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Research Article

Participatory on-farm evaluation of wheat genotypes

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ABSTRACT

In wheat development programs, the evaluation and identification of superior genotypes is the first and leading step in a crop improvement program. Coordinated Farmer's Field Trial (CFFT) was conducted during the three successive wheat growing season of 2010/11, 2011/12 and 2012/13. In CFFT six different wheat genotypes were planted in different outreach sites of research stations of Nepal Agricultural Research Council (NARC) at varying geographical regions. CFFT was conducted according to standard recommended practices of wheat at farmers' field with different sets of genotypes for Terai and hill. In CFFT for Terai Tar and Lower valley (TTL) under timely sown irrigated (TSI) condition wheat genotype NL 1073 produced the grain yield of 3695 kg/ha and under the timely sown rainfed (TSR) that was 2738 kg/ha in 2010/11. In 2011/12, wheat genotype NL 1073 had the highest recorded grain yield of 3691 kg/ha in mid western region which was followed by check variety Vijay in CFFT-TTL in 2011/12 in the same region. Similarly in 2012/13, check variety Vijay showed the highest grain yield of 3818 kg/ha and 3044 kg/ha followed by NL 1094 (2938 kg/ha and 3468 kg/ha) in TSR and TSI environments, respectively. In CFFT for Mid and High Hill (MHH) WK 1204 had the highest grain yield of 3967 kg/ha in TSI which was followed by NL 1008 with the yield of 3890 in 2010/11. In 2011/12 the highest mean grain yield was observed in WK 1204 (4242 kg/ha) followed by BL 3872 (3922 kg/ha). Similarly, in 2012/13 NL 1008 was the best genotypes on the basis of grain yield (3297 kg/ha) followed by NL 1055 (3131 kg/ha) under CFFT-MHH.

Keywords: CFFT, Genotypes, FAT, On-Farm, Participatory

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INTRODUCTION

Wheat is the third important cereal crop of Nepal after rice and maize both in area and production. At present, wheat-sown area is about 735,850 ha, with a total production of 1,879,191 million ton (MOALD, 2017). It is a major winter cereal crop in Nepal and more than 80% of wheat is grown in rice-wheat cropping pattern. It is nutritious, easy to store and transport and can be processed into various types of food (Kandel *et al.*, 2018). After the introduction of semi-dwarf varieties from Mexico, the area and production of wheat in Nepal has been increased dramatically and now it has significant contribution to the national food supply (Poudel *et al*., 2012).

Although remarkable success has been achieved to date in developing widely adapted wheat cultivars, many resource poor farmers in marginal areas have not benefited yet. Farmer's preference on various genotypes should be known to the researchers before and after their release as varieties. Yield gaps are generally associated with the lack of adoption of recommended technologies, some of which are inappropriate (Gomez & Gomez, 1983). This situation prompted the development of a crop management research strategy especially suited to developing countries (Zandstra *et al*., 1981). A major problem with the traditional research approach was that the majority of research was conducted on research stations, which often were not representative of the farmers' environments or circumstances. The modified strategy, in contrast, combines both on-station and on-farm research. Researchers concentrate on developing and testing appropriate technologies in farmers' fields, taking into consideration the physical and socioeconomic circumstances of the farmers. The steps in on-farm research are generally defined as diagnosis, planning, experimentation, assessment, and recommendation (Byerlee *et al*., 1982; CIMMYT, 1988).

Most of the increased production and productivity came from the availability of high yielding varieties as farmers gradually replaced their low yielding traditional varieties with high yielding (Prasai & Shrestha, 2015). Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Joshi & Witcombe, 1996; Witcombe *et al*., 1996). Moreover, participatory research increases the job efficiency of the scientists (Bellon, 2001) and farmers' knowledge that enables to be retained effectively from year to year (Grisley & Shamambo, 1993). Research costs can be reduced and adoption rates increased if farmers are allowed to participate in variety testing and selection (Joshi et al., 1995). In addition, production increases when farmers adopt new varieties identified in participatory research (Witcombe, 1999). The participatory research is conducted under highly diverse farmers' field conditions to examine how farmers' selection criteria could assist breeders in identifying superior wheat cultivars, and to use it in selection of improved cultivar based on quantitative (grain yield) and qualitative data obtained from farmers' preference score. Participatory research has been continued to know the farmer's reaction on the performance of genotypes in theirs adapted domains such as mid and High Hills (MHH) or Terai, Tar and Lower Valleys (TTL). Participatory research could greatly enhance identifying cultivars according to the choice of the farmers.

