0.94**
	Samantarapur	97	1	CROP FAILURE						
	Kolar	97	1	CROP FAILURE						
	Station	98	1	F	15	5	2	0.87**	0.96*	0.96**
		98	1	M	15	5	2	0.88**	0.87*	0.90**
	Samantarapur	98	1	F	15	5	2	0.89**	0.97*	0.97**
		98	1	M	15	5	2	0.93**	0.99*	0.96**
OUAT										
Bhubaneswar	Kothar	98	1	V	25	8	3	0.98**	0.95**	0.90**
		98	1	F	25	8	3	0.99**	0.96**	0.86**
		98	1	M	25	8	3	0.98**	0.84**	0.34
		98	2	V	25	8	3	0.99**	0.94**	0.92**
		98	2	F	25	8	3	0.99**	0.92**	0.96**
		98	2	M	25	8	3	0.97**	0.92**	0.46*

– = not tested or ranked only by one person; W = Kendall's coefficient of concordance; r = Spearman's coefficient of correlation; F = farmers; B = breeders; stage: V = vegetative stage, F = flowering, M = maturity; trial code: L = late; M = medium.

Effect of decentralization assessed through breeders' rankings across sites

Breeders' rankings in the different on-farm trials were compared on an individual basis, with their rankings on-station used as a reference using Spearman coefficient of correlation. For comparisons across all testing sites, the Kendall coefficient of concordance between the breeders' ranks at the different sites was used as described above. A significant correlation or concordance between rankings given by an individual ranker for the various trials would mean little changes in variety ranking between these trials, and could therefore be taken as an indication of limited cross-over interactions and weak effect of decentralization of varietal testing in farmers' fields. It was not possible to do the same thing with farmers because all farmers did not rank all on-farm trials.

Analysis of G × E interactions for yield

Visual ranking has limitations to evaluating the importance of G × E interactions for yield because of subjectivity in the rankings and use of several non-yield based selection criteria. Other methods using only observed yields were used as well to analyze the part of these interactions due to location within year. Because of the lack of replication in farmers' field, it was not possible to compute the significance of the G × E interaction effects. A partitioning of the yield sum of squares according to genotype, location within season, and G × E interaction effects was conducted for each year separately to assess the importance of G × E interaction effects relative to the genotype effect. The proportion of G × E interaction sums of squares due to crossover interactions was computed using a module of Bstat (McLaren, 1994) based on re-ranking and non-re-ranking of genotype performances across environments (De Lacy et al., 1996). This method evaluates the part attributable to change of ranks in different environments, or crossover interactions, and the remainder. The Kendall coefficient of concordance between yield ranks at the different locations was also used as an additional way to check the importance of G × E interactions, following the same procedure as described above for multiple rankings.

Results

Comparison of farmers' and breeders' rankings: the effect of participation

Table 3 presents the results of the farmers' and breeders' rankings for the trials conducted during the two years. The coefficient of concordance among farmers was highly significant in 46 of the 50 trial × year cases tested, significant in 2, and not significant in only 2 cases. This indicated that farmers' rankings were not randomly attributed although the absolute value of W, which indicates the degree of the agreement, was not always very close to the maximum possible value of 1.0 (perfect agreement within the group).

The concordance among breeders' rankings was also high for most trials, generally higher in absolute value than the concordance among farmers' rankings, and less variable across trials, but often not significant. Some of the trials conducted in Faizabad in 1998 and in Raipur in 1997 were exceptions: whether we considered the absolute value of W or its probability, the agreement among breeders was poor.

The rank correlations between farmers' and breeders' average rankings followed a site pattern. The correlations were generally high, although slightly lower at maturity than at flowering or the vegetative stage, for Hazaribag, Faizabad, Cuttack, and Bhubaneswar. Even at these sites, however, lack of agreement was occasionally observed, like at Korahar (1997) or Basalatpur (trial 1 in 1997 and trial 2 in 1998). The correlations were low in Raipur for most trials and, in a few cases, even negative, though not very strongly. Calculating the correlation between the ranking of each breeder taken individually and the average farmer ranking did not improve the results in Raipur.

