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PARTICIPATORY PLANT BREEDING IS BETTER DESCRIBED AS HIGHLY CLIENT-ORIENTED PLANT BREEDING. II. OPTIONAL FARMER COLLABORATION IN THE SEGREGATING GENERATIONS

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SUMMARY

Many public-sector breeding programmes do not use explicit techniques to orient their programmes close to their clients' needs. Participatory techniques can be used to achieve high client orientation but these techniques do not have to involve farmers making selections during the segregating generations. This particularly applies when a sound initial market survey has been made or the learning from a participatory varietal selection (PVS) programme provides feedback to scientists. However, some published results on selection by farmers in the segregating generations (collaborative selection) indicate that it can produce appropriate varieties more effectively than less collaborative research. There is also evidence, from the few cases reported in the literature, that it is cost-effective. Alternative, less collaborative, approaches are also effective. Consultative forms of farmer participation, i.e. where farmers evaluate material grown by scientists, to aid selection in the segregating generations are more widely applicable because they demand fewer resources than collaborative methods. For more time-consuming tasks, such as in the selection of aromatic rice in segregating material, the most appropriate from of participation is contractual i.e., farmers are paid for their work. Mainly using examples from our research in Nepal, we present the particular circumstances in which the involvement of farmers in selection in the segregating generations is desirable or essential. These include: the occurrence of market failure (where the usual mechanisms of supply and demand have failed so there is no incentive to breed new varieties) and supply can only be met by actively involving farmers in the breeding process; when there are cost advantages to involving farmers – this is determined by the particular resources available to the institute undertaking the plant breeding research; when grain quality is both important and determined by a complex set of factors that are difficult to measure in the laboratory; when the objective is to learn in more detail about farmers' selection criteria to better orient the breeding programme to client needs; and when the goal is to empower farmers.

INTRODUCTION

In a previous paper we argued that participatory plant breeding would be better described by its purpose – to achieve high client orientation – rather than by a term

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that describes what is done (Witcombe *et al.*, 2005). We accept that all breeding programmes implicitly have client orientation but few explicitly adopt techniques to meet client needs more effectively. The lack of explicit effort in many public-sector breeding programmes is a real disadvantage as evidenced by farmers continuing to grow landraces or obsolete varieties because new, recommended varieties do not adequately meet their requirements (Witcombe *et al.*, 1998).

We described breeding programmes that use specific techniques to improve their client orientation as highly client oriented. By using a description of the degree of client orientation we intend to remove the artificially created divide between 'participatory' and 'non-participatory' breeding.

An analytical framework based on the purpose of farmer participation – improved client orientation – allowed a more rigorous examination as to why and when farmers should be involved in the plant breeding process (Witcombe *et al.*, 2005). We concluded that highly client-oriented breeding could be accomplished without farmers selecting on their own farms during the segregating generations. The exception is when the objective of involving farmers is empowerment.

COLLABORATIVE PLANT BREEDING – AN OPTION NOT A PRINCIPLE

In this paper we use the typology of Biggs (1989) for participation from consultative (farmers are consulted), contractual (farmers are paid), collaborative (farmers are active partners in the research) to collegial (groups of farmers co-operate to lead research). In the case of farmers selecting on their own farms the participation is collaborative.

Involving farmers in the actual breeding process may not be essential (e.g. Courtois *et al.*, 2001; Morris and Bellon, 2004). This particularly applies if a sound initial market survey has been made or the learning from a participatory varietal selection programme provides strong feedback on client needs into the breeding programme. Hence, programmes labelled as 'participatory' or 'conventional' can be identical when both employ some form of PVS and when both are well-oriented towards client needs. This confirms the speculative answer of Weltzien *et al.* (2003) who asked whether participatory plant breeding (PPB) could achieve the same goals as classical breeding if the programme had the 'right' goals and a thorough knowledge of client preferences. They stated, '*We sense that part of the answer is "yes" for some current PPB cases. That is, if programs focused on farmers' preferences and goals with true rigor, actual collaborative work would not be necessary*.' We agree, with the exception of the collaborative work that takes place during the on-farm selection of varieties – participatory varietal selection. This is because PVS is an essential technique for efficiently identifying appropriate varieties that avoids the customary lengthy delays in a 'pipeline' system of product innovation. In this linear system from research to recommendation to extension many years are required before farmers have access to one or few of the many varieties that were tested on-station.

