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Participatory wheat varietal selection in Gilgit Baltistan of Pakistan

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Participatory varietal selection is a rapid and cost effective way of identifying farmer's preferred variety from diverse genetic material. A number of indigenous advanced wheat lines, and exotic material from CIMMYT, ICARDA and Turkey were tested using participatory varietal selection during 1998 to 2001 in the northern areas (Gilgit Baltistan) of Pakistan. Based on the farmers' preference criteria, annual workshops of field management units and combined data from 1998 to 2001, three wheat lines NR-74, NR-142 and NR-152 were selected. These lines yielded 50% more in grain and straw, and had desirable grain colour and bread making quality than local varieties. Seeds of these lines were distributed in small quantity among the village Organisations and Woman Organization for seed multiplication. The results of a household-level survey during 2007 showed that the selected wheat lines were cultivated over an area of 70% in the target area, indicating that the adoption rate of varieties was improved by farmers' participation. Participatory varietal selection approach is, therefore, suggested to adopt in resource-poor areas to develop varieties that best suit the needs of the farmers.

Key words: Gilgit Baltistan, farmers' participatory research, wheat, participatory varietal selection.

INTRODUCTION

Federally administrated Gilgit-Baltistan region of Pakistan is located in the panorama of three world's highest mountainous ranges Himalaya, Karakuram and Hindukush. Majority of the area is rouged mountainous with a population of one million in 650 villages scattered over 72,500 km^2 (Anonymous, 2002). Average land-holding is below one hectare (ha), half of which is devoted to wheat. Wheat is grown from November to July in regions up to 1800 m altitude, whereas in April-May to August-September in regions 1800 m above sea level. Wheat occupies a central position in the fascinating and complex farming system of Gilgit-Baltistan region of Pakistan. It is grown for both its grain and straw, since grain is the main dietary item of the farmers and wheat straw is the major cattle feed during the severe winter (Qamar et al., 2004). Farmers of the region have been involved in empirical selection of wheat varieties for centuries either by exchanging seeds of new varieties between villages or bringing seeds from far-flung regions (Hussain, 1986). Farmers of the region prefer varieties with desirable grain colour and bread-making quality, and high grain and straw yield. Majority of the farming community believe that the dwarf or semi-dwarf varieties released for plains of the country are inferior in grain quality and yield of straw to the tall varieties (Hussain, 1986). The tall varieties/land races, being grown in the

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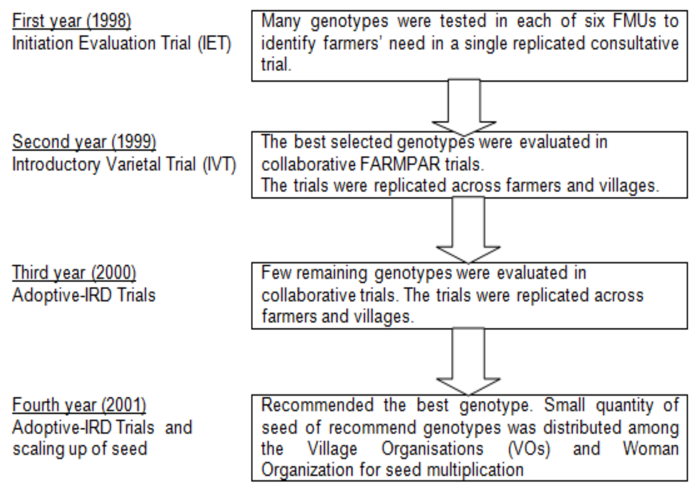
region, are low yielding due to their susceptibility to diseases (smut and rusts) and lodging. Factors contributing to the low yields of wheat in this region include lack of research institutes for developing improved varieties along with specific production technology, perpetuation of traditional farming system, shorter growing season, poor soil texture and structure, and low soil fertility, So far, no significant research efforts aiming at the development of specific plant ideotype for this region have been undertaken. Consequently, the yields of varieties are significantly lower as compared to their yields in plain areas of the country.

