2009

Rapid gains in yield and adoption of new maize varieties for complex hillside environments through farmer participation. II. Scaling-up the adoption through community-based seed production (CBSP)

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Published in *Field Crops Research* 111 (2009), pp. 144–151.
doi:10.1016/j.fcr.2008.11.007

Submitted 15 January 2008; revised 11 November 2008; accepted 13 November 2008

Rapid gains in yield and adoption of new maize varieties for complex hillside environments through farmer participation. II. Scaling-up the adoption through community-based seed production (CBSP)

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Abstract
Participatory varietal selection (PVS) led to the identification of Population-22 and its later release as Manakamana-3. Subsequently further mother–baby trials tested five unreleased open-pollinated varieties (OPVs), ZM-621, Shitala, Population-45, Hill Pool White, and Hill Pool Yellow to compare them with Manakamana-3. Farmers again preferred Manakamana-3 as well as ZM-621 for their stable, higher grain yield, and for other traits such as stay-green, non-lodging, large white grains, and tolerance to foliar diseases. However, Manakamana-3 and ZM-621 both had late maturity, open husks and dented grain. Both were tested with farmers on-farm coordinated farmers field trials (CFFTs) and had not been identified as this was more contractual type of participatory research. Individual traits were measured but overall farmers' preferences were not elicited. In the more collaborative participation of the mother– baby trials the overall preference was determined and farmers traded-off the late maturity and dented grains of Manakamana-3 and ZM-621 against other favorable traits. Depending on location, these genotypes yielded 15–45% more grain than the local varieties in the mother–baby trials. These results led to the release of ZM-621 as Deuti in 2006. Farmers had adopted Manakamana-3 (released in 2002) and ZM-621 (Deuti) as a direct result of PVS trials and increased area under them year after year. Farmers awareness of the varieties has increased and seeds of these varieties are under community-based seed production (CBSP). Involving farmers through a collaborative mode of participation in varietal selection overcame bottlenecks to finding new varieties that had occurred with more contractual on-farm research.

Keywords: Participatory varietal selection, Mother–baby trial, Genotype × environment interaction, Farmers' perceptions, Seed supply, Variety uptake, Adoption, Dissemination, Mid-hills

1. Introduction

In Nepal, maize is a staple food for subsistence farmers cultivating land in extremely marginal agricultural environments (Tiwari et al., 2009). Open-pollinated maize varieties developed through conventional breeding programs in Nepal have primarily targeted favorable environments and have not been adopted by resource-poor farmers in marginal areas (Ransom et al., 2003). Pixley et al. (2007) reported that many new technologies have little or no impact because they are never adopted, remaining on the shelves of research institutions. These authors further expressed that even successful technologies are seldom directly adopted by farmers in the manner prescribed by the researcher. Participatory methods successfully identified an open-pollinated variety of maize with adaptation to the local farming systems of the mid-hills of Nepal (Tiwari et al., 2009).

In this study, participatory varietal selection (PVS) (Joshi and Witcombe, 1996; Witcombe et al., 1996) was employed using a system known as mother–baby (MB) trials (Snapp, 1999; Banziger and de Meyer, 2002). This allowed farmers to evaluate and select from maize varieties in trials conducted in their own fields, entirely under their own management.

In the first paper in this series beside PVS, the effectiveness of participatory plant breeding (PPB) in maize was also discussed (Tiwari et al., this volume). Because of some institutional changes seeds of those newly generated entries using PPB approach were unfortunately lost.

Table 1. Description of varieties tested in mother–baby trials for the mid-hills over years (2004–2006).

Variety	Grain color and type	Lodging tolerance	Maturity relative to local	Release status	Test year 2004	2005	2006
Hill Pool White	Flinted-white grain	Tolerant	Same	Pre-release for mid-hills	√	√	√
Hill Pool Yellow	Flinted-yellow grain	Tolerant	Same	Pre-release for mid-hills	√	√	√
Pop√lation-45	Flinted-yellow grain	Tolerant	Same	Pre-release	√	√	√
Shitala (Population-44)	Semi-dent, white grain	Tolerant	Later	2006	√	√	√
ZM-621	Semi-dent, white and large grain	Tolerant	Later	2006	√	√	√
Manakamana-3 (Population-22)	Semi-flint, white and large grain	Tolerant	Later	2002	√	√	√
Local	White and yellow- flinted grain.	Prone to lodging	–	Local	√	√	√

We compared open-pollinated variety Manakamana-3, already released on the basis of participatory data, with newly available germplasm. The results are discussed in the context of the modes of participation employed using the typology of Biggs (1989). In this paper we describe the uptake and adoption of PVS identified varieties both Manakaman-3 and ZM-621.