The degree of agreement between farmers and breeders was strongly influenced by the constraints faced by the crop and the overall performance of the lines. In situations like those at Cuttack (1997 and 1998) or Kothar (1998), where early floods strongly affected survival and further performance of the tested material, the varieties showed very contrasting behavior and the rank correlations were very high.

Comparison of breeders' rankings across sites: the effect of decentralization

If decentralization had little effect, the correlations between rankings given by an individual ranker at the various sites should be high. The results for breeders are presented in Table 4. Of 64 station/on-farm trial pairs tested, 75% showed no significant correlation,

Table 4. Correlations between breeders' ranking at maturity in farmers' fields and on-station for the PVS trials conducted in eastern India, 1997–98

Site	Village	Year		Breeder 1	Breeder 2	Breeder 3
CRURRS Hazaribag	Station vs Chichi	97	r	0.40	–0.04	
	Station vs Handio	97	r	0.76**	–0.46	
	Station vs Korahar	97	r	0.37	–0.09	
	All trials pooled	97	W	0.69**	0.22	
	Station vs Chichi	98	r	0.44	0.39	
	Station vs Handio	98	r	0.38	0.64**	
	Station vs Korahar	98	r	0.63**	0.30	
	All trials pooled	98	W	0.60**	0.53**	
NDUAT Faizabad	Station vs Munghespur 1	97	r	0.50	0.40	0.54*
	Station vs Munghespur 2	97	r	0.48	0.54*	0.70**
	Station vs Munghespur 3	97	r	0.21	0.80	0.42
	Station vs Sariyawan 1	97	r	0.23	0.64*	0.63*
	Station vs Sariyawan 2	97	r	0.54*	0.39	0.67**
	Station vs Sariyawan 3	97	r	0.50	0.55*	0.49
	Station vs Basalatpur 1	97	r	0.01	0.37	0.27
	Station vs Basalatpur 2	97	r	0.21	0.66**	0.39
	All trials pooled	97	W	0.51**	0.53**	0.57**
	Station vs Munghespur 1	98	r	0.61*	0.22	0.14
	Station vs Munghespur 2	98	r	0.57*	0.45	–0.32
	Station vs Sariyawan 1	98	r	0.43	–0.37	0.33
	Station vs Sariyawan 2	98	r	0.06	–0.57*	0.03
	Station vs Basalatpur 1	98	r	0.08	0.20	0.31
	Station vs Basalatpur 2	98	r	0.44	0.24	0.21
	All trials pooled	98	W	0.37**	0.21	0.20
IGAU Raipur	Station vs Tarpongi 1	97	r	–0.53*	–	–
	Station vs Tarpongi 2	97	r	0.12	–	–
	Station vs Saguni 1	97	r	–0.07	–	–
	Station vs Saguni 2	97	r	–0.18	–	–
	All trials pooled	97	W	0.16	–	–
	Station vs Tarpongi 1	98	r	–	–0.12	–
	Station vs Saguni 1	98	r	–	0.06	–
	Station vs Khairkhoont	98	r	–	0.07	–
	All late trials pooled	98	W	–	0.38	–
CRRI Cuttack	Station vs Samantarapur	98	r	0.53	0.32	–

r = Spearman coefficient of correlation; W = Kendall coefficient of concordance.

indicating a relatively strong effect of decentralization from station to farmers' fields. When all trials were pooled, the coefficient of concordance W, which measures the non-randomness of the ranks, was not significant in only 42% of the cases, indicating a better agreement across trials with this method which gives equal weight to all trials. In addition to the influence of G × E interactions, an important breeder effect was observed in some trial × year combinations (e.g. Hazaribag, 1997), showing that breeders' subjectivity played a role in the rankings.