What is the evidence so far?

A few groups have tried collaborative plant breeding (Table 1), where farmers were active participants in the selection phase breeding process. Often, solid conclusions

Table 1. Examples of collaborative plant breeding where farmers have been involved as partners during the selection generations.

Crop	Country/region	Comparison made between selections of farmers and breeders	Measure used	Author
Beans	Rwanda	Yes	R	Sperling *et al.* (1993)
Beans	Colombia	Yes	R	Kornegay *et al.* (1996)
Barley	West Asia and North Africa	Yes	SD	Ceccarelli *et al.* (2001)
Maize	Eastern India	Yes	R†	Virk *et al.* (2005)
Maize	Western India	Yes	R†	Witcombe *et al.* (2003)
Maize	Nepal (Gulmi)	No		Sunwar *et al.* (2002)
Maize	Brazil	No		Toledo Machado and Silvestre Fernanades (2001)
Rice	Eastern India	Yes	R†	Virk *et al.* (2003)
Rice	Nepal (high altitude)	Yes	R†	Sthapit *et al.* (1996)
Rice	Nepal (mid-hills)	Yes	R	See footnote§
Rice	Nepal (low altitude)	Yes	R	Gyawali *et al.* (2005)
Rice	Philippines	Yes	R‡	Frossard (2002)

†A comparison between two varieties produced with different amounts of farmer involvement.
‡An informal evaluation not published in a peer-reviewed Journal.
§Six farmers and two breeders independently selected panicles in an F_3 bulk of the cross of Mansara/Khumal-4 grown in 2002 at 1500 m in the mid-hills of Nepal. The selections were compared in the F_5 and there were no significant differences between the two sets of selection in overall performance. However, farmers had only selected panicles with red-pigmented glumes, whereas breeders had selected panicles irrespective of glume colour.

cannot be drawn because comparisons were confounded by the location of selection; breeders tend to select on research stations and farmers on their farms. However, in several of the few examples of collaborative breeding formal comparisons were made between farmers' and breeders' selections. Usually these comparisons were based on the selection response (R) found in the subsequent generation or generations, the realised genetic gain, whereas Ceccarelli *et al.* (2001) compared the size of the selection differential (SD) achieved by breeders' or farmers' visual selection.

Positive results from collaboration during the selection stage. Contrary to the advantages that formally-trained breeders might be expected to have over farmers when selecting in the segregating generations, Sperling *et al.* (1993) reported that farmers' selections realized, in the subsequent generation, a higher yield gain than that achieved by breeders. In another case, farmers selected as many (or sometimes more) higher yielding entries of barley than breeders on the basis of visual evaluation (Ceccarelli *et al.*, 2001). In other cases, farmer selections may not yield more but have a superior combination of yield and earliness to those of the breeders (e.g. Gyawali *et al.*, 2002; Joshi *et al.*, 2002), or a superior combination of yield and quality where the increased market price of the grain more than offsets a lower yield (Kornegay *et al.* 1996 for beans). Hence, involving farmers during the selection phase can help to produce better varieties. It is also probably cost-effective to do so although comparisons are lacking on the specific costs of involving farmers in selection with the costs of on-station selection by researchers. The relative costs of on-station and on-farm research vary with local circumstances providing a further complication to any comparison.

Positive results from client-oriented breeding that cannot specifically be attributed to collaboration during the selection stage. In maize breeding programmes, farmers selected in some of the selection generations in both western India (Witcombe *et al.*, 2003) and eastern India (Virk *et al.*, 2005). However, no comparison was made between farmers' selection with breeder's selection – the programmes had the aim of producing new varieties for resource-poor farmers rather than testing hypotheses on selection. Overall, these programmes were more cost-effective than conventional ones and this could be attributed mainly to the use of PVS trials. These saved time by simultaneously testing varieties on farmers' fields and on the research station thus increasing the effective genetic gain per annum.