2. Materials and methods

2.1. Institution

The participatory variety selection program was carried out through the Hill Maize Research Project (HMRP), which is implemented by the International Maize and Wheat Improvement Center (CIMMYT) through national research and dissemination partners in Nepal and with funding from the Swiss Agency for Development and Cooperation (SDC). The study was conducted in various villages typical of the mid-hills of Nepal, where maize is a staple food for hundreds of thousands of people. The HMRP involves multiple partners who develop, evaluate, validate, and disseminate improved varieties. They include five agricultural research stations under the Nepal Agricultural Research Council (NARC), several NGOs (LI-BIRD, CAERD, CeCRED, DoS Gorkha, TTRI, etc.) involved in development activities, a few community-based organizations such as TUKI association, and several district agriculture development offices (DADOs) under the Department of Agriculture (DoA). The project focuses on disadvantaged groups[1] and on increasing the involvement of food-deficit households. More than 300 farmers were directly involved over the 3 years in trial management, evaluation, and delivery decisions, specifically for Manakamana-3 and ZM-621 (Deuti). Of the total, 60 households were surveyed in 2006 from four sites from two mid-hill districts (three sites in Tahrathum and one in Dhakuta) whether there has been any adoption of these varieties after evaluating them.

Furthermore, structured surveys were used to measure the extent to what Manakamana-3 adopted in three mid-hill districts, i.e. Palpa, Syangja and Okhaldhunaga. Technicians from the respective district agriculture development officers (DADOs) were oriented and they selected the representative sites, key informants, and organized focus group discussion in 2007. Focus group discussions were also used, as described by Witcombe and Joshi (1996) for preference ranking of the varieties and assessment of the extent of adoption of the varieties.

2.2. Selection of varieties for participatory varietal selection (PVS)

Six maize varieties that closely matched the traits that farmers had valued (e.g. tolerance to lodging and foliar diseases, larger grain type and stay-green) were used in the PVS trials (Table 1). They were selected from advanced breeding materials of the national maize breeding program. Manakamana-3, Shitala, and Popuation-45 were acquisitions from CIMMYT, Mexico and ZM-621 from CIMMYT, Zimbabwe. The most popular variety in the PVS villages where the MB trials were implemented was used as a local check. These local varieties varied among villages and years. For statistical analysis, the local variety was the check and was considered to be the same across locations and years as was uniformly the farmers' best available option.

1. Groups of poor people that suffer from discrimination based on caste, gender, or ethnicity. These groups include women, dalit, janajati and the poorest of the poor.

Table 2. Testing location for on-farm participatory varietal selection PVS mother–baby trials from 2004 to 2006.

Variety	Number of baby trials 2004	2005	2006	Total
Hill Pool White	8	17	18	43
Hill Pool Yellow	8	17	16	41
Population-45	10	19	18	47
Shitala	7	17	22	46
ZM-621	16	20	22	58
Manakamana-3	11	16	22	49
Local	17	20	22	59
Location (maximum location each year) 59	17	20	22	
Number of baby trials	77	126	140	343
Number of mother trials	–	–	15	15

(–) No evaluation.

2.3. On-farm trials

Two types of on-farm trials were conducted: the coordinated farmers' field trials (CFFTs) of the national maize research program and mother–baby (MB) trials (Snapp, 1999). For the CFFTs, the trial design, and the mode of conduct and management were very similar to that followed in on-station research trials, but with fewer entries and a larger plot size for each entry (i.e. 13.5 m^2).

For the mother–baby trials, several varieties were provided to farmers for testing and selection under their own management (see Tiwari et al., 2009). The MB trials were conducted over 3 years (17 sites in 2004, 20 in 2005, and 22 in 2006) between 1000 and 1750 m altitude, across the mid-hills (Table 2). The research sites stretched from east to west (885 km) at 26°22′N to 30°27′N latitude and 80°4′E to 88°12′E longitude (Fig. 1). Interested maize growers from poor and disadvantaged households were selected. The environments for the trials ranged from fertile crop terraces to stressed environments and captured much of the range of biophysical conditions under which farmers grow maize. Only data from 2006 are reported for mother trials that were conducted under two contrasting management conditions: the recommended dose of fertilizer (60N:30P:0K kg ha^{-1} and 10 t ha^{-1} FYM), and farmer fertilizer management (15 t ha^{-1} FYM plus nil to 2–3 g urea per plant side dressed at second hoeing).