G × E interactions for grain yield

The G × E interaction analyses based on sum of squares partitioning (Table 5) showed a pattern which

Table 5. Analysis of G × E interactions for grain yield between trials, eastern India, 1997–98

Location	Year	G × E interactions analysis method				
		Analysis of variance and re-ranking analysis (for crossover interactions)				Kendall coefficient of concordance between yield rankings
		% sum of squares due to genotype effect	% sum of squares due to location within season effect	% sum of squares due to G × E interactions	*% G × E sum of squares due to crossover interactions*	W
CRURRS Hazaribag	1997	8.7	39.4	51.9	*24.5*	0.10
CRURRS Hazaribag	1998	14.3	65.7	20.0	*10.7*	0.37
NDUAT Faizabad	1997	33.9	39.1	27.0	*18.2*	0.57**
NDUAT Faizabad	1998	36.5	36.2	27.2	*15.8*	0.57**
IGAU Raipur	1997	11.0	73.3	15.7	*16.8*	0.21
IGAU Raipur (L)	1998	43.8	16.0	40.2	*19.4*	0.58*
CRRI-OUAT	1998	24.4	47.8	27.7	*19.4*	0.52*

L = trials with late varieties.

differed between ecosystems. In the upland ecosystem, the location within season effect was the main effect and G × E interactions were larger than the genotype effect. In the rainfed lowland ecosystem, with the exception of Raipur in 1997, the genotype effect was generally larger than the G × E interaction effect. The two years of data for Raipur were not comparable because the initial single trial of 1997 was split into two trials in 1998 on the basis of maturity. Because of partial changes in the composition of the varietal sets from year to year, it was not possible to include the season effect in the partitioning itself, but the results presented show that large differences in the G × E interaction pattern from season to season were observed.

This partitioning pools together the G × E interactions due to non-additivity and the G × E effect due to crossover interactions, whereas breeders are more concerned in the changes in ranks because it complicates selection decisions. The proportion of crossover interactions in the G × E sum of squares is given in Table 5. It varied between 10 and 25% and seemed consistent across sites and years except for Hazaribag. As another measure of the magnitude of crossover interactions, we computed the Kendall coefficient of concordance on yield ranks across trials (table 4). The coefficient was low for two site × year combinations (Hazaribag in 1997 and Raipur in 1997), meaning that yield ranking varied across trials, an indication that crossover interactions were high for these sites. For the other sites, however, W was highly significant, therefore indicating smaller rank variations on a yearly basis.

Based on the limited data set available, both Hazaribag, the upland site, and Raipur, one of the rainfed lowland sites, seemed to record the highest G × E interactions.

Representativeness of the station compared with selected farmers' fields

A simple way to check whether the station is representative of the farmers' situation is to compare the average yield of the trials on-station and in farmers' fields. A systematic superiority or inferiority of the station trial would translate into a bias linked, for example, to differences in soil fertility level and would increase the risk of crossover interactions if the mean yield range were too broad. The average yields are given in Table 6, with an index using the station yield as a reference. In the upland ecosystem, the average yield on-station was at the low range of yields in farmers' fields, with the index varying from 133 to 355. In the rainfed lowland ecosystem, in Raipur, the station recorded the highest yields, with the index varying from 38 to 92. The station position varied according to years for NDUAT, with the index ranging from 96 to 176 in 1997 and from 46 to 101 in 1998, mostly because of yield variation in farmers' fields. For CRRI-OUAT, the one year of data did not allow us to make clear-cut conclusions.

Table 6. Mean grain yield in the PVS trials, eastern India, 1997–98

Site	Village	Year	Trial	Mean grain yield (t/ha)	Yield relative to station (%)
CRURRS Hazaribag	Station	97	1	1.57	100
	Chichi	97	1	2.76	176
	Handio	97	1	–	–
	Korahar	97	1	2.09	133
	Station	98	1	0.86	100
	Chichi	98	1	3.05	355
	Handio	98	1	1.14	167
	Korahar	98	1	1.75	204
NDUAT Faizabad	Station	97	1	3.41	100
	Munghespur	97	1	5.09	149
		97	2	6.00	176
		97	3	5.32	156
	Sariyawan	97	1	4.53	133
		97	2	5.68	167
		97	3	3.28	96
	Basalatpur	97	1	3.48	102
		97	2	3.33	98
	Station	98	1	3.77	100
	Munghespur	98	1	1.95	52
		98	2	2.01	53
	Sariyawan	98	1	3.31	88
		98	2	1.72	46
	Basalatpur	98	1	3.25	86
		98	2	3.81	101
IGAU Raipur	Station	97	1	4.03	100
	Tarpongi	97	1	2.21	55
		97	2	2.20	55
	Saguni	97	1	1.72	43
		97	2	1.54	38
	Station	98	1 (M)	3.15	100
	Tarpongi	98	1 (M)	2.19	70
	Station	98	2 (L)	2.46	78
	Saguni	98	2 (L)	2.90	92
	Khairkhoont	98	2 (L)	2.28	72
CRRI Cuttack	Station	97	1	0.80	100
	Station	98	1	2.57	100
	Samantarapur	98	1	2.03	79
OUAT Bhuban.	Kothar	98	1	4.30	167
		98	2	3.42	133

F = farmers; B = breeders; L= late variety; m = medium-duration variety.