Wheat production in developing countries dramatically increased in 1960s with the introduction of semi-dwarf wheat varieties. These high yielding varieties were more responsive to agricultural inputs and were, therefore, adopted in more favourable agricultural environments (Witcombe, 1996). Wheat production in Pakistan also increased significantly following the introduction of semi-dwarf varieties. However, majority of the poor farmers in marginal areas did not benefit from these varieties. Varieties released for mainlands of Pakistan performed poorly in the marginal mountainous lands of Gilgit-Baltistan (Qamar et al., 2004). Moreover, similar to other developing countries, little efforts have been made to develop varieties that best suit the requirements of resource poor farmers. As a result, majority of farmers in the marginal areas grow the low yielding local varieties or land races.

Several approaches have been recommended (Maurya et al., 1988; Farrington and Martin, 1988; Sthapit et al., 1994; Joshi and Witcombe, 1996; Witcombe, 1996; Witcombe and Virk, 2001; Smith et al., 2001) for poor farmers of marginal areas to identify desirable varieties. Josi and Witcombe (1996) concluded that varieties suited for resource-poor farmers existed amongst the released varieties, but farmers had no opportunity to try them in their fields. Chambers et al. (1989) reviewed a successful story of the selection of desirable variety by farmers when offered with 'a basket of choice' of diverse genetic material. In Uttar Pradesh, India, farmers identified superior rice varieties by participatory approach (Maurya et al., 1988). In a collaborative research between ICRISAT and Rajasthan Agriculture University, India, farmer participatory research was used to identify pearl millet varieties suited for Rajasthan (Weltzien et al., 1996). Witcombe et al. (1996) declared the 'top down' centralized approach of research inappropriate for the farmers in resource-poor areas. They thought that farmer's preferred varieties were not being selected using this approach, Similarly, Witcombe et al. (1998) observed a lower adoption of the modern improved varieties by farmers in the district of India with poor productive agro-ecological conditions. Witcombe (1996) recommended participatory varietal selection (PVS) and participatory plant breeding (PPB) for the development and promotion of new agriculture technologies suited for resource-poor farmers living in complex, diverse and risk prone environments. PVS helps farmers evaluate near-finished or finished products in collaboration with professional breeders, whereas PPB aids farmers select desirable genotypes from segregating population. The objective of the present study was to assess the impact of participatory varietal selection in a resource poor area (Gilgit-Baltistan) of Pakistan.

MATERIALS AND METHODS

A systematic farmer's participatory research approach for wheat varietal selection was initiated during 1998 to 2002 by Agha Khan Rural Support Programme (AKRSP), following the recommendation of John R. Witcombe, a consultant from Centre for Arid Zone Studies, University of Wales Bangor, UK. The selection scheme (proposed by John R. Witcombe) followed during the FAMPAR programme is outlined below:



The program was initiated with collaboration of Wheat Program at National Agricultural Research Centre (NARC) and farming community in six Field Management Units (FMUs) of AKRSP throughout the program area in the Gilgit region, Northern Areas of Pakistan. The plant material used in the PVS included NARC elite lines (NRs) and exotic material from CIMMYT, ICARDA and Turkey. NRs performed better than the exotic genotypes, so data of the exotic genotypes are not given here. These new elite wheat lines were tested in collaboration research, Farmer Managed Participatory Research (FAMPAR) varietal trials. In these trials, seeds of advanced lines were given to selected farmers of different Village Organizations (VOs) and woman organizations (WOs) in each FMU. The advanced lines along with local varieties were evaluated under farmers' managed practices. The trials were replicated across farmers and villages and were assessed by participatory methods (farm walks, focus group discussion and household-level questionnaires). Farm-walks and focussed group discussions were held on the characteristics of each NR to identify farmer's preference. In farm walks, groups of farmer visited each other's fields along with AKRSP researchers, encouraged the farmers to assess the performance of the new elite wheat lines (NRs). Yield data were recorded and analysed using Statistical Package for the Social Sciences (SPSS).

