Participatory Varietal Selection in High-Potential Production Systems

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Abstract

This paper reviews some of the participatory research in high-potential production systems on participatory varietal selection in high-potential production systems. This collaborative research is conducted by the Centre for Arid Zone Studies, UK; Local Initiatives in Biodiversity Research and Development (LI-BIRD), Nepal; the Gramin Vikas Trust, India; and the Punjab Agricultural University, India.

The justification for participatory research on varietal selection in marginal areas is reviewed and then compared to the needs of high-potential production systems (HPPSs). Some of the more significant findings on participatory varietal selection (PVS) in HPPSs are summarized and the roles of decentralization and participation in the research are reviewed. Participatory methods can increase the efficiency of formal breeding programs and in HPPSs they have a great potential for contributing to higher and more stable food production.

Why farmer participatory research is advocated in marginal areas

Participatory research in marginal areas can be used to empower farmers and promote development in farmers' communities (e.g., Sperling 1996; Ashby et al. 1996). It can also be used to increase the efficiency of formal breeding programs in producing and popularizing varieties appropriate for resource-poor farmers. Research funded by the Department for International Development (DFID) Plant Sciences Research Program has concentrated on improving efficiency, although benefits in empowering farmers are achieved coincidentally to this process. Increasing breeding efficiency helps meet the goal of the research: the improvement of the livelihoods of poor people.

An extensive analysis of the testing of varieties in India for marginal areas revealed weaknesses in the formal testing system that reduced the chances that varieties released for marginal areas would meet farmers' needs (Witcombe et al. 1998b). The failure of the system is evidenced by, e.g., the rejection of many varieties by farmers, who did not adopt them, and the rapid and high adoption by farmers of nonreleased varieties, such as Mashuri rice, that had been rejected in the formal testing system (Maurya 1989). Most important, farmers in marginal areas often continue to grow landraces and have only adopted modern varieties to a limited extent (figure 1). Resource-poor farmers in marginal areas, where yields are appreciably lower, are benefitting less from modern varieties than farmers in more favored regions.

The deficiencies in the system of trials that is used to test varieties is one of the causes of this low adoption in marginal areas. An analysis of any multilocational trials from several crops in India over a number of years showed the following:

- The trial sites were located according to the available research infrastructure and often poorly represented the major areas in which the crop was grown (Packwood et al. 1998). Sometimes the trials were divided into zones but these were so large that they included diverse environ-

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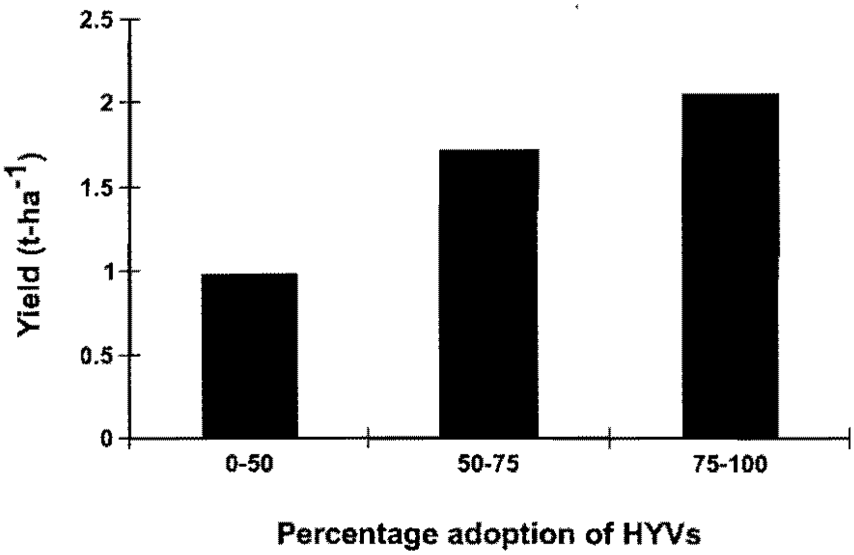

Figure 1. Mean yield of rice in 149 districts in six states, categorized by three levels of adoption of high-yielding varieties (Witcombe et al. 1998a)

ments. This could not be overcome by further division into smaller agroecological zones as there were too few trial sites to do this. Some of the agroecological zones would not be represented at all and others would have only a single trial site.