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MATERIALS AND METHODS

Two main activities namely Coordinated farmer's field trials(CFFT) for Terai Tar and Lower Valley (TTL) and for Mid and high hills (MHH) were conducted in three consecutive years 2010/11, 2011/12 and 2012/13. These experiments were conducted at the different outreach sites of research stations of NARC. The research was conducted in eastern (Tarahara, Sunsari and Itahari, Sunsari), central (Rampur, Chitwan; Hardinath, Dhanusha; Parwanipur, Bara and Jitpur, Bara), western (Bhairahawa, Rupandehi); mid-western (Khajura, Banke and Dasharathpur, Surkhet) and far western (Bhagetada, Doti) regions with the CFFT-TTL sets of wheat. Six promising genotypes including standard check Gautam in 2010/11 and Vijay as check in 2011/12 and 2012/13 for Terai Tars and lower valleys (Table 1). The plot size allotted to each genotype was 50 m^2 and row to row distance was 25 cm apart. The seed rate used was 120 kg/ha. The recommended dose of fertilizer for irrigated condition was 100: 50: 25 kg NPK/ha and that for the rainfed condition was 60:30:20 kg NPK/ha. The total number of sets tested was 70 in all years.

Table 1: List of the wheat genotypes tested under CFFT-TTL during the 2010/11-2012/13

SN	2010/11	2011/12	2012/13
1	NL 1073	NL 1073	BL 4009
2	BL 3819	BL 3819	NL 1097
3	BL 3623	NL 1044	NL 1044
4	NL 1050	NL 1050	NL 1094
5	NL 1053	NL 1055	NL 1055
6	Gautam	Vijay	Vijay

Similarly, the CFFT-MHH sets were planted in the different outreach sites of the research stations of NARC at hill area. These are in eastern (Pakhribas, Dhankuta), central (Kabre, Dolakha; Khumaltar, Lalitpur), western (Lumle, Kaski), mid-western (Dailekh, Jumla and Surkhet) and far-western (Bhagetada, Doti) regions. Both the trials of hill sets and terai sets were tested in the Surkhet and Doti. The numbers of genotypes tested in CFFT-MHH were six in each year with the WK1204 as check variety. The plot size allotted to each entry was 20 m^2. The recommended dose of fertilizers was 80:40:20 kg NPK/ ha under timely sown irrigated condition whereas the fertilizer dose recommended was 60:30:20 kg NPK/ha for rainfed condition. The total number of sets tested was 40.

Table 2: List of the genotypes tested under CFFT-MHH during the 2010/11-2012/13

SN	2010/11	2011/12	2012/13
1	NL 1064	NL 1064	NL 1055
2	NL 1073	NL 1073	NL 1082
3	NL 1008	NL 1008	NL 1008
4	BL 3629	BL 3629	BL 3629
5	NL 1067	BL 3872	BL 3872
6	WK 1204	WK 1204	WK 1204

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Among the provided number of CFFT sets some data from the farmer's field testing sites of the research stations were received. The data was grouped based upon the geographic locations (Terai and hills) from east to west regions. Mean grain yield of the tested genotypes from the different region were analyzed and ranked.The experimental data were processed by using Excel 2010 and analyzed by using Genestat 13.2. The experimental data were processed by using Excel 2010 and analyzed by using Genestat 13.2. The treatment means were compared by the Least Significant Difference (LSD) test at 5% level (Gomez & Gomez, 1984; Baral *et al.*, 2016; Shrestha, 2019; Jan *et al.*, 2009; Sharma *et al.*, 2016; Kandel & Shrestha, 2019).