On the basis of participatory appraisal system, six NRs were promoted for second year (1999) testing. These six NRs along with eight additional NRs were put in introductory varietal trial (IVT) in all six FMUs for evaluation in collaborative research (Farmers managed research varietal trials) trials. The trials were replicated

Table 1. Comparison of the highest yielding NRs with local types in Gilgit Baltistan region of Pakistan during 1998.

Location /FMU	Highest yielding line	Yield ton ha^{-1}	Yield ton ha^{-1} (local check)	% increase over check
FMU Gilgit				
Pari	NR-74, NR-152	5.0	3.2	56.3
FMU Nagar				
Sikanderabad	NR-33, NR-74	5.2	2.0	160.0
Nilt	NR-142	5.6	2.2	154.5
Broshal Hopper	NR-74	4.1	2.0	105.0
FMU Hunza				
Hasanabad	NR-74	4.1	1.8	127.8
Nasirabad	NR-33	5.7	3	90.0
Faizabad	NR-58, NR-33	4.1	2.7	51.9
Aliabad	NR-61	5.3	2.3	130.4
Sheshkat Gojal	NR-100	3.5	3	16.7
FMU Punyal				
Gahkuch Bala	NR-33	4.3	1.8	138.9
Gahkuch Pain	NR-33	3.8	3.1	22.6
Hasis	NR-152	4.8	3.3	45.5
FMU Gupis				
Gupis proper	NR-33	3.8	1.9	100.0
FMU Astore				
Astore proper	NR-58	2.5	1.8	38.9

across farmers and villages. The participatory methods applied for performance evaluation were farm-walks and focussed group discussions. The quantitative data like grain and straw yield were obtained and analysed by AKRSP researchers in collaboration with farmers. The farmers were asked to compare the NRs with local checks for different traits like vegetative growth, diseases and pest resistance, plant height, seed size and colour, bread quality, taste, adaptability to local conditions and grain and straw yields.

Based on the excellent performance in IVT, the six NRs were promoted to Adoptive-IRD trials for third year (2000). In adoptive-IRD, the promoted entries were evaluated in collaborative trials. The trials were replicated across farmers and villages. The entries were evaluated by participatory assessment techniques using farm-walks and group discussions. Grain and straw yield data were compiled and analysed by using statistical package for the social sciences (SPSS). Analysis of performance of the entries in adoptive-IRD trials across location was done by using ranking of entries in the trial. On the basis of excellent performance, NR-74, NR-142 and NR-152 were promoted for scaling up of seed. Small quantity of seed of recommended entries was distributed among the Village and Woman Organisations across the FMUs for seed multiplication. Farmers were allowed to evaluate the elite lines as per their preferences.

During 2007, a household level survey was conducted to review the dissemination of recommended wheat lines and their impact on wheat production in the target area. Four villages were selected for the survey. The data were generated and evaluated by focused group discussions held on the sites of the varieties grown. Household-level questionnaires were used to determine the type of varieties and reaction of household members to the varieties they grew.

RESULTS

In the Initiation Evaluation Trials (IETs), grain and straw yields of seven NRs, NR-33, NR-58, NR 61, NR-74, NR 100, NR-142 and NR-152 were higher than the local/check varieties (Tables 1 and 2, Figure 1). Increase in yield over local check ranged form 16.6% in FMU Hunza to 160% in FMU Nagar (Table 1). At FMU Gilgit, which is double cropping zone, NR-74 had the highest grain yield (5 ton ha^{-1}) followed by NR-152 (4.9 ton ha^{-1}) and NR-58 (4.5 ton ha^{-1}) (Table 2 and Figure 1). At FMU Nagar, NR-74 produced maximum grain yield (4.9 ton ha^{-1}) followed by NR-142 (4.8 ton ha^{-1}) and NR-33 (4.5 ton ha^{-1}). NR-33 performed best in FMUs Hunza, Punyal and Gupis, whereas NR-58 produced the maximum grain yield in Astore (Figure 1, Table 2). On the basis of average performance over the FMUs, the highest grain yields were produced by the lines NR-74 (4 ton ha^{-1}), NR-152 (3.9 ton ha^{-1}) and NR-33 (3.9 ton ha^{-1}) (Table 2 and Figure 1). Farm-walks and focused group discussions on different attributes of the advanced lines ranked NR74

Table 2. Yield (ton ha^{-1}) of the best NRs in different FMU in 1998.