- The trials poorly represented the growing conditions in farmers' fields. The environments in which the trials were conducted were too favorable and the trials had too high a level of purchased inputs applied to them. For example, an analysis of sorghum trials in 1989 showed that the average yield of the trials was over three times the yields achieved by farmers in the districts in which the trials were conducted (figure 2). This analysis is typical of the many that were made (Packwood et al. 1998). A more recent example is the direct-sown early rice trial of 1999. The average yield over 10 sites was 2.6 t ha^{-1} and the highest yield was 4.1 t ha^{-1}. Compare this to the average yields of less than 1 t ha^{-1} obtained by poor farmers in upland conditions in the states of Bihar, West Bengal, and Orissa. This difference is far too large to be explained simply as a result of higher potential of the new varieties in the trial, and mainly results from a more favorable environment on the research stations than on farmers' fields.
- The reliability of the trials was poor. Many trials are rejected because they have high coefficients of variation (which tends to be correlated with nonsignificant between-entry variances). In part, this is because the plot sizes are small and nearly all trials have only three replicates. Individual trials poorly predict the overall performance of genotypes in the multilocational trial—the correlation coefficient, r^2, between the yields of the entries in any one trial site and the trial mean across all locations is usually low. This certainly reflects error, i.e., uncontrolled variation, in the trials but it also indicates the possibility of high specific adaptation of genotypes to sites or groups of sites. Such specific adaptation, of course, cannot be exploited when selection is exerted for overall performance across locations.
- The allocation of resources to entries at different stages of testing was inefficient. In theory, the resources (a product of the number of trials, replicates, and plot size) allocated to the entries in each year of testing should be equal. However, many more resources are spent on

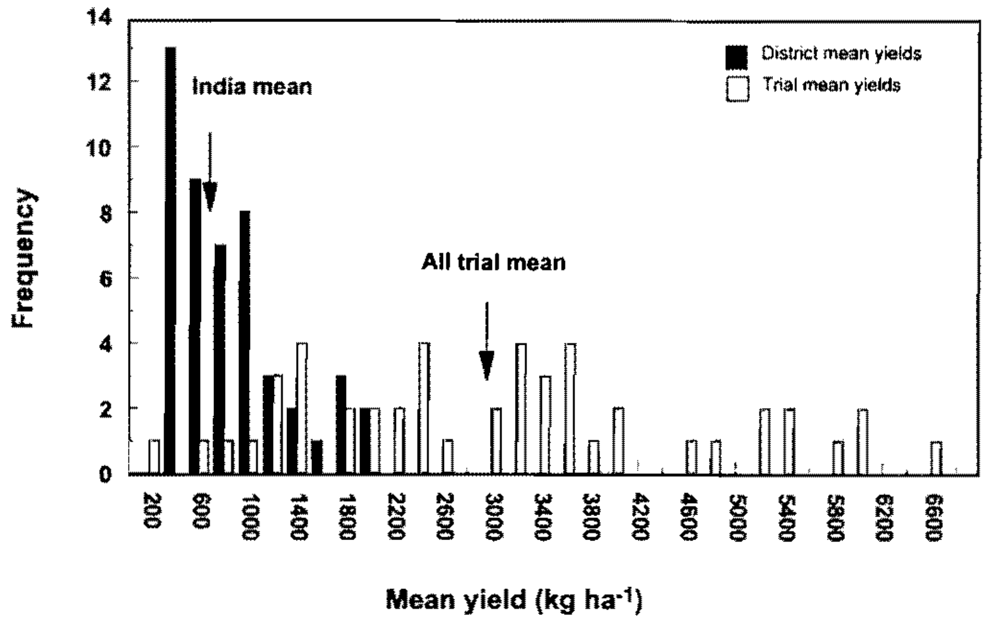

Figure 2. Comparison of yields in the All-India Coordinated Sorghum Improvement Project trials and in the districts in which these trials were conducted, 1989 (Packwood et al. 1998)

testing the least important entries—those in the first year of the trials—than the more important entries undergoing the second or third year of testing (Witcombe et al. 1998c).