Discussion

We analyzed the reactions of farmers and breeders to sets of varieties grown both at breeding stations and in farmers' fields and used these trials to assess the relative effect of participation of farmers in varietal evaluation and decentralization of varietal testing into farmers' fields.

The concordance among farmers' rankings was nearly always highly significant, although unanimity was approached in only few cases. This good agreement goes against the initial assumption underlying the socio-economic component of the project that the diversity of farmer socioeconomic conditions would induce various patterns of selection criteria and that it would be necessary to establish a typology of farmers in order to disaggregate the results. Factors such as wealth, farm size, education (Feder et al., 1985; Rogers, 1995), and access to information (Sall et al., 1997) are commonly said to affect adoption. The results from the on-going farmer survey will permit us to say if the sample of farmers in the variety evaluation represented a diversity for such socioeconomic conditions broad enough to consider the study as a reliable user consultation. In most sites, however, it will be difficult to check whether any form of disaggregation based on socioeconomic variables would have improved the agreement within or between groups because of the limited number of farmers involved in the field evaluations.

The agreement among breeders was less often significant than for farmers. The power of the W statistic used to evaluate agreement is influenced by the number of rankers (E[W] = 1/k). Because there are, in all cases, fewer breeders than farmers, more agreement is required to detect non-randomness among breeders. However, the high absolute value of W, which is the key parameter, generally indicated a good degree of consensus within the breeders' group. The disagreement among breeders observed in some cases, notably in Raipur, came as a surprise to the participating breeders and shows that we should not take for granted that breeders constitute a homogeneous group. Breeders are supposed to have a prior understanding, for a given ecology, on the selection criteria to be used and the ideotype they are looking for. Differences in experience, familiarity with the specific site, frequency of visits, and ability to disregard their prior knowledge about the lines, were mentioned by breeders as possible explanations for their lack of agreement.

When comparing farmers' and breeders' rankings, we found that in the majority of the cases there was good concordance but also in a few cases there was not. The decrease in consensus at maturity might be explained by a miscommunication between breeders and farmers on whether grain characteristics could be included in the evaluation or should be taken into consideration later on during the sensory evaluation. Comparisons between average rankings are not meaningful when some degree of agreement within each group does not exist. The difficulties in setting such a threshold are discussed in Snell (1983). As a matter of fact, low correlations between groups' rankings were often associated with poor consensus within one or the other groups. Leaving aside the problem created by the intrinsic variability of opinions within a group, it is important to determine in which conditions and for which traits there is a good agreement and when there is not. One hypothesis is that in market-oriented production systems, the concordance between farmers and breeders on the characteristics of final products is better than in subsistence-oriented production systems characterized by a higher diversity in farmer goals. This point can be explored when the surveys are exploitable.

Participation, seen in a narrow perspective as a way to improve breeding efficiency, will probably bring little benefit when the concordance between farmers' and breeders' opinions is good. It has to be stressed, however, that the choice of the tested varieties has a major influence on the conclusions about the degree of agreement between the two groups. The varieties have to be adapted to the hydrology of the fields where they are tested and this imposes some key features. Taking the example of plant height, varieties have to be tall in the deep lowlands to tolerate a variable water level while semi-dwarf varieties can be used in the shallow lowlands. The same applies to maturity type, which is also strongly determined by hydrology (e.g., the sowing-maturity duration should not exceed 105 days in the upland set while it has to be in the range of 135 to 150 days for the rainfed lowland fields located at the bottom of the toposequence), as well as other traits. To include varieties lacking adaptation would automatically increase the rankers' agreement as does a severe selection pressure as observed in Cuttack and Kothar. Within a set of adapted material, it is useful to include contrasted lines otherwise the ranking procedure becomes difficult. The problem arose in Raipur where some sister lines were included which were not easy to differentiate and might at least partly explain the discrepancies among breeders' and farmers' rankings.