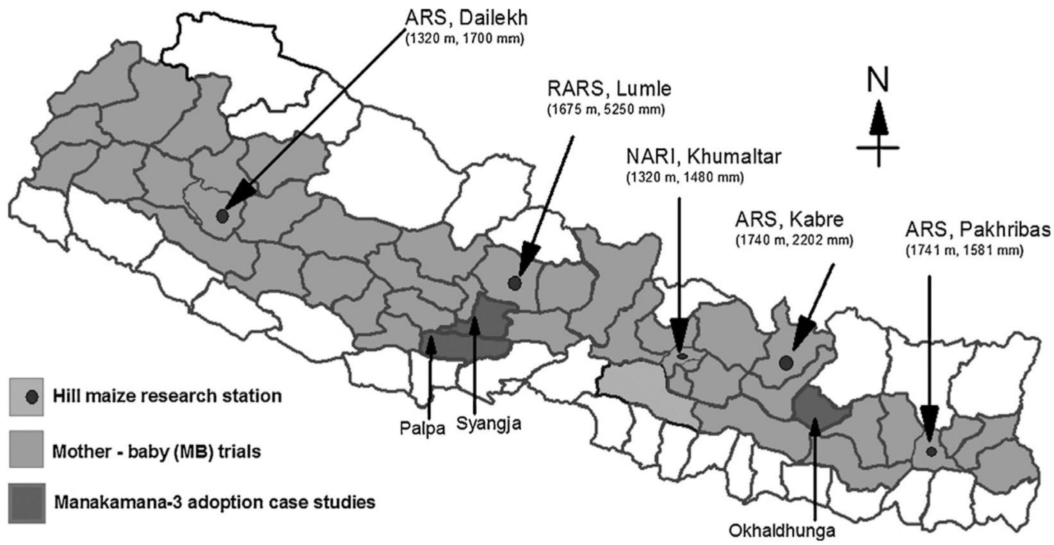

Fig. 1. Map of Nepal indicating the districts where mother–baby trials, and Manakamana-3 adoption case studies were conducted. The location of Hill Maize Research Stations are indicated with altitude (m) and mean annual precipitation (mm per year).

Baby trials were more numerous (77 in 2004, 126 in 2005, and 140 in 2006) and involved each farmer growing one new variety alongside his/her local variety in a single replication, with farmers serving as replicates. Group meetings were organized at the onset of each trial and usually 1 kg seed of each of the varieties was allotted at random to participating farmers who were asked to grow them under their own management. The trials were generally sown at the normal planting time – early April through late May from east to west – except in 2004, when crop sowing was delayed by 2 weeks across the mid-hills due to late rains. As part of a risk-aversion strategy, farmers used a higher seeding rate than recommended. Depending on location and farmer, the plot size for the baby trials was 200–350 m^2.

Varietal evaluation involved preference rankings for multiple traits through focus group discussions with farmers at about 80–90 days after sowing, when the crop was at late reproductive (milking) stage, and again 2–3 months later for postharvest traits in 2005 and 2006. Farmer perceptions were obtained using the methods described in Tiwari et al. (2009).

2.4. Data summary and statistical analysis

Analyses of the baby trials were conducted on the fixed set of varieties at random sites in 3 years (2004–2006). The data for varieties were unbalanced; we used a mixed effect REML analysis (Virk and Witcombe, 2008) for grain yield using GenStat 8 in which sites and years were treated as random effects. The REML model was:

$$\text{fixed model} = \text{constant} + \text{variety} + \text{random model}$$
$$= \text{site} + \text{year} + \text{site} \times \text{year}$$

The significance of difference in the REML analysis was tested with a Wald statistics which forms a chi-square distribution.

Qualitative data from farmers' perceptions were summarized for preharvest and postharvest traits. Analyses variance (ANOVA) using GenStat Discovery was carried out on the mother trial data. Each individual mother trial (each conducted by a different farmer) was taken as a replicate-block, and a two-way ANOVA was run with varieties and farmers (=replicate-block) across sites as cross-classified factors. The variety × farmer interaction was used as the error in computing an F-test.

The mean value of all baby trials at a site (generally five farmers for each variety per site) was assumed as a replicate-block because some of the partners only reported across village means and not the values for each baby trial. The LSD was computed to compare varietal differences in mother–baby trials (Snedecor and Cochran, 1973).

The grain yields of ZM-621, Manakamana-3 and the local variety from all of the trials from 2004 to 2006 were regressed on to the trial means that represented an environmental index (Finlay and Wilkinson, 1963).

At each site several groups had ranked the varieties (1 = best and 7 = worst). The mean scores at each site were computed and again converted to integers to give ranks. The data were then subjected to an ANOVA with each site being a replicate.