- The trials did not allow selection of specifically adapted varieties . For example, earliness is extremely important in marginal areas because it allows the escape of end-of-season drought. (Earliness is prized by farmers in HPPSs as well because it increases the possible options in the cropping system and gives more time for the timely sowing of the following crop.) However, analysis of many trials showed that in nearly all there was selection against early- and later-maturing entries (Witcombe et al. 1998c). In selecting for wide adaptation, i.e., the entries that yield best on average, there is selection for mediocrity in flowering time (figure 3).
- The selection system to promote entries from one trial stage to the next did not allow a trade-off between different traits. The promotion criteria are heavily biased towards grain yield, and little or no consideration is given to other traits, such as early maturity, stover yield, and grain quality. Only if an entry survives three years in the trial can other traits be taken into account when it is considered for release. Traits other than yield will have been ignored in the earlier stages of promotion—initial to advanced trial, or promotion to a second year of testing in an advanced trial. Hence, in practice, varieties with advantages in non-yield traits can only be selected if they have a yield advantage in the first two years of testing (Witcombe et al. 1998c).

In summary, in marginal areas, the following disadvantages of multilocational trials were seen:

- Trial sites poorly represented the crop area.
- Trial sites poorly represented farmers' fields.
- Trials were unreliable.
- Resources were allocated inefficiently between varieties in different years of testing.
- Selection for wide adaptation selected against specific adaptation.
- The selection criteria used rarely allowed trade-offs between traits.

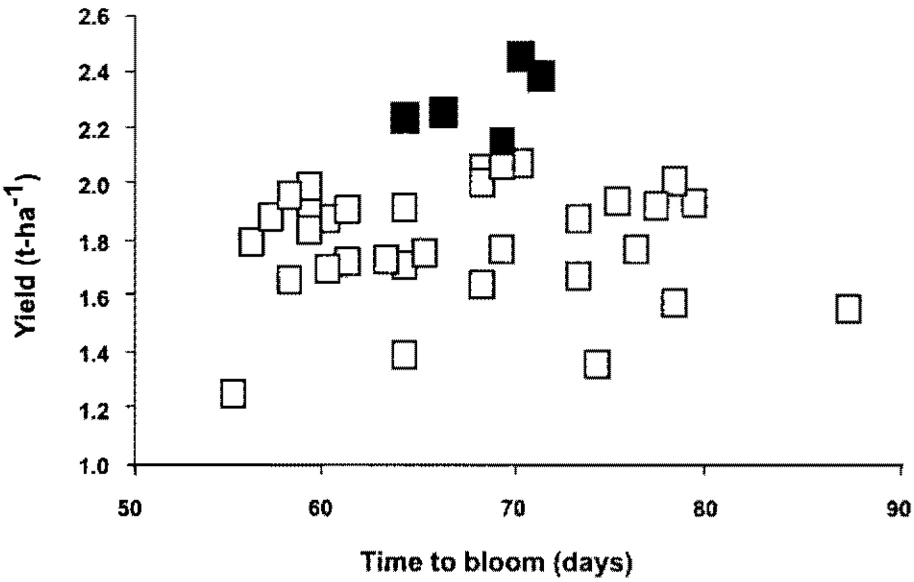

Figure 3. Time to bloom and yield of entries in the very early, direct-sown rice trial of the All-India Coordinated Rice Improvement Project of 1993 (The four highest yielding entries are all of intermediate flowering time; early-flowering entries are eliminated.)

Trials for favorable areas share the disadvantages of trials for marginal ones

Although it is not the perceived wisdom, the drawbacks described for trials targeted at marginal agricultural environments are shared with those targeted at high-potential production systems (HPPSs).

There are very few trials to represent the often extremely large areas of high-potential production systems. For example, in state-level trials there are only four trial sites for rice in the Indian Punjab to represent a rice area of about 2.2 million hectares and only two sites in the All-India coordinated trials. The Punjab does not represent a single target environment; there are marked differences in adoption of varieties by farmers from district to district; however, not all of the districts are represented in the formal trial system.

High-potential production systems are not uniform (Witcombe 1999) but have great physical and socioeconomic diversity. Physical variation is often related to the cost and availability of irrigation water that can be supplied predominantly by tube well in some areas and by canal in others. Variation in soil and land type is significant. For example, in rice there are niches, such as more waterlogged areas, where long-duration rice is required (figure 4). In contrast, in some areas short-duration varieties are needed either because of physical variation (limited water) or temporal variation (a need to harvest the crop early for timely sowing of the following crop).