NRs	FMU Gilgit	FMU Nagar	FMU Hunza	FMU Punyal	FMU Gupis	FMU Astore	Average
NR-33	4.2	4.6	4.5	4.3	3.8	1.9	3.9
NR-58	4.5	4.3	4.2	3.8	3	2.5	3.7
NR 61	4.1	4.2	4.4	3.6	3.2	1.6	3.5
NR-74	5.0	4.9	4.3	4.0	3.7	2.2	4.0
NR 100	4.0	4.1	4.1	3.2	2.9	1.8	3.4
NR-142	4.3	4.8	3.9	3.9	3.5	2	3.7
NR-152	4.9	4.5	4.0	4.2	3.4	2.4	3.9

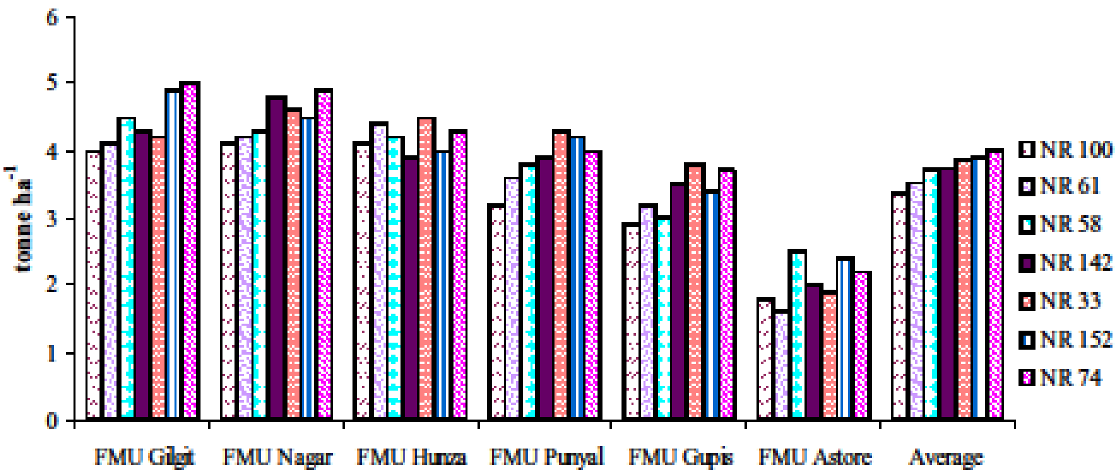


Figure 1. Yield of best NRs in different FMUs during 1998.

Table 3. Preference ranking$^{\lambda}$ of Wheat lines on the basis of performance for grain and straw yield and other traits in 1998$^{¥}$.

NRs	FMU Gilgit	FMU Nagar	FMU Hunza	FMU Punyal	FMU Gupis	FMU Astore	Average rank
NR 33	5	3	1	1	1	7	3.0
NR-58	3	5	4	5	6	1	4.0
NR 61	6	6	2	6	5	5	5.2
NR-74	1	1	3	3	2	3	2.2
NR 100	7	7	5	7	7	6	6.5
NR-142	4	2	7	4	3	4	4.0
NR-152	2	4	6	2	4	2	3.3
Local Check	7	5	6	7	4	3	5.3

$^{\lambda}$ Preference ranking on a scale from 1(excellent) to 7(Worst); $^{¥}$ mean of pre harvest and post harvest assessment by farmers and AKRSP agriculturists during farm walks, group discussions and annual FMU workshops.

first followed by NR-33, and NR-152 (Table 3). NR-33, NR-58, NR-74, NR 100, NR-142 and NR-152 showed excellent performance in IVT during 1999 (Table 4). In adoptive-IRD trials during 2000, NR-152 ranked first and both NR-142 and NR-74 ranked second (Table 5). These three NRs also had desirable grain colour (white), good taste and were suitable for local bread and chapati making. NR-74 and NR-152 were earlier than local check, whereas NR-142 was similar to local check in maturity.