Case studies on the adoption of Manakamana-3 and ZM-621 (Deuti) were conducted. Data were collected in 2008 from 60 farmers who had participated in on-farm evaluation. The four sites were from two districts, i.e. Dhankuta and Tehrathum. These households were randomly selected within four selected villages where PVS were implemented since last 3–4 years where Manakamana-3 and ZM-621 were examined. The sampled farmers were asked how extensive was the area planted to PVS varieties at a household level over the years.

Similarly, three hill districts, Palpa, Syangja and Okhaldhunga were purposively selected to see how extensive is the area planted to Manakamana-3. This was assessed by focus groups discussions and the information was verified through triangulation by key informants in each district who were asked to provide estimates of the area under Manakamana-3. Adoption was considered irrespective of the source of seed used to plant the variety except for farm-saved seed that had been recycled for more than 3 years.

3. Results and discussion

3.1. PVS trials

ZM-621 and Manakamana-3 had higher grain yields than the local check over 3 years. On average across the 3 years Manakamana-3 and ZM-621 yielded the same with the exception of 2004, where ZM-621 produced higher yield than Manakamana-3 ($P < 0.05$). Yearly variation in grain yields was also observed, 2004 being the lowest-yielding year due to both early and terminal droughts (meteorological data not shown).

The late-maturing maize varieties like Manakamana-3 and ZM- 621 were more tolerant of drought stress than the early maturing ones, when drought occurred at an early vegetative stage. The explanation was that these varieties could recover their growth at a later stage. Moreover, they also escaped the terminal drought experienced by earlier entries as there were late rains. Experience has shown that occurrence of an early drought during the maize season was more frequent than mid-season and terminal drought because Nepal's rainfall patterns.

In the mother trials fertilizer applied at 60N:30P:30K kg ha^{-1} plus 10 t ha^{-1} FYM had a significant effect on grain yields over the farmers' management of maize crop ($P < 0.05$), which was not surprising. However, simple analyses of yield taken into account neither the cost nor risk of adding fertilizers. The interaction between fertilizer and variety was not significant.

In Nepal, genotype development is usually carried out on research stations, under optimum management conditions. The national on-farm research program in CFFTs are also carried out in farmers' fields to verify and validate on-station findings for a wide range of environments to represent the suitability of the target environment. The CFFT trials are problematic, as they are conducted under environments that mimic on-station environments. Researchers emphasize the need to select better sites, and apply the same level of inputs, and timely irrigation, and other intercultural operations as they apply for their on-station work. These conditions are quite different from those of the target environments: farmers' fields. More importantly, multi-location variety trials on farmers' fields use recommended fertilizers and other recommended production inputs implying that the target farmers apply these inputs. However, in researcher-managed trials use much higher levels of inputs than those used by resource-poor farmers in marginal environments who can ill afford the costs and risks of applying them (Bisset, 2002; Witcombe et al., 2003).

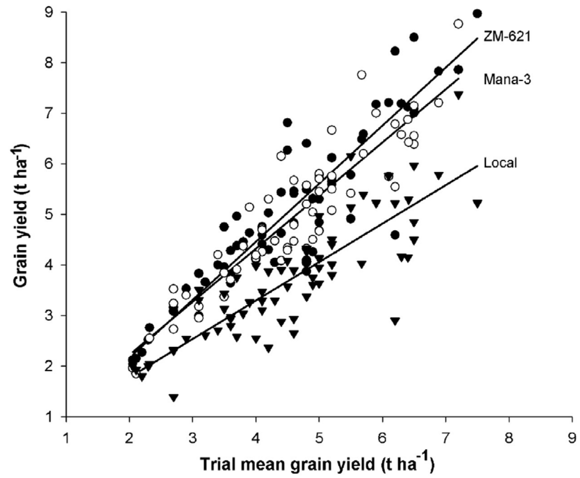

Fig. 2. Regression of grain yield (t ha^{-1}) of ZM-621 (Filled circles), Manakamana-3 (open circles) and Local (triangles) on to the mean grain yield of all varieties grown in a trial over locations conducted from 2004 to 2006. The computed regression parameters were: Deuti ($R^2 = 0.81$; $a = 0.13 \pm 0.32$; $b = 1.15 \pm 0.07$); Manakamana-3 ($R^2 = 0.85$; $a = 0.12 \pm 0.28$; $b = 1.05 \pm 0.06$); Local ($R^2 = 0.71$; $a = 0.26 \pm 0.27$; $b = 0.76 \pm 0.06$).