Unlike marginal areas, the disparity in the level of inputs on the research station trials and farmers' fields is indeed much less and this is not a major reason why trials poorly represent farmers' fields in HPPSs. However, unlike marginal areas where the planting date used by both researchers and farmers is dictated by significant rainfall events, there can be a large disparity between the sowing dates of farmers and the sowing dates of research station trials. Coordinated research trials require a

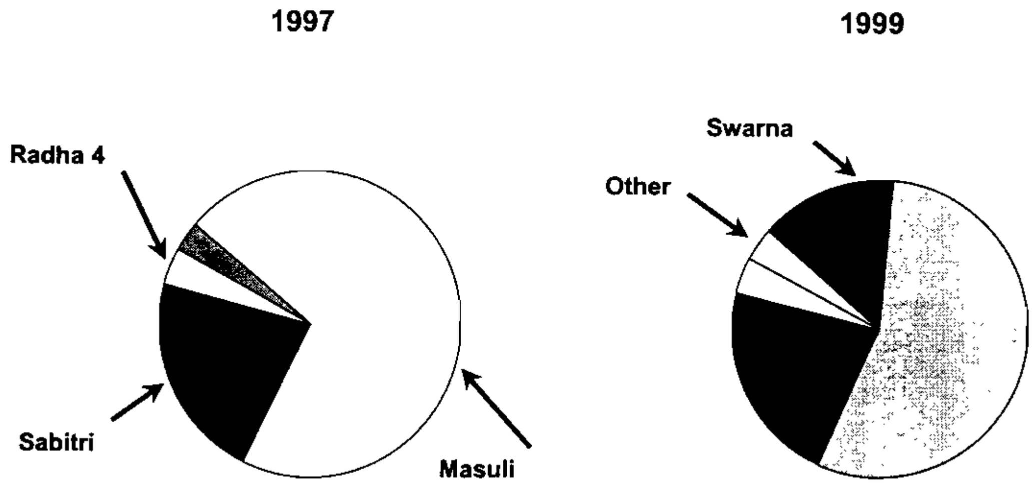

Figure 4. The adoption of Swarna, a late-maturing variety for wetter areas, in a village in Chitwan, Nepal, after two seasons (data from K.D. Joshi, LI-BIRD)

great deal of organization to assemble and redistribute the seed to the trial sites. Hence, it is common in a crop such as rice, where the seed is produced in the off-season just before the main season trials, for the trials to be sown later rather than earlier in the season. Apart from the practical difficulty of representing earlier sowing dates, the low number of trial sites means that the range of planting dates used by farmers cannot be represented. For example, both the sowing and transplanting of rice extend over a three-week period in Lunawada District, Gujarat (figure 5). It is a practical impossibility to have all these sowing dates in a formal trial system, yet significant interactions between sowing date and variety occur.

Trials in HPPSs, although more reliable than those in marginal areas because of the existence of irrigation and more uniform land, can still suffer from high experimental error because of small plot sizes and limited replication.