Two rice varieties were bred in eastern India with farmer participation (Virk *et al.*, 2003). Variety Ashoka 200F was produced by a farmer selecting in an F_4 bulk in his own field (collaborative breeding) whereas Ashoka 228 was produced by farmers and breeders selecting among F_4 bulk lines on the research station (consultative breeding). Both varieties were released and both are being rapidly adopted in upland rice areas where, despite decades of breeding efforts, there previously was no significant adoption of any modern variety. Both varieties yield about the same in eastern India – the only significant difference is that Ashoka 228 is later to mature by several days, a trait that farmers do not particularly like. In Tamil Nadu, Ashoka 228 has been selected by breeders as a promising genotype. In PVS and on-station trials in other parts of India (Gujarat, Madhya Pradesh, and Rajasthan), Ashoka 200F is usually found to yield more than Ashoka 228. Overall this might indicate that the collaborative approach is better but the comparison is unreplicated. We have demonstrated that collaborative and consultative breeding during the segregating generations are *effective* but have not attempted to show they are *essential*. Indeed, consultative breeding in the segregating generations was not essential because both breeders and farmers selected Ashoka 228. It was helpful because it reduced the costs of yield testing as only jointly selected entries were promoted to PVS trials.

It was the general approach of orienting the breeding programme closer to client needs that was essential in providing the first real success in upland rice breeding for these difficult areas. Prior to the Ashoka varieties no improved variety had been highly accepted by farmers. High client-orientation determined the full varietal specification at the beginning of the programme: the varieties had not only to be high yielding and drought tolerant (this had already been achieved with conventional breeding) but also had to have superior (i.e. fine-grained) quality. Inferior grain quality had severely constrained the adoption of modern varieties in the rainfed uplands of eastern India (Virk *et al.*, 2005), but improved grain quality was never an objective of previous upland breeding programmes. Indeed many breeders still hold the opinion that upland rice growers prefer coarse-grained varieties even though the fine-grained Ashoka varieties rapidly replace coarse-grained landraces and modern varieties.

Under what circumstances is collaboration during the selection phase essential?

Weltzien *et al.* (2003) considered when farmer collaboration is essential in plant breeding and the circumstances that we list below are almost the same as theirs. The only major difference is that we do not discuss their case of '*minor crops which cannot be very effectively addressed by formal research'*.

The circumstances where collaborative breeding is indispensable or, at the least, highly desirable is when one or more of the following apply:

1. There is 'market failure' where supply (of new varieties) fails to meet the demand for those varieties from farmers. A common example of market failure is that which occurs in marginal agricultural areas where the demand is too poorly articulated by client groups for the public-sector to invest in breeding programmes and the size of the market is too small for private-sector investment.
2. The resources available to the institution undertaking the breeding programme are such that it is cheaper for it to do participatory research than on-station research.
3. Consumer perceptions of grain quality are important and too complex (determined by many traits) to be selected for simply on the basis of laboratory tests.
4. Farmers have selection criteria where they trade off traits amongst each other.
5. The objective is to learn more from farmers about selection criteria and preferred traits.
6. The objective of the breeding activity is to empower farmers: to strengthen farmers' skills and knowledge on the principles and practices of utilizing genetic diversity, and on the processes of searching for, selecting, maintaining and exchanging seed of preferred varieties.

Under all of these circumstances collaborative participation in the segregating generations is likely to be helpful or essential. We describe these six circumstances in detail below.

1. Market failure for specialized niches

In the remote hill district of Gulmi, Nepal, maize farmers have never had access to seed of new varieties. LI-BIRD introduced farmers to over 200 modern varieties in a project funded by the Consultative Group for International Agricultural Research Systemwide Program on Participatory Research and Gender Analysis (Sunwar *et al.*, 2002). Farmers liked only one of them, Rampur Composite, which was not recommended for the hills but had better quality for traits farmers considered important such as good quality '*aato*' (maize 'grit' used for cooking a rice-like dish) and good stover value for fuelwood and fodder.

Farmers asked LI-BIRD to find them an even better variety but, given the very low success rate of introducing research-station-bred varieties, the only possible solution was to breed a new variety. There was no formal research station in the area, and the national programme did not have a breeding programme targeted for this very atypical, remote hill area: in the hills maize is usually sown in May but Gulmi farmers sow in March to benefit from early rain in their highly drought-prone region. Farmers enthusiastically welcomed the option of collaborating in breeding because maize was essential for their livelihoods and increasing its yield was one of the very few options to increase income.