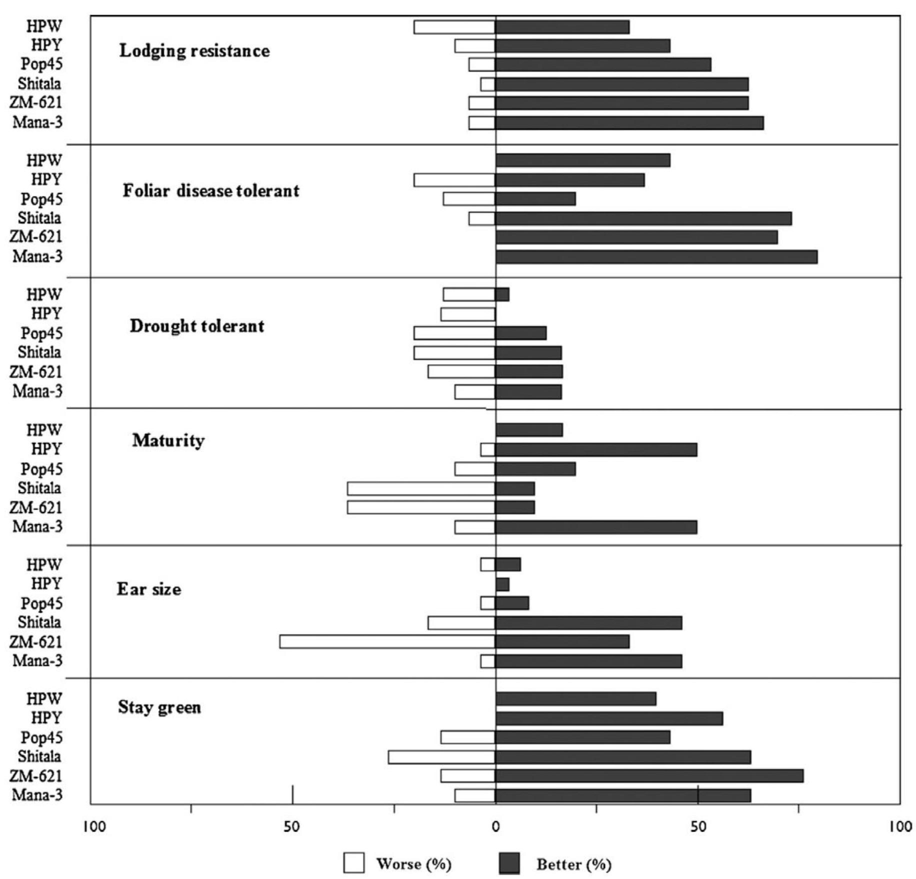

Fig. 3. Farmers' perception on preharvest assessments of six PVS varieties during 2005–2006. Farmers' perceptions as to whether the test varieties were better or worse than the local varieties are indicated by lines in percent. The shorter the line, the more similar the variety is to the local. Percentage of farmers expressed as similar to the local is assumed to be zero (neither better nor worse) that is why it does not add to 100%.

If there is no difference in the conduct and management of trials between on-station and on-farm, there is no difference in expected results, making it a waste of resources and efforts (Bisset, 2002). Rather, on-farm research should explore the variation that exists in farmers' fields, and how local biological and socio-economic conditions interact with known genotype effects. Smith et al. (2001) noted the advantage of testing technology in farmers' environments instead of using on-station tests: better recommendations can be made as to the conditions under which a variety will be worthwhile and for whom.

3.2. Farmers' preference rankings

Manakamana-3 was still the most widely preferred genotype, followed by ZM-621. The rank of Manakamana-3 was highly consistent across environments and the local variety was the least preferred (Table 4).

3.3. Genotype × environment (G × E)

The great heterogeneity of crop production conditions in the mid-hills of Nepal presents numerous challenges for researchers and farmers for identifying suitably adapted varieties. Selection of suitable varieties thus becomes more difficult than is the case under favorable conditions (Bellon, 2006). In marginal areas, abiotic and biotic stresses play an important role in the performance of any crop variety.

The regression coefficients of both ZM-621 and Manakamana-3 were close to one, an average response, while the local variety responded less to improved environments and could be superior in poor maize growing environments of less than 2 t ha^{-1} (Fig. 2). Both Manakamana-3 and ZM-621 showed a better general adaptation to the environments sampled in the mother–baby trials than local. Both Manakamana-3 and ZM-621 were derived from broad-based populations that had broad adaptation.

In general, there was a good agreement between the preference ranking by farmers based on visual observation and grain yield observed by them. Farmers' rankings based on visual observation considering traits they liked (Figs. 3 and 4) generally with higher stable grain yields (Fig. 2, Table 3).