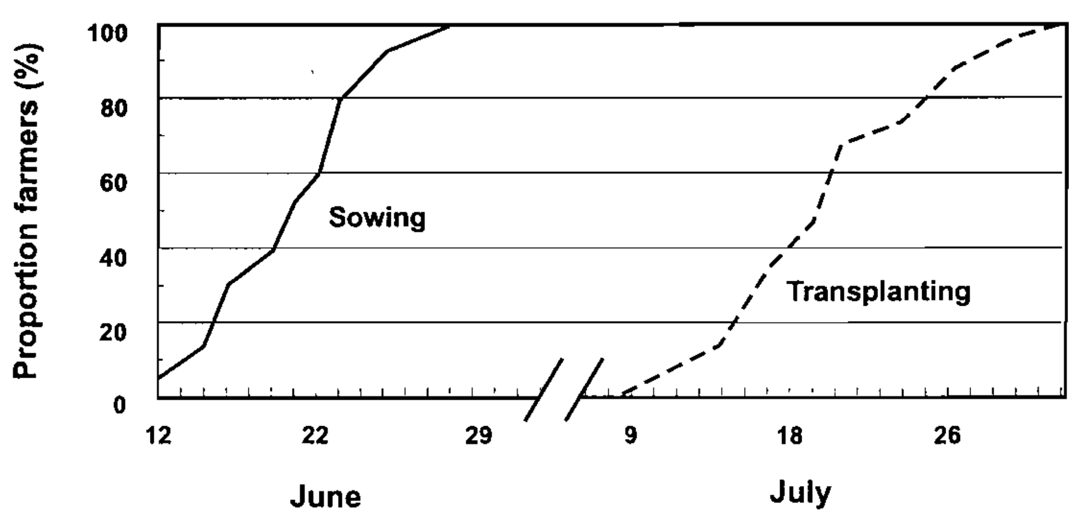

Figure 5. Sowing and transplanting dates of rice in Lunawada District, Gujarat (Virk et al., this volume)

The deficiencies in resource allocation, described for trials in marginal areas, are caused by the promotion criteria used. These criteria are used independently of the targeted production system, so resource allocation is just as poor in trials for HPPSs as in those for marginal areas.

In trials for HPPSs, the trade-off between multiple traits is no better than in trials targeted at marginal areas. The value of shorter-duration crops is insufficiently recognized in the trial system for HPPSs where selection is almost entirely for yield and division of the trials by maturity class is lacking or inadequate. Early maturity can allow another crop to be grown during a year, either a cash crop or a green-manure crop, and it can spread demands for labor at sowing, transplanting or harvest time. Trade-offs between yield and other important traits (e.g., fodder yield or grain quality) also receive insufficient attention.

What are the roles of participation and decentralization in PVS?

The deficiencies identified in the multilocational trial system can be removed by radically modifying the design of the multilocational trials without significantly increasing farmer participation. Alternatively, the problems can be addressed by introducing a major component of participatory varietal testing (Witcombe and Virk, forthcoming). This raises the question as to whether modifications to the design of the trial system, all of which result in decentralization, are simpler and cheaper than employing participatory approaches.

The six problem areas identified in the multilocational testing are examined to see if redesigning the trials by decentralization or increased farmer participation is the most efficient solution. Both decentralization and participation help to solve these problems because they can do the following:

1. allow trial sites to better represent the crop area
2. allow better representation of the environments in farmers' fields
3. increase the reliability of the trials
4. allocate resources more efficiently between varieties in different years of testing
5. allow varieties to be selected for specific adaptations
6. allow trade-offs between traits

In the first five of these, decentralization or participation can provide a solution mainly by allowing more replication, particularly replication that increases the number of test sites. Adding more researcher-managed test sites in a decentralized testing program is expensive. Adding farmers in a participatory testing program is cheaper because there are many farmers who are willing to collaborate with minimal cost.

These six issues are considered in more detail below.

1. **Allow trial sites to better represent the crop area**
   Trials can be modified to better represent the target areas (or, indeed, the niches within areas) by having more trials divided into more zones and types. However, clearly many more formal trials would be needed to do this and the increase would consume many more resources. Participation provides a more cost-effective solution. Moreover, the participation of farmers does not just allow varieties to be tested in more niches, it helps to identify them.

2. **Allow better representation of the environments in farmers' fields**
   The formal trial system can be modified to reduce purchased inputs to farmers' levels. After surveying farmers' cultivation practices, more realistic management can be adopted in

research-station trials. However, only participatory methods, which allow many farmers to be sampled, can realistically account for the range of management practices and sowing dates found in farmers' fields. Replication across sites is the key to representing the diversity of the environments of farmers' fields, and participatory methods would appear to be the only cost-effective way of achieving the amount of replication required.

3. **Increase the reliability of the trials**
The overall reliability of a multilocational trial can be increased by increasing the number of sites, the number of replicates at each site, the size of plots, or any combination of these. Of the three components, the number of sites is the most critical. The number of formal testing sites that can be controlled and managed by scientists can be increased but at considerable expense in both requirements for infrastructure and running costs. Increasing trial sites is cheaper with participatory methods because farmers are interested in participating in varietal trials without any financial incentive other than the provision of seed free of cost. The major costs are then for data collection. Qualitative data are "scientific," analyzable, and more cheaply collected than quantitative data. Hence, if breeders and release committees were prepared to accept qualitative data on yield and other traits, rather than the current insistence on quantitative data, the costs of this data collection would be considerably reduced.