In 2001, farmers mostly grew the promoted lines on medium fertile lands using their own management practices. The grain yield and other agronomical traits were measured for on-farm plots and were used for

Table 4. Preference ranking[λ] of Wheat lines for grain yield and other agronomic traits in 1999.

Lines/check	FMU Gilgit	FMU Nagar	FMU Hunza					FMU Punyal				FMU Gupis	Average rank[Ɣ]	Decision
	Pari	Nilt	Broshal Hopper	Nasirabd	Faizabad	Aliabad	Sheshkat Gojal	Gahkuch Pain	Hasis 1	Hasis 2	Imit Mujawa	Gopis proper		
NR-33	•	×	3	1	3	2	•	1	•	•	•	1	1.8	Promoted
NR 38	×	×	×	×	×	×	×	×	•	•	•	×	•	Rejected
NR 43	×	•	×	×	×	×	×	×	×	×	•	×	•	Rejected
NR 51	•	×	×	×	×	×	×	×	•	•	•	×	•	Rejected
NR-58	•	×	2	2	2	2	2	•	•	•	•	•	2	Promoted
NR 61	•	×	•	•	•	1	3	×	•	•	3	•	2.3	Rejected
NR-74	1	×	1	•	•	•	•	×	•	2	1	•	1.3	Promoted
NR 100	•	×	•	1	1	•	1	3	•	1	•	•	1.4	Promoted
NR 102	•	•	•	×	×	×	×	•	3	•	2	•	2.5	Rejected
NR 138	3	3	•	×	×	×	×	×	•	•	•	•	3.0	Rejected
NR-142	1	1	×	×	×	×	×	2	•	3	•	2	1.8	Promoted
NR 149	•	•	×	×	×	×	×	×	•	•	•	•	0	Rejected
NR-152	2	2	×	×	×	×	×	×	1	•	×	×	1.7	Promoted
NR 176	×	×	×	×	×	×	×	•	2	•	•	3	2.5	Rejected
Local Check	•	•	•	•	•	•	•	•	•	•	•	•	•	

[λ] Mean of pre harvest and post harvest assessment by farmers and AKRSP Agriculturists during farm walks, group discussions and annual FMU workshops. First (1), Second (2), third (3); • unranked; × not included; [Ɣ] Average rank over locations.

Table 5. Preference ranking[λ] of Wheat lines for grain yield and other agronomical traits in 2000 [¥].

Lines/check	FMU Nagar		FMU Punyal			FMU Gupis	Average rank	Decision 1999	Decision 2000
	Sikanderabad	Budalus	Chamlaing	Gahkuch Pain	Imit Mujawa	Hamar Dass			
NR 33	1	5	×	3	5	4	3.6	Promoted	Rejected
NR-58	5	4	×	4	×	1	3.5	Promoted	Rejected
NR-74	4	3	5	2	4	2	3.3	Promoted	Promoted
NR 102	×	×	4	×	×	5	4.5	Rejected	Rejected
NR 138	×	1	6	×	×	×	3.5	Rejected	Rejected
NR-142	3	×	2	5	×	×	3.3	Promoted	Promoted
NR-152	2	2	1	1	2	3	1.8	Promoted	Promoted
Check (Kohistan 97)	6	6	6	2	3	6	4.8		
Check (Tatara)	6	6	6	6	1	6	5.2		

[λ] Preference ranking on a scale from 1(excellent) to 6 (Worst); [¥] Mean of pre harvest and post harvest assessment by farmers and AKRSP agriculturists during farm walks, group discussions and annual FMU workshops; × not included.

Table 6. Grain yields of the best wheat lines as percentage of yield of the local check in different FMUs in 2001

NRs	FMU Nagar			FMU Punyal		FMU Gupis	Average
	Sikanderabad	Budalus	Chamlaing	Gahkuch Pain	Imit Mujawa	Hamar Dass	
NR-74	181	200	153	122	88	120	144
NR-142	187	×	189	115	×	×	164
NR-152	195	119	200	120	90	130	159

Table 7. Average preference ranking [λ] of promoted lines at maturity in 2001.