3.4. Farmers' perceptions

Farmers perceived that compared with the local the new varieties had shorter and stronger stems that conferred resistance to lodging (Fig. 3). The test entries had higher resistance to foliar diseases, particularly turcicum blight (*Exserohilum turcicum*) and gray leaf spot (*Cercospora zeae-maydis*). Manakamana-3 and ZM- 621 were perceived to have similar levels of drought tolerance to that of the local varieties that farmers considered as adapted to harsh environments, including drought. ZM-621 had smaller ears, whereas Manakamana-3 had the largest ears of all the varieties. Both ZM-621 and Manakamana-3 had stay-green traits (Fig. 3) that made them preferable for livestock (Fig. 4). For shelling percent, Manakamana-3 was better than ZM-621, but both were inferior to the local check. Taste and color preferences were similar, since both were white-grained the preferred color in the mid-hills of Nepal (Tiwari and Sinclair, 2002).

Manakamana-3 and ZM-621 had higher market values, since they had larger grains; however, farmers perceived them

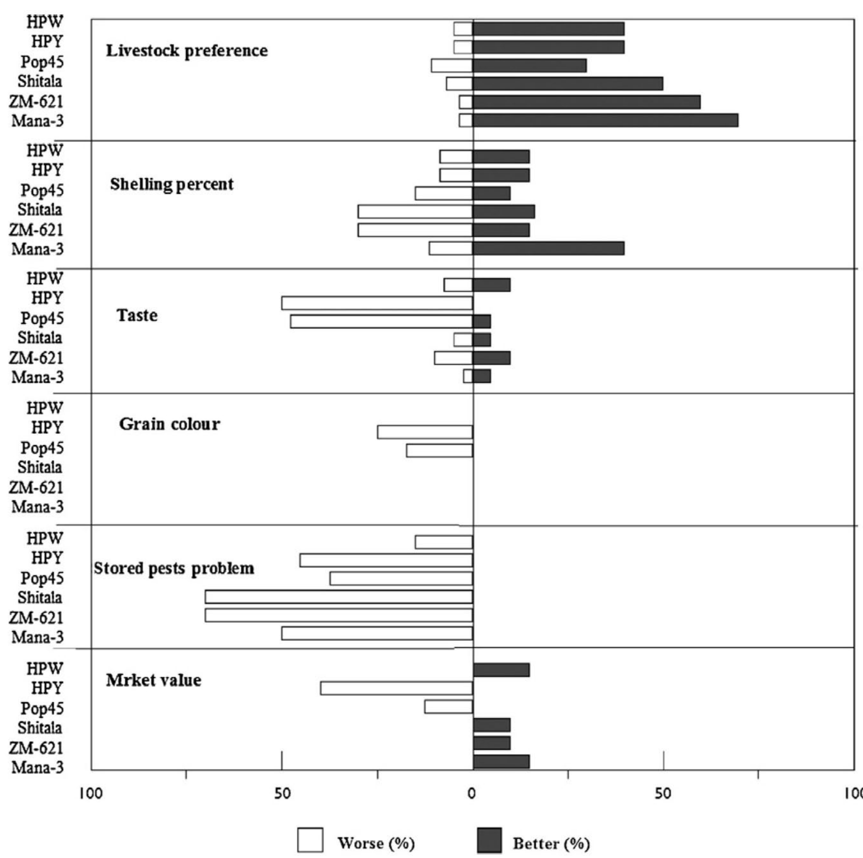

Fig. 4. Farmers' perception on postharvest assessments of six PVS varieties during 2005–2006. Farmers' perceptions as to whether the test varieties were better or worse than the local varieties are indicated by lines in percent. The shorter the line, the more similar the variety is to the local. Percentage of farmers expressed as similar to the local is assumed to be zero (neither better nor worse) that is why it does not add to 100%.

as susceptible to stored grain pests (Fig. 4). These observations revealed that participatory varietal selection relying on focus group discussions – particularly involving the poor and women members of farming households – provided farmer feedback (Table 4) not normally accessible through on-station trials or researcher-managed CFFTs.

3.5. Release of Population-22 and ZM-621

Manakamana-3 (Population-22) and Deuti (ZM-621) were released by the variety release and registration sub-committee under the national seed board for cultivation in the mid-hills of Nepal, as farmers perceived them as their favorites. Comprehensive data from all national coordinated program trials obtained before 2000 and from on-farm PVS trials (during 1999–2001) were considered for the release of Manakamana-3. Manakamana-3 was the most preferred variety over others with higher grain yield (Tiwari et al., 2009). For Deuti's release, the on-station data from2000 to 2004, as well as data from2003 to 2005 on-farm CFFTs and on-farm PVS trials (during 2003–2006), were considered. Farmer perceptions and the rankings of Manakamana-3 and Deuti as favorites significantly helped their commercial release.