The farmers' traditional practice was to select only among the harvested ears, so they were trained in mass selection techniques in the standing crop. The breeding programme began with selection from segregating (F_2 onwards) populations generated from randomly intermating five elite populations as well as the crossing of the local landrace, *Thulo Pinyalo* (a high-yielding but lodging-susceptible variety), with Rampur Composite and lodging-resistant introduced genotypes. Collaborative breeding produced a composite superior to all the introduced varieties including Rampur Composite. The farmers named the new composite as Resunga Composite; it is being widely adopted (Sunwar *et al.*, 2002) and farmers are multiplying it in community-based seed production schemes. This composite came from the intermating of the five elite populations and did not involve the local landrace, but the five elite populations may have had locally adapted varieties in their parentage.

In the northern areas of Pakistan, farmers grow wheat at altitudes of 1500 m and above under irrigation from snow melt. This is a highly specialized environment and is more complex because there is winter and spring wheat and cropping zones that pass from a double cropping system (two crops a year are possible) through a transition zone to a higher altitude single cropping zone. It is unsurprising for this niche environment that breeding programmes have not been specifically targeted for them. It is more cost effective for an NGO, the Aga Khan Rural Support Programme (AKRSP), working in this area to gain access to farmers in this target population of environments than for an Islamabad-based national programme (Pakistan Agricultural Research Council [PARC]) with responsibility for breeding for several million hectares of irrigated wheat. AKRSP and CAZS-NR are using collaborative breeding to improve on the performance of varieties from PARC that performed well in PVS trials (e.g., NR 74 and NR 152) but show limited adaptation to lower fertility conditions or the single cropping zone. A few crosses were made between these varieties and local landraces as a cheaper alternative to establishing three research station sites, one in each zone, with trained breeding staff. The very promising performance of the F_3 and F_6 generations (depending on the cross) in 2004 indicate that this collaborative research is on track to being successful.

2. Cost-effectiveness – qualified examples from Nepal

All of the rice breeding done in Nepal by LI-BIRD and CAZS Natural Resources with the collaboration of the National Rice Research Programme (NRRP) requires the collaboration of farmers. LI-BIRD has no research station and limited resources, so collaborating with farmers in all stages of the breeding programme is essential and all the breeding material is grown on farmers' fields. This is a very cost-effective way of working because there is no investment in research-station infrastructure. It also results in a constant interaction with farmers but, despite this, collaborative breeding in the segregating generations of the breeding programme is not the most commonly used method of selection. Breeders have found that there is a high overhead in training and motivating farmers (without this the uptake by farmers was found to be low) so alternative models are being used or under test. We found that it was highly cost-effective to involve farmers in a consultative method of participation where they evaluated progeny rows grown by breeders on farmer's land (Joshi *et al.*, 2002). For more collaborative approaches we now concentrate on working with a few farmers who have proven to be highly interested in plant breeding. Effectively they become hands-on plant breeders specifically trained in the techniques of selection during the segregating generations. Their continued involvement places high demands on their time so monetary or non-monetary incentives are required.

Similar experiences were encountered in a project conducted in Nepal by LI-BIRD and NRRP with International Plant Genetic Resources Institute funding. Two approaches were tried: either collaborative selection by providing a small amount of seed of F_3 and F_4 segregating bulks to farmers, or advancing bulks of segregating materials on a rented farmer's field and the consultative selection of individual bulks after a 'farm walk' with farmers. The first approach, which followed that used in the high altitude villages of Chhomrong and Ghandruk (Sthapit *et al.*, 1996) was found, in contrast to the prior successful experience, to be impractical because of the diverse ecology in the target area and the small quantity of seed that could be provided. Very few farmers continued the selection from the segregating materials and maintained seed for sowing the next generation. A major limiting factor was that there was little investment in training farmers and interacting with them in the field. Learning from these difficulties, seed from selected plants from F_3 bulks that were grown by farmers were also advanced and multiplied on rented land in larger plots until the F_6 generation where families derived from individual F_5 plants were jointly evaluated by farmers and breeders. This experience again suggests that for collaborative selection a more intensive interaction with fewer farmers is required.

3. Where quality is important and complex – the example of organoleptic assessment in rice in Nepal

In the client-oriented rice breeding programme in Nepal, quality is tested before yield. This may be the reverse of the conventional approach, but it is much cheaper to reject entries for poor grain quality than for low yield. We regard this quality testing to be part of the earlier stage of selection in segregating generations. We do not regard it as participatory varietal selection that involves trials on farmers' fields.