RESULTS

The grain yield of the wheat is the important trait to be considered because of the grain as the economic and useful trait. The selection of the genotypes is mostly based upon the grain yield. The analyzed data used for the ranking and selection of the genotypes have been tabulated below.

Table 3: Region-wise grain yield (kg ha^{-1}) for six wheat genotypes evaluated in CFFT-TTL during 2010/11

Genotypes	Irrigated					Rainfed			
	Central Region	Western Region	Mid Western	Mean	Rank	Central	Western	Mean	Rank
	$^{\Psi}$ (n= 26)	(n=8)	(n=4)	(n =38)		(n=6)	(n=3)	(n = 9)	
BL 3623	3549	3359	4374	3761	II	3240	1633	2437	VI
BL 3819	3475	3538	3918	3643	IV	3492	1933	2713	III
Gautam	3609	2756	4555	3640	V	3677	2700	3188	I
NL 1050	3257	3588	4003	3616	VI	3290	1733	2512	IV
NL 1053	3282	3656	4390	3776	I	3258	1617	2438	V
NL 1073	3293	3894	3898	3695	III	3492	1983	2738	II
Grand mean	3411	3465	4190	3689		3408	1933	2671	
SEM	62.3	115.7	27.5	27.5		71.0	165.4	116.6	
CV%	4.47	11.21	6.76	1.8		5.1	20.9	10.7	
LSD (0.05)	140.8	240.6	170.8	105		146	340	243	
F-test	**	*	**	**		**	ns	*	

*$^{\Psi}$ number of locations of which data was received.*Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05).*

In 2010/11the highest mean grain yield was obtained in the variety NL 1053 (3776 kg./ha) in CFFT-TTL which was followed by BL 3623 (3761 kg/ha) and NL 1073 (3695 kg/ha). Similarly, under rainfed condition Gautam variety ranked first position with the mean grain yield of 3188 kg/ha followed by NL 1073 (3738 kg/ha) and BL 3819 (2715 kg/ha) (Table 3). The genotype NL 1073 had the good yield in both the irrigated and the rainfed condition. The

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NL 1073 is a CIMMYT line Francolin #1. Similar Result was obtained by Bhattarai *et al* (2017) in the testing of elite wheat genotypes.

Table 4: Region-wise grain yield (kg/ha) for six wheat genotypes evaluated in CFFT-TTL during 2011/12

Genotypes	Central Region (n=18)	Mid Western Region (n=11)	Mean(kg/ha) (n = 29)	Rank
NL 1073	3342	3691	3466	I
BL 3819	2779	1944	2563	VI
NL 1044	2888	2868	2881	V
NL 1050	3137	3314	3200	III
NL 1055	3023	3173	3076	V
Vijay	3257	3605	3380	II
Grand Mean	3071	3099	3094	
SEM	88.1	261.1	136.5	
CV%	7.0	20.6	10.8	
LSD (0.05)	207	550.7	330	
F-test	**	ns	*	

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05)*

Table 5: Region-wise grain yield (kg ha^{-1}) for six wheat genotypes evaluated in CFFT-TTL during 2012/13

Genotypes	Rain-fed			Irrigated					
	Central (Region (n=10)	Mean yield (kg/ha) (n=10)	Rank	Central Region (n =10)	Western Region (n = 2)	Mid Western Region (n = 5)	Far Western Region (n = 3)	Mean yield (kg/ha) (n=20)	Rank
BL 4009	2931	2931	IV	3150	4650	2332	3680	3453	III
NL 1044	2750	2750	VI	2900	3200	1983	3713	2949	VI
NL 1055	3042	3042	II	3400	4400	1749	3697	3311	IV
NL 1094	2938	2938	III	3530	3800	1882	4660	3468	II
NL 1097	2720	2720	VI	2840	4500	1966	3840	3287	V
Vijay	3044	3044	I	2950	5800	1948	4573	3818	I
Grand mean	2904.2	2904.2		3128.3	4391. 7	1976.7	4027.2	3381	
SEM	57.2	57.2		115.9	357.4	79.2	188.1	116.1	
CV%	4.8	4.8		9.1	19.3	9.8	11.4	8.4	
LSD (0.05)	302	302		343	455	102	430	243.8	
F-test	**	**		*	ns	**	*	**	