Table 3. Performance (yield t ha^{-1}) of PVS (baby trials) varieties across 17 sites in 2004, 20 in 2005 and 22 in 2006 (see Table 2).

Variety\year	2004	2005	2006	Combined
Hill Pool White	4.30	4.89	4.39	4.53
Hill Pool Yellow	4.18	4.85	4.51	4.54
Population 45	4.39	5.05	4.74	4.76
Shitala	4.04	5.13	4.72	4.73
ZM-621	5.08	5.02	5.25	5.12
Mananakamana-3	4.69	5.08	5.17	5.02
Local	3.32	3.65	3.81	3.61
Mean	4.29	4.81	4.66	4.62
Significance	***	***	***	***
S.E.D.	0.19	0.25	0.20	0.16

*** $P < 0.001$

Table 4. Combined analysis of variance for farmers overall preferences (rank 1 = best and 7 = worst) among PVS varieties irrespective of years (2004–2006) and locations.

Variety\year	2004	2005	2006	Mean	Rank
Hill Pool White	3.9	2.9	3.3	3.4	IV
Hill Pool Yellow	3.6	3.0	5.4	4.3	VI
Population-45	3.0	4.6	3.0	3.3	III
Shitala	3.3	3.5	3.6	3.5	V
ZM-621	2.3	3.5	2.2	2.5	II
Manakamana-3	2.5	2.1	1.8	2.1	I
Local	4.6	6.4	5.4	5.3	VII
Mean	3.3	3.7	3.5	3.5	
Significance				***	
S.E.D. (variety)				0.301	

*** $P < 0.001$

3.6. Adoption of Manakamana-3 and Deuti

In the formal research system, promising varieties do not become immediately available to farmers when researchers identify them as outstanding; official release for seed multiplication and distribution to farmers takes several years. Morris et al., 1994 cited a lag phase of about 7–8 years between variety development and appreciable adoption by farmers, through conventional breeding, with less guarantee of adoption and a reduction in benefits to farmers and society related to the extent of the delay in adoption. The increased speed of adoption of a variety is a major advantage of participatory approaches, as it leads to higher returns on investment in crop improvement (Pandey and Rajatasereekul, 1999; Brennan and Morris, 2001). Virk et al. (2005) concluded that the greatest efficiency gain from PVS was that it reduced the time a variety took to reach farmers' fields by 8–10 years. In our case PVS also enhanced the dissemination rate since farmers were able to adopt varieties after testing them as they had access to seed (Table 5). Adoption and dissemination of Manakamana-3 began in 2000 and Deuti in 2005, through farmer-to-farmer seed exchanges within villages. Visits to fields of participating farmers in the following crop seasons revealed that some farmers had expanded the area of maize (Table 5). Manakamana-3 was adopted somewhat more rapidly than Deuti and both have contributed to an overall increase in maize production at household level over years (Table 5). The higher adoption of Manakamana-3 as compared to Deuti is mainly due to the fact that Deuti is relatively recently released and has not been so popularized as Manakamana-3.

Community-based seed production was pursued to provide timely access at affordable prices to quality seed of the improved varieties in remote areas where the national seed system was not working (Fig. 5). For both varieties, community-based seed production began prior to formal release. Year by year, as demand for the varieties has risen, the area in communities dedicated to multiplying seed has increased significantly (Fig. 5).

The area planted to Manakamana-3 in Palpa, Syangja and Okhaldhunga districts was assessed (Table 6). Overall, 11% of the area planted to maize in Palpa was Manakamana-3, while it was 10% in Syangja and 35% in Okhaldhunga. This contributed to increased maize production that led to more income and improved food security at household level. Considering the time and limited resources invested this is a significant contribution, which was only possible with the collaborative approach that the HMRP had followed where farmers played major roles in decision. It was also learnt that the diffusion of Manakamana-3 had diffused to neighboring districts and beyond, mainly through farmers networks of information and seed exchange.

Morris, 2001 reported that about 50% of maize farmers in nontemperate regions plant farm-saved seed of traditional varieties, thus failing to benefit from conventional maize breeding. Maize in the mid-hills is grown chiefly from farm-saved seed of local cultivars—only about 6% of all the maize grown in the

Table 5. Increase in area (ha) and production (t ha^{-1}) of PVS varieties (Manakamana-3, Deuti) at household level over years.

