Paradigms of participatory enhancement of rice productivity: Suggestions based on a case study in India

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Tribal areas in Orissa are rich in crop diversity including rice. Farmers require rice varieties with preferred cooking properties. Modern high-yielding varieties do not fulfil this need. Therefore local varieties and landraces rich in genetic diversity are still grown. Increasing costs of cultivation and livelihood disrupt this practice, consequently hastening genetic erosion. In this back-drop, providing them a sustainable livelihood is a prime concern. The results of a designed study of rice production under farmers' management and practices have suggested a few paradigms of participatory genetic enhancement outlined in this paper.

REMARKABLE improvement in crop productivity and food production has been achieved in recent times in India. Yet, the per capita food availability continues to be a critical function of population growth and productivity increase. Decelerating the population growth is one continuing intervention to lead to more land and food availability. Even then there is no escape from increasing productivity as the growth of population remains above that of crop production. High yielding varieties (HYVs) introduced in the country have made a commendable impact on total production on areas with assured inputs including rainfall/irrigation. Yet large areas still remain to be covered by the HYV technology. Tribal areas, in particular, are relatively uninfluenced by the technology as they are away from the usual reach of Government extension activities. Jeypore tract of Orissa represents one such area with a number of tribal villages. Though the tribal farmers are economically poor, their areas are rich in crop genetic diversity. A number of crops, like pigeonpea (*Cajanus cajan*), peanut (*Arachis hypogaea*), horsegram (*Dolichos biflorus*), finger millet (*Eleusine coracana*), sugarcane and vegetables, are native to this tract. They harbour many useful genes in their usually long duration, local varieties and landraces. However, rice is the major staple crop of the tribals. Known as a secondary centre of origin, a large number of local rice varieties and landraces carrying rare genes for stress resistance, cooking quality, medicinal properties and the like were grown earlier in this tract. But, for consumption, farmers prefer only those varieties of rice with traits suiting their cooking habits and quality. HYVs give higher yields but do not match the local varieties in farmer-preferred traits. Therefore farmers still grow local varieties and landraces and maintain diverse genetic accessions as a routine at personal cost.

However they face a number of problems such as rain-fed lands, high cost of inputs, timely non-availability of quality seeds, increasing costs of labour and living. Any technological intervention to foster conservation of the rich diversity and its sustainable use in this back-drop should first provide more food and be farmer-friendly. Participatory plant breeding (PPB) is a possible option to deal with such needs. The first step of gaining knowledge on farmer's practices of cultivation was planned on designed experimental plots in the fields. The study provided the base to suggest a set of paradigms for participatory improvement outlined in this paper.

Jeypore tract is a vast stretch interspersed with small villages. Many tribes live in these villages with varying traditional customs and use several plant species for a variety of purposes. Local races of various species are used for curing specific diseases including rheumatism, malaria, influenza, skin disorders and various parts of the plants are utilized for this purpose[1]. Villages are well separated, involving arduous travel along muddy pathways. Rice is grown in three land types, in general – upland, medium land and lowland. Upland are areas situated about 900 m above mean sea level (msl), medium land about 600 m above msl and lowland are those in flat plains. All areas are rainfed. In upland, direct broadcasting of seeds with the onset of monsoon is the normal method of sowing; both direct seeding and transplanting are practiced in medium lands. Lowlands are generally transplanted and limited irrigation like lift, lake and canal irrigation is possible. The time and method of cultivation are tradition-bound and most of the tribals are averse to applying chemical fertilizers, though they apply farmyard manure. They adopt mainly mono-cropping and many varieties are of long duration. Monsoon-dependent risk-prone agriculture compounded by traditional methods of cultivation does not provide good yield. In general, the realized yields are far below the potential yields. The soils are good and devoid of major deficiencies. The landraces and local varieties possess a number of desired traits like stress resistance, nutritional and cooking quality and stover yield.

Yet, tribal farmers are unaware of modern cultivation practices or their technological advantages. Possibilities exist for integrating modern methods with traditionally sound practices of cultivation. However, commercial organizations exploit the genetic wealth of the tribal areas offering no benefits in return. Such activities have put the tribal farmers on an alert evoking slow response to any new intervention.