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05)*

During 2011/12 the highest mean grain yield of 3466 kg/ha was observed in NL 1073 followed by check variety Vijay (3380 kg/ha) and NL 1050 (3200 kg/ha) under the irrigated

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condition (Table 4). Highly significant difference among the genotypes for the grain yield was observed in the central region of the Nepal. The Same variety NL 1073 was performing well in the previous year also.

Similarly, in 2012/13 result of the 10 trials of CFFT was obtained from the central region and the highest mean grain yield was obtained in Vijay (3044 kg/ha) followed by NL 1055 (3042 Kg/ha) and NL 1094 (2938 kg/ha). Under the irrigated condition total 20 results were obtained in that year and Vijay had the highest mean grain yield (3818 kg/ha) followed by NL 1094 (3468 kg/ha) and BL 4009 (3453 kg/ha) (Table 5). Under the both conditions the yield of the Vijay variety was highest.

Table 6: Region-wise grain yield (kg ha^{-1}) for six wheat genotypes evaluated in CFFT-MHH during 2010/11

Genotype	Irrigated					Rainfed		
	Central Region (n=5)	Mid Western Region (n=8)	Far Western Region (n=4)	Combined yield (kg/ha) (n= 17)	Rank	Western Region (n=4)	Mean (kg/ha) (n=4)	Rank
NL 1064	3530	2698	4625	3618	IV	2475	2475	IV
NL 1073	3334	3018	4450	3600	V	2518	2518	III
NL 1008	3802	3392	4475	3890	II	2655	2655	II
BL 3629	4157	3125	4350	3877	III	2195	2195	VI
NL 1067	3439	3223	3150	3271	VI	2363	2363	V
WK 1204	4233	2592	5075	3967	I	2745	2745	I
Grand mean	3749.2	3008	4354.2	3703.8		2491.8	2491.8	
SEM	154.9	126.0	262.5	106.4		80.9	80.9	
CV%	10.1	10.2	14.8	7		7.9	7.9	
LSD (0.05)	391	321	971	186		160	160	
F-test	**	*	ns	**		*	*	

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05)*

In the year 2010/11, WK 1204 had the highest mean grain yield both in irrigated (3967 kg/ha) and rainfed (2745 kg/ha) condition of the hill. The same variety was followed by NL 1008 with the grain yield of 3890 kg/ha under irrigated condition and 2655 kg/ha under rainfed condition. The BL 3629 had the grain yield of 3877 kg/ha under the irrigated condition and the NL 1073 had the third position with the yield of 2518 kg/ha under the rainfed condition (Table 6).Highly significant difference among the genotypes for the grain yield was observed in the central region under irrigated condition.

In 2011/12 WK 1204 had the mean grain yield of 4242 kg/ha followed by the BL 3872 (3922 kg/ha). Similarly the yield of the NL 1064 was 3514 kg/ha with the yield consistency in all regions (Table 7). The BL 3872 is a line developed through the cross and selection in Bhairahawa. The NL 1064 was received from CIMMYT.