Year	Area (ha) per household		Production (t ha^{-1}) per household	
	Manakamana-3 (n = 39)	ZM-621 (Deuti) (n = 21)	Manakamana-3 (n = 39)	ZM621 (Deuti) (n = 21)
2003	0.03 ± 00	0.02 ± 00	0.06 ± 0.01	0.04 ± 0.01
2004	0.17 ± 0.11	0.11 ± 0.07	0.24 ± 0.02	0.16 ± 0.01
2005	0.29 ± 0.13	0.14 ± 0.08	0.45 ± 0.02	0.21 ± 0.02
2006	0.38 ± 0.12	0.23 ± 0.09	0.75 ± 0.02	0.61 ± 0.02

Numbers against each mean value are S.E.M; average landholding in Nepal hill condition = 0.75 ha, however, maize area under cultivation is much smaller.

Table 6. Manakamana-3 adoption in Palpa, Syangja and Okhaldhunga, 2008. Information were collected from FGDs by respective DADO staff and triangulation was done by key informants in August 2008.

Situation	Districts		
	Palpa	Syangja	Okhaldhunga
Total maize area in district ('000 ha)	20	31	12
Total households ('000)	50	62	30
Total households growing maize in district ('000)	42	45	25
Total maize production (t)	40	102	23
Total households growing Manakamana-3 ('000)	8	10	10
Total area under Manakamana-3 (ha)	2	3	4
Manakamana-3 yield (t ha^{-1})	2.8	4.2	2.4
Local variety yield (t ha^{-1})	1.7	2.5	1.3
Increase in household maize production (t ha^{-1}) after adopting Manakamana-3	1.1	1.7	1.1
Increase in food availability at household level (month)	1	1	1.7

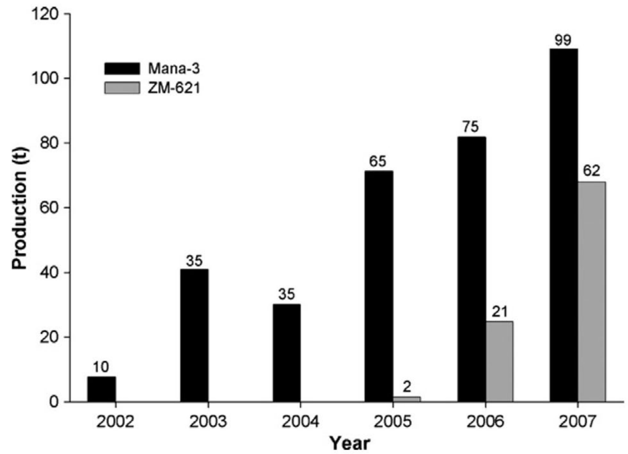

Fig. 5. Seed production of Manakamana-3 and Deuti (t) by farmers groups with area of production (ha) indicated above the bars.

mid-hills comprised modern varieties (Chemjong et al., 1995). This rises to 30% in project-intervened and accessible areas, where farmers were directly involved in technology verification and dissemination (Ransom et al., 2003).

The program has demonstrated that it can make the greatest contribution in tackling the rural food deficit by offering new technologies in the mid-hills: previous studies have shown that variety alone contributed 15–20% of yield gain (Tiwari et al., 2004). In present study this was found to be as high as 45%. This higher contribution might be because this study covered new geographical areas as well as farmers where intervention of new maize varieties was almost negligible.

4. Conclusion

Farmer participation in technology development is very important since they are the ultimate arbiters of whether a particular technology is adopted. Researchers must decide how and when to involve farmers in meaningful participation and decision making. In the present study, farmers traded-off higher grain yield against longer maturity—something researchers had not been prepared to do. Involving farmers helped to overcome the hesitancy of researchers to recommend these varieties. Given the farmers' expressed preference for these varieties and the evidence of their early adoption and seed multiplication by communities, it is likely the varieties will be widely adopted through the farmers' innovation system. The direct food security impacts of new improved seeds received by rural-poor through PVS or CBSP was important for improving household level food security.

Acknowledgments — This publication is an output from a collaborative initiative between Nepal Agricultural Research Council (NARC) and the International Maize and Wheat Improvement Center (CIMMYT) funded by the Swiss Agency for Development and Cooperation (SDC) through the Hill Maize Research Project (HMRP). The views expressed in this paper are not necessarily those of these agencies. We are thankful to farmers of the mid-hills across Nepal. Help received from hill stations under NARC, hill DADOs under DoA, NGOs and CBOs, and their associated staff, is thankfully acknowledged. The authors appreciate the assistance of Mr. Surath Pradhan in editing figures. We would also like to thank Dr. Kevin Pixley, Associate Director, Global Maize Program, for his support and guidance. Thanks are also due to Prof. J.R. Witcombe, CAZS Natural Resources, Bangor University for his help, and Dr. D.S. Virk for guiding data analysis. Finally, we thank CIMMYT editors Allison Gillies and Mike Listman for their assistance.

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