Farmers are the major actors in identifying the important post-harvest quality traits and in the screening of genetic materials for those identified traits. We regard this farmer collaboration as essential because laboratory tests can only provide a proxy for some of the traits and cannot provide a system of trade-off between traits. In practice, many varieties are rejected before cooking and tasting on the basis of milling percentage and visual appearance but this still requires farmers' judgements, particularly because visual appearance (including size and shape) varies according to the culinary purpose for which the rice is to be used. Hence all promising genetic material, at the earliest in the F_4 generation, is screened for quality traits:

milling qualities (percentage recovery and percentage of unbroken grains), visual appearance, and organoleptic quality (taste, aroma, consistency, cooking time). After this collaborative selection for quality varieties that reach the PVS trials have proven to be generally superior for post-harvest quality traits and few are subsequently rejected for poor grain quality.

However, in the breeding of high-value, high-quality rice such as aromatic rice the work in selecting for quality is usually onerous. Many entries need to be screened because of the usually low frequency of high quality entries in most crosses including those where both parents have high grain quality. Hence, contractual arrangements are used because farmers have to devote several days to the exercise. Examples of this procedure are:

- Gyawali *et al.* (2005) screened 142 accessions of Jethobudho (a high quality rice landrace from the Pokhara valley). The judging panel (farmers, housewives, cooks and scientists) rejected 70 % of the accessions due to poor post-harvest quality traits. The selection procedure took five days to complete.
- In the LI-BIRD and CAZS-NR breeding programme in Chitwan, selections were made for aromatic rice. A group of farmers and a scientist in Gitanagar village spent two days evaluating a trial of 185 family bulks, from a population derived from Pusa Basmati-1, to identify high-quality, aromatic lines. One of the lines from this programme, Sugandha 2002, is highly aromatic, high-yielding and disease resistant and is under consideration for official release in Nepal.

4. Learning more about farmers selection criteria

Farmers selecting among early generation lines has been even more illuminating than PVS in identifying the traits that farmers really want (Joshi *et al.*, 2002) because in the early generation material they see a much greater range of variability.

We compared the results of selection by farmers and breeders (Table 2). First, farmers and a breeder jointly evaluated the lines, but the farmers alone made the final decision on the ones that were selected. Five days later, two breeders (K. D. Joshi and J. R. Witcombe) independently evaluated the plots. The total number of lines selected by each breeder and the farmers differed, so the expected number of random agreements was calculated and the actual number of agreements was then described as a ratio (Table 2). The agreement in the selections made by the two breeders was reasonably high (improvements over chance in excess of three fold). However, the agreement between the breeders and the farmers was lower and was not significantly better than chance in one of the two crosses.

The lower agreement between the breeders and farmers was further analysed. The lines selected by farmers and by neither of the two breeders were all found to be early maturing. In all cases, breeders had not selected them because they had a high incidence of disease. Presumably farmers were prepared to tolerate these levels of disease in their fields – they were not sufficient to have a considerable impact on yield – but breeders are more stringent because they realise that epidemics can occur on a widely grown, susceptible variety. Nonetheless, it underlined the higher emphasis that

Table 2. Farmers' and breeders' selections among F_6 families derived by selecting individual F_5 plants from an F_5 bulk in two crosses, early rice season, Chitwan, 2001.

Comparison for agreement	Number selected by breeder 1	Number selected by breeder 2	Number selected by farmers	Random expectation of agreement	Actual agreement	Improvement from chance (ratio‡ of actual/expected)
Kalinga III/IR64†						
Between the two breeders	19	15		2.8	10	3.5*
Breeder 1 and farmers	19		21	4.0	8	2.0n.s.
Breeder 2 and farmers		15	21	3.1	6	1.9n.s.
Radha 32/Kalinga III†						
Between the two breeders	35	24		5.2	16	3.1**
Breeder 1 and farmers	35		28	6.1	13	2.1*
Breeder 2 and farmers		24	28	4.1	11	2.6*

†Total of 100 lines in Kalinga III/IR64 cross, and 161 lines in Radha 32/Kalinga III cross.
‡For example, for a ratio of 2 the selectors agreed twice as well as expected by chance.
*$p < 0.05$ from Chi squared test of random expectation of selected v. non-selected against actual.
**$p < 0.05$ from Chi squared test of random expectation of selected v. non-selected against actual.
n.s. = non-significant.

farmers place on earliness compared to breeders. Farmers rarely selected entries that matured even at the same time as the most widely grown variety in the early rice season, CH 45, and never selected later entries. Breeders were previously unaware of this evident dissatisfaction with the long duration of CH 45. This had not been apparent from the PVS trials as only one entry that was appreciably earlier than CH 45 was tested, and its preference by farmers was determined by multiple traits.