Lines/check	Male Farmers (6 VOs, n = 120)[€]	Female Farmers (6 WOs, n = 60)	Overall Farmers (n = 180)	AKRSP Agriculturists (n = 3)	Overall (n = 183)	Yield (ton ha^{-1})
NR-74	2	2	2	3	3	4.61
NR 102	3	4	4	4	4	3.50
NR-142	2	1	2	1	1	5.25
NR-152	1	3	2	2	2	5.09
local Check	4	5	5	5	5	3.20
Rank correlation (r)			0.69[X]	0.83[Y]	0.94[Z]	-0.97[¥]

[λ] Preference ranking on scale from 1(excellent) 6 (worst); [€] n, indicates number in group; [X] Correlation coefficient (r) between male and female farmers' preference ranking; [Y] r between male farmers and AKRSP agriculturists preference ranking; [Z] r between all farmers and AKRSP agriculturists preference ranking; [¥] r between perception of all participants and crop harvest results.

preference ranking. NR-74 yielded 81, 100, 53, 22 and 20% higher than the local check in villages Sikanderabad, Budalus, Chamlaing, Gahkuch Pain and Hamar Dass, respectively, whereas its yield was 12% lower than local check in Imit Mujawa (Table 6). On average, NR-74 produced 44% higher yield than the local check across the FMUs. NR-142 produced 87, 89 and 15% higher grain yields than local check in Sikanderabad, Chamlaing and Hamar Dass, respectively, with an average of 64% higher grain yield than the local check. Similarly, NR-152 yielded 95, 119, 100, 20 and 30% higher than local check in the villages Sikanderabad, Budalus, Chamlaing, Gahkuch Pain and Hamar Dass, respectively with an average increase of 59% over the local check. Based on grain yield, NR-142 was the best line, followed by NR-152 and NR-74. The average yields of NR-74, NR-142 and NR-152 were 5.25, 5.09 and 4.61 ton ha^{-1}, respectively (Table 7) with an increase of 64, 59 and 44% than local check.

Grain and straw yields were positively correlated in 1999, 2000 and 2001 (Figure 2). Evaluation scores of men and women farmers were in agreement (r = 0.69) (Table 7). Evaluation scores of farmers and AKRSP researchers were also highly correlated (r = 0.94). Similarly, there was a strong agreement between farmers' perceptions of variety and crop harvest results (r = 0.97).

Results of the household level survey during 2007 showed that NR-152 was cultivated on 50%, NR-74 was on 20% and other varieties/land races were grown on 30% of total cultivated area in Manapin (Figure 3). In Nilt, NR152, NR-74 and NR142 were grown on 60, 10 and 5% of wheat fields, respectively, whereas other varieties/land races were grown on 25% wheat fields. Results showed that the selected elite wheat lines were cultivated over an area of 70% in the targeted area. This indicated that the adoption rate of wheat varieties was improved by increased farmers' participation in varietal selection program in resource-poor areas. In Jagolate Goro and Sultanabad, NR74 occupied 55 and 60% of wheat fields, respectively. NR-152 occupied 10% whereas NR-142 was cultivated on 8 and 7% of wheat field in Jagolate Goro and Sultanabad, respectively. Despite being top ranked in 2000 and 2001, NR-142 was adopted on a very small area in the four villages. However, in some other villages, NR-142 was reported to be grown on larger area than NR-152 and NR 74. In general, the selected wheat lines were found being cultivated on more than 70% wheat fields in the target area.