Tribal farmers cultivate crops in plots of varying sizes adopting highly variable practices. They plant varieties

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with seeds they have earlier saved, or manage to purchase or obtain on loan. Most often, seeds are not pure with varying viability. Plot sizes, varieties grown and management practices vary widely. Data from such plots cannot provide an unbiased picture of the base status.

Therefore a participatory rural appraisal was organized. With the help of the farmers, three districts and two blocks in each of them were identified. One farmer in each village practising upland, medium land and lowland cultivation was selected on the principle of voluntary participation. The selected sample thus consisted of 18 farmers (Table 1). However, 4 farmers did not continue participation leaving a final sample of 14 farmers. Seeds of popular varieties suggested by the farmers themselves were procured from available sources. No seed purification was done. Six varieties each for upland, medium land and lowland were selected in addition to one HYV and seeds were distributed to the farmers. They were asked to lay out plots of a fixed size (80 sq m) contiguously and plant varieties following their own practices. Scientific methods of cultivation were not introduced lest such data vitiate the base status.

To assess the value and success of any improvement intervention introduced in farmers' areas, indicators need to be developed. After a comprehensive survey of the farmers' fields, three indicator variables, benefit-cost ratio (BCR), yield per hectare and time lag in sowing (TLG), were selected.

The cost of cultivation was computed as the total labour cost involved in land preparation, manuring, transplanting (where applicable) or direct seeding, weeding, irrigation (where applicable), harvest, drying seeds and packing. When lunch was provided to the labourers and wages were given in kind their equivalent costs were included. Likewise, when farm household members themselves worked in the field, the equivalent labour costs were added while computing the total cost.

The total grain yield was obtained as the sum of quantities exchanged with neighbours towards loan and other liabilities, sold in open market, used for self-consumption and kept as seed. Approximate values of stover and excess seedlings in market were added to the market value of the total grain yield to obtain the benefit value. From the cost and benefit values, benefit–cost ratio (BCR) was obtained.

There was a variation of more than a month in the dates of sowing. The optimal sowing date under normal weather was 14 June. Taking this as the base, the time lag in days to sowing (direct seeding or transplanting, as appropriate) was calculated and used as the variable, TLG.

Data on indicator variables were pooled over the varieties for the following reasons: (1) Farmers were tuned-in to organized cultivation for the first time and collecting reliable data on each variety was not found feasible; (2) Data on large plots of a single variety would not represent base status better than data on seven varieties.

Table 1. Details of villages chosen for participatory research in Jeypore tract

District	Block	Upland	Medium land	Lowland
Koraput	Jeypore code	Balia (6) **1:** K/UL/01	Okilaguda (8) **3:** K/ML/01	Bhaluguda (43) **5:** K/LL/01
	Boipariguda code	Kolar (39) **2:** K/UL/02	Bhaluguda (43) **4:** K/ML/02	Pujariput (21) **6:** K/LL/02
Malkangiri	Khairput code	Khemaguru (60) *M/UL/01	–	–
	Mathili code	–	Uduliguda (63) *M/ML/01	Sindhabeda (67) **7:** M/LL/01
	Malkangiri code	Batapalli (115) *M/UL/02	Teakguda (116) *M/ML/02	Batapalli (115) **8:** M/LL/02
Nabrangpur	Nabrangpur code	Badakumuli (62) **9:** N/UL/01	Mentry (65) **11:** N/ML/01	Mentry (65) **13:** N/LL/01
	Nandahandi code	Mentry (65) **10:** N/UL/02	Badakumuli (62) **12:** N/ML/02	Hatibeda (60) **14:** N/LL/02

Figures in parentheses are the distances of villages in km from Jeypore; *, dropped out midway; Code: Sl. no. and identity of farmer.

Table 2. Modes of disposal of grain yield of rice by Jeypore farmers

	Area (ha)	Total yield ←	Y/ha —	SC quintals	OM —	VS —	SD →
Range	2.02–20.23	18.75–425.0	3.49–30.89	7.5–150.0	0–150	0–100	2.1–16.4
Mean	6.16	100.80	16.37	39.44	38.11	17.06	9.12

SC, Self-consumption; OM, open market sale; VS, within village sale; SD, kept as seed; Y/ha, yield/ha.