In the following years the selected entries were tested in PVS trials. The best performing entries proved to be those selected by all three selectors (farmers and both breeders) or by both breeders. No line selected only by farmers, only by one breeder, or by one breeder and farmers was successful. This illustrates the usefulness of employing multiple judges to select among entries but does not confirm the results of work reported by others that found that farmers' selections are superior.

Ceccarelli *et al.* (2001) found that in barley, farmers' selection criteria often differed from breeder's selection criteria and there are many similar experiences of such differences in other crops. The involvement of farmers in collaborative breeding can then be seen as a learning exercise where farmers learn from breeders and breeders learn from farmers. The selections of farmers and breeders will become increasingly close as they learn from each other and their selection criteria converge. Indeed, Sthapit *et al.* (1996) found excellent agreement between farmers and breeders selections '*because farmers were carefully chosen for their skills, and breeders had been exposed to farmers' preferences*.' Hence, this learning exercise may not need to be repeated; even if farmers' preferences change this ought to be detected through feedback from PVS trials and impact assessment studies.

5. Trading off traits-multi-trait evaluation

The economics of plant breeding theory show that genetic improvement should be for traits of economic importance (e.g. Simmonds, 1979). However, formal trial systems have over-emphasized grain yield as a selection criterion, have measured a limited number of traits, and rarely if ever, have employed a system of trade-offs among important traits (Witcombe and Virk, 1997). Hence, in highly client-oriented breeding a reason for undertaking initial market surveys was to determine the relative importance of multiple traits, and a reason for undertaking PVS was to allow multi-trait evaluation by farmers who could trade-off the traits with each other, e.g. lower grain yield against higher stover yield, higher grain quality or earlier maturity. In some cases, trade-offs are avoided by fixing qualitative genetic traits liked by farmers such as glume or grain colour and PVS trials provide a constant feedback on the traits liked and disliked by farmers.

When such techniques greatly improve client orientation it can be expected that collaboration during the selection in the segregating generations may not be essential. Nonetheless, continuing participation of farmers in selection among early generation material will provide more information as it has more diversity than the varieties in PVS trials. Whether the benefits of continuing farmer participation at the selection stage are cost effective will depend on the relative costs of on-station, collaborative or consultative research. Consultative methods, where farmers evaluate researcher-managed nurseries, provide a very cheap and effective way of getting feedback from farmers.

6. Empowering farmers

Collaborative plant breeding is *essential* when the objective is to empower farmers. MASIPAG, a Philippine farmers' organisation, was founded on the political objective of gaining independence from what they considered as the unacceptable rice production technology of the International Rice Research Institute (IRRI). Farmers demanded knowledge from scientists on how to make crosses and how to select. Initially they were trained to do so by university scientists and later MASIPAG developed the capacity to train farmers themselves. There are no data in peer-reviewed journals on the performance of MASIPAG varieties for yield or disease and pest resistance. However, Frossard (2002) reports observations he made at a single location that there were no significant differences in yield between IRRI and MASIPAG varieties. There are many other examples of empowering farmers through participation in plant breeding and varietal selection and it is often a useful, additional product from our research. However, further examples lie beyond the scope of this paper that is limited to improving research efficiency.

CONCLUSIONS

Many breeding programmes that are highly client-oriented do not involve farmers in selection during the segregating generations. Indeed, in some programmes such as the breeding of inbred lines for hybrids the opportunities for such collaboration are extremely limited. Hence, collaboration during the segregating generations can be considered as an option rather than a prerequisite in highly client-oriented breeding where the objective is to improve research efficiency rather than empower farmers. However, there are circumstances where farmer participation during the selection process in the early generations is essential and even more circumstances where it is desirable because it increases plant breeding efficiency and cost effectiveness. Consultative methods of working with farmers are particularly cost-effective because they involve less investment in time for interacting with farmers but still provide valuable feedback to breeders. When farmer involvement in the segregating generations is considered, screening of grain quality with farmers and other stakeholders before yield testing is one of the most important ways of improving research efficiency.

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