DISCUSSION

The centralized plant breeding of green revolution increased wheat yields in more favourable agricultural environments of developing countries. However, green revolution has not improved wheat production in marginal areas of the world having resource poor farmers (Sthapit et al., 1996). In order to address the problems of resource poor farmers, farmer participatory approaches were advocated by many workers (Farrington and Martin, 1988; Sthapit et al., 1994; Josi and Witcombe, 1996;

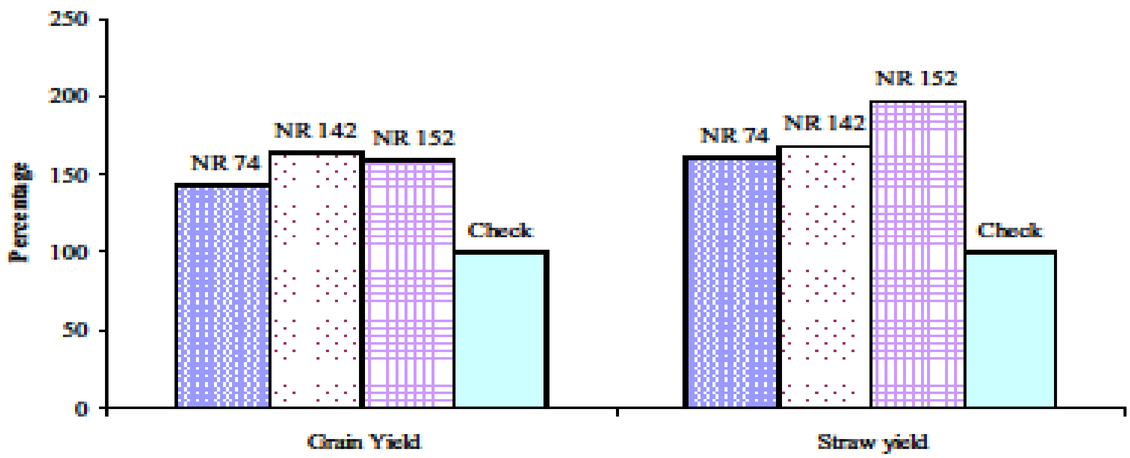


Figure 2. Grain and straw yields of three best wheat lines as percentage of local check in 2001.

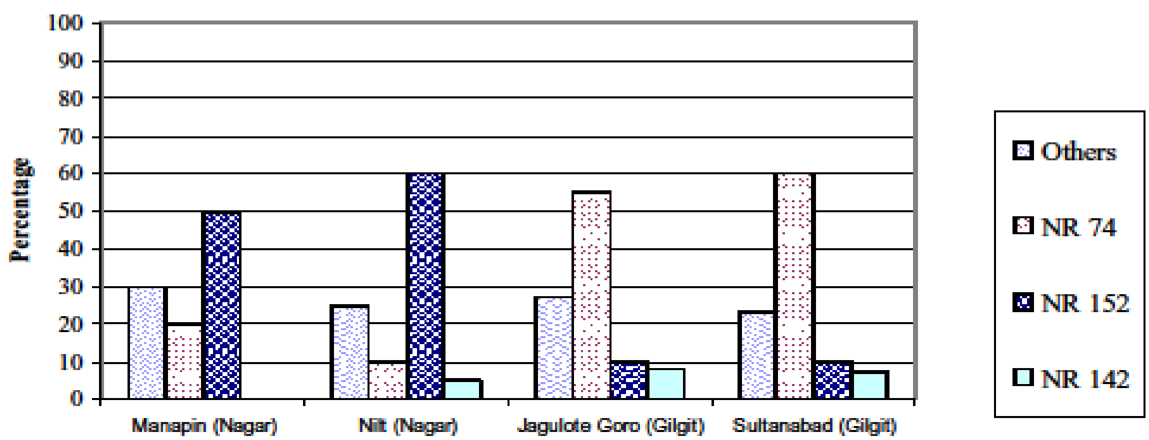


Figure 3. Percent area under different wheat lines grown by farmers in four villages in 2007.