4. **Allocate resources more efficiently between varieties in different years of testing**
Participatory approaches, because of the quantities of seed required, would concentrate on more advanced entries, which would automatically correct the imbalance that concentrates too many resources on varieties that are at an early stage of testing. With PVS, the number of sites, i.e., farmers' fields, in which a variety is tested can easily and systematically be increased as a variety is promoted through the testing stages.

5. **Allow varieties to be selected for specific adaptations**
The higher the number of trial sites, the more accurately selection can be targeted to niches—either physical or socioeconomic. This allows specific adaptations to be exploited, as was seen for the example of Swarna rice in Nepal. Although a higher number of trial sites in the formal system would allow the selection of more specifically adapted varieties, it is a more expensive alternative to increased participation.

6. **Allow trade-offs between traits**
It is certainly feasible to introduce a trade-off between traits in a formal trial system after consultative participation that determines the traits that farmers consider important and how farmers trade them off. Trials can then be split according to farmer-important traits, e.g., trials for high grain yield, high stover yield, and dual-purpose varieties for grain and stover. Selection indices can also be constructed to allow the promotion of a greater range of varietal types in any trial. These methods, however, are complex and require traits to have standard weightings even though they differ from farmer to farmer and from season to season. Collaborative participation that allows farmers to decide overall which variety or varieties they prefer is a simpler and more effective solution.

Six issues have been considered in this comparison of the roles of decentralization and participation. However, there is a seventh important issue that only participation addresses.

7. **Participation promotes the speed of adoption of preferred varieties**
   No matter how decentralized a breeding program and its varietal testing system, if it does not involve farmers, it cannot directly promote adoption. Only participation can do this.

Conclusions on PVS in HPPSs

Other papers in these proceedings will attest to the efficiency of PVS in more favorable agricultural environments (Virk et al., this volume; Malhi et al., this volume; Joshi and Witcombe, this volume). It is highly effective and has been demonstrated to achieve the following:

- Identify and promote varieties that were not recommended for the area in which the PVS was done (this means that the recommendation domains of many varieties that are adapted to HPPSs are too small)
- Increase varietal biodiversity (more varieties are adopted because farmers, when given choices, can identify varieties for niches)
- Promote acceptable recommended varieties (recommended varieties are adopted more quickly in villages where PVS is done than in control villages)
- Identify recommended varieties that are either not accepted by farmers or are poorly accepted

However, PVS has certain limitations. It is dependent on a seed supply to start the PVS trials, and often the seed of released varieties is surprisingly difficult to obtain. When nonrecommended varieties are identified, the seed supply limits the speed of their adoption. The success of a PVS program depends on other external factors such as the timing and success of recent releases in the target area. PVS is much less likely to be considered successful when introduced varieties compete against a very recently released variety that is liked by farmers than when, perhaps for more than a decade, there has been no significant change in the variety grown. PVS is also dependent on pre-existing varieties. If there are no suitable varieties among those currently available, then it will not succeed. In contrast, PPB approaches that generate new variability do not suffer from this limitation. In participatory approaches in maize and rice breeding in marginal areas (Goyal et al., this volume; Kumar et al., this volume), 30% gains in yield were obtained over the best varieties—about three times the rate of genetic gain using conventional methods. Success in HPPSs is yet to be demonstrated but research in this area is underway (Witcombe et al., this volume).

Participatory varietal selection in HPPSs is much more difficult to justify to scientists and policymakers than it is in marginal areas where the need for and success of a different approach was evident. The need was clear from a lack of adoption of new varieties and the success of PVS has been convincingly demonstrated by many (e.g., Sperling 1996; Witcombe et al. 1999). PVS in high-potential production areas is new research from which results are only just emerging. It is an alternative to an entrenched system that can justifiably claim success—the adoption of modern varieties is, after all, almost universal in HPPSs. However, this success does not necessarily equal efficiency—a 100% adoption of modern varieties can be achieved with or without extensive participation. However, could participatory methods be more cost-effective, produce better varieties, and create and maintain greater varietal biodiversity in farmers' fields? The theoretical basis as to why this might be so has been presented here, and the evidence to justify this theoretical assumption is emerging.

It is extremely important for these issues to be thoroughly explored. HPPSs produce most of the world's food. If the production increases from PVS of 10%-40% found so far in these production systems were to be widely replicated, this would have a considerable impact on improving food security and would directly, and indirectly, greatly benefit the poor.

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