Usually one comes across an array of varieties in fields across villages. Hence, base status from data pooled over the varieties will be fair and logical; (3) Being purely a rainfed crop, data on multiple varieties would provide a fair average status and avoid data distortions due to failure of a single variety; (4) Farmers were able to observe for the first time comparative performance of seven varieties in the same land. Their opinions may be useful for future programme interventions; (5) BCR across varieties prevalent in their area would be a better indicator of farmers' base status than on a single variety experiment.

Four of the farmers grew the crop in upland, 4 in medium land and 6 in lowland conditions (Table 1). There was a good variation of about a month in land preparation and transplanting or direct seeding of rice. This was due to variation in the onset of monsoon. However, the benefit of early sowing was reflected in high yield (22 q/ha) obtained even without fertilizer application by an upland farmer (Code no. 9, Table 1) in Nabrangpur. In contrast, another farmer from Koraput (Code no. 1, Table 1), who had planted the crop in late August, could realize a yield of only 13 q/ha despite application of fertilizers. Such differences were common in the other areas too.

Wide variation was observed among farmers in the pattern of retention and sale of produce. Overall, 39% of the yield was retained for self-consumption, 9% as seed and 38% sold as grain in the open market (Table 2).

Likewise, the economics of rice cultivation also varied. For instance, yield varied from 3.49 to 30.89 q/ha and BCR from 0.26 to 4.44. The farmers invested in inputs and labour proportionate to the area. But the correlation between area and BCR showed a bimodal pattern. Farmers (Code nos 1–3, 5, 12) who had an area of 7 ha and above recorded a BCR positively associated with area (r, the correlation coefficient between area and BCR = 0.87, significant at 5% level). The r-value for farmers who had an area less than 6 ha (Code nos 4, 6–11, 13, 14) was significantly negative ($r = -0.69$). Small farmers (i.e. those having an area up to 6 ha) realized a better return than those with a relatively large area in this sample of 14 farmers. The results implied that small farmers had spent the available resources optimally and tended their crop with care and concern to obtain substantial benefits. Large farmers had invested more in inputs and management to reap proportionate benefits.

The observations, restricted by the sample size, were unlikely to be influenced by the land type on which the crop was grown. This is because the varieties selected were adapted to the area and were locally popular. Such varieties were comparatively productive under the traditional cultivation practices adopted in their area. Therefore varietal variation was not reckoned as a major problem in drawing conclusions of a general nature.

The variation in the three indicator variables, BCR, yield/ha and TLG, was analysed on a two-factor design considering locations (districts) and land types (upland, medium land and lowland) as factors. In general, location differences were predominant followed by land type differences and location × land type interaction (Table 3). But the variation in TLG was accounted for by significant differences in land types, as would be expected (particularly since the initial date of monsoon onset varied). However, the overall coefficient of variation was highest for TLG and lowest for yield/ha, BCR falling in between (Table 3).

The experimental plots, when the rice crop was one month old, reflected a wide variation in crop management. In most fields, direct broadcasting of seeds resulted in uneven clusters of germinated seedlings, poor land preparation led to germination of plants in clods disconnected with soil and overcrowding of plants led to early yellowing. In contrast, two progressive farmers (Code nos 7 and 8) raised excellent transplanted crops. Other farmers residing far away from these plots could neither visit them nor learn the method of cultivation. These observations point to the following needs:

(i) Training farmers in optimal cultural practices to establish early a healthy crop growth should be a priority participatory intervention.
(ii) PPB programmes should enable mutual visits of the crop by farmers. Participatory dialogues would help in finding appropriate solutions to problems in addition to generation of new ideas.

Further, a participatory dialogue with the farmers brought to focus crucial problems specific to their sites. Some of these could be common across many regions and would need corrective steps for participatory programmes to make progress.

The area being exclusively rainfed, farmers had to plant the crop only after the onset of monsoon. The variable pattern of onset of monsoon influenced planting date and pattern delaying nursery raising and transplantation and forcing direct seeding even in lowland areas. This was a reason why the variable TLG showed highly significant variation across the three land types.
(iii) While monsoon variation is inevitable, varieties adapting to target areas can be developed. PPB would be the right option.

Optimal techniques of site-specific cultivation are hardly extended by institutional mechanisms to tribal farmers. Thus they rarely get an opportunity to know about HYVs and their adaptation potential to their areas. PPB can evaluate HYVs in such areas and take up genetic amelioration of HYVs, particularly for farmer-desired traits.