Witcombe, 1996; Witcombe et al., 2003; Weltzien et al., 2003; Ashby and Lilja, 2004; Morris and Bellon, 2004; Ceccarelli and Grando, 2005; Mangione et al., 2006; Sharma and Duveiller, 2006) in selection and breeding programs. In centralized breeding system, a number of advanced breeding lines are tested and selected under research station conditions that may not resemble the environmental conditions where the lines will be subsequently grown. In the process, some of the lines suited to a particular ecological condition may be discarded. For example, the elite wheat lines of Wheat Program, National Agricultural Research Centre, Islamabad, Pakistan, NR-74, NR-142 and NR152 failed to be released as commercial varieties via conventional breeding approach. However, these lines were selected for resource-poor areas of Gilgit-Baltistan region of Pakistan using PVS approach. These wheat lines were tested in farmer managed participatory research trials in which farmers were allowed to evaluate and compare these with their local varieties. Farmers evaluated the new varieties at all stages of crop growth and considered a number of traits in the evaluation. Moreover, farmers of each locality had their own preferences for different cooking and eating qualities of the grain. For example, farmers preferred NR-74, NR 142 and NR 152 not only due to high grain and straw yield potential but also for grain colour, local bread (chapatti) making quality, and straw quality. Farmers considered straw quality in selection as livestock in this region largely depends on wheat straw in harsh winter. Farmers also carefully considered the adaptability of the lines for specific environmental condition of their area. For instance, NR-152 was preferentially selected by farmers in Manapin and Nilt of Nagar having transit cropping system, whereas NR-74 was preferred in the double cropping villages (Jaglote Goro and Sultanabad) of Gilgit (Figure 3). The present study demonstrated an example of how PVS can be successfully adopted as a crop improvement strategy in marginal areas of the world having resource poor farmers. Similar success stories of PVS have been reported in grain legumes, rice, pea, millet and maize in Colombia, Nepal, India and Rwanda (Witcombe, 1996).

Farmers' participatory approaches have been advocated for accelerated adoption and promotion of genetic diversity, improvement in breeding efficiency and selection of more acceptable varieties in particular environments (Weltzien et al., 2003; Ashby and Lilja, 2004; Morris and Bellon, 2004; Ceccarelli and Grando, 2005). Decentralized participatory research approach may be more expensive as large numbers of lines are evaluated in many environments. However, as PVS approach relies on testing advanced lines, the time and labour involved in the early generations of a line in conventional breeding approach is saved (Morris et al., 1992). In addition, the relative economic returns from participatory breeding approach are higher than conventional approach, and its benefits to farmers are readily achieved. Mangione and Collogues (2006) found the aggregate cost of participatory approach to be 5 to 28% lower than that of centralized-breeding program.

The present study showed that the area cultivated with the preferred lines increased rapidly within three to four years of their selection. The selected wheat lines occupied more than 70% (Figure 3) of wheat fields in the target area. Meanwhile, some farmers would have already started distributing seeds of the preferred varieties/lines to other community members even before final selection during adoptive trials. Furthermore, as many village organizations and women organizations in each FMU across the region were practically involved in the selection process, benefits and information about the preferred lines were already known. Consequently, the preferred lines substantially spread over a large area within three to four years of their selection. Witcombe et al. (2003) also reported the development of an early maturing maize variety through farmer participatory approach in fewer years than conventional approach in resource-poor area of Gujarat, India. They also concluded that participatory approach was economically more profitable compared to conventional breeding, and advantageous in providing information on farmers' preference that is otherwise not available.

In addition, being more representative (involving more farmers and a range of environmental conditions), the participatory trials produce biological and agronomic data of better quality than the on farm formal trials (Mangione et al., 2006). Smith et al. (2001) found that a collaborative participatory maize selection on the farm with the lowest yield potential presented greater yield advantage than the selection on experimental station. They recommended farmer-participatory approaches in marginal environments where experiment station conditions vary most significantly from farmers' conditions. Furthermore, it is often difficult to identify a single or a few superior genotypes across all sets of environmental conditions. A decentralized participatory approach can identify varieties that are adapted to farming systems in marginal environments or that use very few external inputs (Dawnson et al., 2008). Participatory plant breeding and varietal selection could solve these problems by evaluating/selecting genotypes with attributes that increase economic returns to farmers. This is not possible in conventional plant breeding as the lines are usually tested under ideal input conditions. Varieties released under such conditions may not perform well when grown in low input environments. Furthermore, different environments have different biotic and abiotic stresses that require development/selection of varieties specifically adapted to particular environments.

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