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Table 7: Region-wise grain yield (kg ha^{-1}) for six wheat genotypes evaluated in CFFT-MHH during 2011/12

Genotype	Eastern Region (N=4)	Western Region (N=7)	Mid Western Region (N=9)	Far Western Region (N=4)	Mean (kg/ha) (N=24)	Rank
NL 1064	3673	3608	3321	3627	3514	III
NL 1073	3223	2204	3642	3987	3210	VI
NL 1008	3408	3124	3316	4163	3416	IV
BL 3629	3485	3317	3026	4298	3400	V
BL 3872	3678	4847	3053	4501	3922	II
WK 1204	4825	5122	3239	4378	4242	I
Grand mean	3715	3704	3266	4159	3617	
SEM	232.7	449.5	91.4	128.7	157.8	
CV%	15.3	29.7	6.9	7.6	10.7	
LSD (0.05)	890	2222.5	210	244	422	
F-test	ns	ns	**	**	*	

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05)*

Table 8: Region-wise grain yield (kg ha^{-1}) for six wheat genotypes evaluated in CFFT-MHH during 2012/13

Genotypes	Eastern Region n=1	Central Region n=2	Western Region n=7	Mean kg/ha n=10	Rank
BL 3629	2850	2715	3520	3028	III
BL 3872	2332	2586	4051	2990	IV
NL 1008	3666	2796	3429	3297	I
NL 1055	3266	2965	3163	3131	II
NL 1082	2400	2614	3169	2728	VI
WK 1204	2266	3111	3286	2888	V
Grand mean	2797	2797	3436	3010	
SEM	233.3	83.9	135.8	80.0	
CV%	20.4	7.4	9.7	6.5	
LSD (0.05)	1189	249	330	260	
F-test	ns	**	*	**	

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns = non-significant difference among the tested genotypes (where, p > 0.05)*

In 2012/13 wheat genotype NL 1008 had the highest mean grain yield with 3297 kg/ha followed by NL 1055 (3131 kg/ha) and BL 3629 (3028 kg/ha) (Table 8). The yield of the genotypes was good in the western development region.

DISCUSSION

Successful breeding of high yielding varieties depends on the yield contributing morphological traits. Grain yield of wheat is a complex trait and is affected by various components like; number of tillers/m^2, number of grains per spike, 1000 grain weight, and plant height and spike length. In our experiments there were significant differences among the genotypes for grain yield studied which are in agreement with Sharma (1994); Kamat (1996); Ginkel *et al*., (1998); Dwivedi *et al*., (2002); Sinha *et al*., (2006); Kamboj (2007) and

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Baloch *et al*., (2013) who reported high variability for different traits including grain yield in wheat. This yield trait is affected from yield components (Dogan, 2002; Pireivatlou et al., 2011); therefore yield and yield components could be considered and studied in breeding programs (Carew *et al*., 2009). Grain yield is resultant of genetic capacity, environmental conditions and agronomic practices. In our experiments, the grain yield of wheat varieties varied with locations. These results agree with those of Porfiri *et al*. (2001) who reported that the grain yield of wheat lines is mostly associated with the environmental conditions (Trethowan *et al*., 2003). There was reasonably sufficient variability in the research material, which provides ample scope for selecting superior and desired genotypes by the plant breeder together with the participation of the farmer for the better adoption and dissemination after its recommendation.

CONCLUSION

Selection of the genotypes based upon the trials at the farmers' field ensures the adoption of the genotypes and its dissemination. Considering the yield trait at farmers' field after the on-station trials assists in its conformation of the potentiality of the genotypes at the place of end users. The results from the on-farm research in Terai in the three consecutive years have shown the variation in the result and rank in different years. However, NL 1073 and Vijay consistently produced higher yields both in irrigated and rainfed conditions. These genotypes also got high farmers overall preference. Therefore the yield of the NL 1073 was found to be better option for the Terai condition. Similarly, in the hill condition the test entries NL 1064, NL 1055 and BL 3629 were found to be performing better and promising lines to be recommended for the mid and the high hill condition.

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Authors' contributions

Shesh R. Upadhyay, Nutan Raj Gautam, and Dhruba Bahadur Thapa guided the research and revised the article. Jiban Shrestha improved the manuscript for the final approval of the version to be published. Deepak Pandey and Hemanta Chaudhari conducted the trial and recorded data, analyzed and create the final manuscript. Bhakti Ram Ghimire assisted in the preparation of the trial sets.

Conflict of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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