The performance of the seven landraces across the locations evaluated in the crop season, suggested a few strategies of participatory improvement outlined below:

(1) Disruptive ecological selection: No opportunities exist for tribal farmers to test local varieties adapted to one site at any other site. Since there is a broad commonality in

Table 3. ANOVA of some parameters of rice cultivation in Jeypore

Source	Degrees of freedom	BCR	Yield/ha (q)	Time lag in sowing[@] (days)
		Mean sum of squares		
Location (LOC)	2	1.35	104.96	77.10
Land type (LAN)	2	1.07	66.56	642.01*
LOC × LAN	4	1.60	39.92	140.16
Residual	5	1.00	106.86	103.90
Total	13	1.29	79.83	193.72
Range		0.31–4.44	3.49–30.89	0–43
Exp. C.V.		78.62	52.21	82.90

[@]See text for explanation; *significant at 5% level.

the type of land areas, climatic regime and traditional practices of cultivation, it is possible that local varieties from one site may perform much better in another site which can be a better niche. Such a 'disruptive ecological selection' can become a safe short-term avenue for enhancement of production.

(2) Participatory genetic enhancement: Genetic divergence between local landraces and varieties in various sites is large. This could be estimated and evaluated. The Indian Council of Agricultural Research has a wide research network through which HYVs are released for various growing tracts of the country. Two types of initiating crosses, Local × Local and Local × HYV, can be envisaged for deriving high-yielding farmer-preferred varieties.

Local × Local cross is suggested to take advantage of substantial genetic diversity among the local cultivars and landraces. The recombinants from Local × Local crosses would be adapted to the target area and free from genotype × environment interaction. At the same time, traits of local preference at various sites within the target area could easily be pyramided and homogenized into a new variety derivative. This process may enhance yield *per se* to a certain extent but would bring in a broad spectrum of desired quality and consumer preference.

Local × HYV cross is a potential avenue to introgress genes for high yield from the HYV retaining the desired quality traits of the local variety. Varieties derived from Local × HYV crosses have been demonstrated to have quality traits preferred by farmers. For instance, a variety of bean from a Local × HYV cross was ranked best by farmers due to its preferred grain quality though it yielded lower than other HYVs[2].

The F_1 seeds of such crosses can then be obtained on a participatory mode. Farmers, both men and women, can be trained in emasculation–pollination techniques. They would generate F_1 seeds under scientific supervision. More than generating a large quantity of F_1 seeds economically, the method would give a feel of scientific research participation to the farmers and enhance the chances of application of other PPB methods sustainably. Large F_2 populations can then be grown in farmers' fields at several target areas and the farmers encouraged to select desirable segregants. This would provide a basic understanding of the farmers' methods of selection. When blended with formal principles, realized genetic advance could improve substantially.

(3) Participatory varietal selection: Simultaneously, as has been reported in various published studies, farmers could be asked to select desired lines from near-homogeneous F_5 (and further generations) populations so that a site-adapted variety can be homogenized on a participatory mode. As a relatively safe strategy, this has been largely adopted in PPB programmes[3].

Finally, we need to realize that the extent and success of participatory paradigms are direct functions of the structure, social status and environment infrastructure of the target farmers. Any PPB activity has to chronicle and evaluate those aspects of ground information to plan a feasible work schedule as attempted in this study.

1. MSSRF, Eighth Annual Report, 1997–98. Chennai, M.S. Swaminathan Research Foundation, Chennai, 1998.
2. Kornegay, J., Beltram, J. A. and Ashby, J., in *Participatory Plant Breeding* (eds Eyzaguirre, P. and Iwanaga, M.), IPGRI, Rome, 1997, p. 151.
3. WARDA (West Africa Rice Development Association), Participatory Varietal Selection: The Spark that Lit a Flame, Bouaké, Côte d'Ivoire, 1999.

ACKNOWLEDGEMENTS. The work was done under a project funded by Swiss Agency for Development and Cooperation to M.S. Swaminathan Research Foundation (MSSRF), Chennai, India. My sincere thanks are due to Mr Susanta S. Chaudhury and Mr Gopal Mohapatra, for initial field survey and data collection and Dr S. D. Sharma, for initiating PPB work at Jeypore and active supervision. I thank the Chairman, MSSRF for enabling my coordination of the project.

Received 20 December1999; revised accepted 26 April 2000