This shows the relativity of conclusions based solely on visual rankings. Because ranking results depend on the range of variability displayed in the varieties included in the tested sets, they should not be the only way to evaluate the consensus about selection criteria. If a characteristic is not present in the material tested its importance would go unnoticed with field evaluation alone. For example, if Shyamala, one of the rare varieties with purple sheath, had not been included in the rainfed lowland set in Raipur, we might have missed the farmers' interest in the sheath color for facilitating weeding in areas infested with wild rices. This demonstrates the importance of interviews to elicit more systematically farmers' selection criteria.

An additional potential drawback of ranking is that it confounds the selection criteria and the trade-off between them. We are presently getting separate information on both aspects by direct interviews of farmers for the selection criteria, and by weighted ranking for the trade-off (Paris et al., 2000). The principle of the 'trade-off' exercise is that farmers, after listing their selection criteria, are given a fixed amount of a fictional currency and are asked to indicate how they would split it among the main traits previously identified. But in this case as well, it is important to distinguish between traits which are needed for basic adaptation and do not carry a possible trade-off, and the others.

When looking at the decentralization effect through variations in breeders' rankings across sites, it seemed that the differences between station and farmers' fields were more important than differences among farmers' fields, the coefficient of concordance being higher and more uniform for pooled analyses. The differences in yield averages between station and farmers' fields and among farmers' field showed the same trend. The larger the differences of yields between the station and farmers' fields, the higher the risk of cross-over interactions modifying the rankings across sites (Cecarelli, 1989) and the interest to perform selection in farmers' fields. In most our sites, although the yield range was large, the proportion of the yield variability due to crossover interactions between trials seemed to remain moderate and stable across sites and years (10–25%). Nevertheless, it is possible to improve the representativeness of the station in places like Hazaribag, with a mean yield consistently below the farmers' field average, and may be Raipur, consistently above, by modifying the station management practices, mostly the fertilization and rotation practices, or by performing varietal selection under several management conditions.

Based on the limited sample of location available, G × E interactions for yield appeared to be moderate in comparison with the genotype effect in the three rainfed lowland sites where a sound characterization of the land type was made. In contrast, the upland area surrounding Hazaribag, which is ecologically less subdivided, might benefit from a split according to fertility level. Villages similar to Chichi, for example, where soil fertility is consistently good because of a rotation with vegetable crops on which organic manure is applied, might constitute a separate cluster in the future. Environmental classification can always be refined and part of the G × E interactions, when their causes are understood, transferred into a repeatable effect controlled by the partitioning into sub-targets (Cooper et al., 1996). It has to be stressed, however, that the part of G × E interactions which could be evaluated was only the location within season and, even with supposedly homogeneous environmental units, temporal variability often remains an important component of the variability. For that reason also the representativeness of the testing sites can be questioned. For example, Hazaribag encountered two reasonably normal seasons while Faizabad conditions for the two seasons were similar but quite atypical. For all these reasons, a larger and more representative sampling for locations and year for each site would allow to reach more robust conclusions and explore the nature of the variation further.

With the moderate and stable level of cross-over interactions observed in our study, decentralization of varietal evaluation down to farm level would clearly bring some improvement in the choice of the right varieties. Because G × E interactions were not the sole source of discrepancies between breeders and farmers' estimation of variety performances, however, decentralization alone would not be enough to match the products to the needs, even if financial means would be available. In the relatively common situations where farmers and breeders' agreement was not perfect, participation would help in the fine tuning necessary to fit all farmers' goals.

Conclusions

From the breeders' perspective, this study opened areas for discussion among breeders on how to perform varietal selection, confirming the soundness of the hydrological structuring of the program but showing the need for adjustments in management of the various stations to get to practices closer to those used by farmers, and to modify the balance of resources between the station and farmers' fields. It has stimulated the interest in more systematic, rigorous on-farm testing and consultation with farmers and the importance of introducing such practices into the formal breeding and varietal release systems. It has illustrated that combined farmers and breeders efforts might lead to more suitable varieties that would ultimately benefit farmers.

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