Journal of Innovative Agriculture: 8(3) : 11-16, 2021
DOI: 10.37446/jinagri/rsa/8.3.2021.11-16
Research paper

On-farm assessment of productivity of improved varieties of wheat

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Received: 01 April 2021
Accepted: 06 July 2021
Published: 30 September 2021

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Genetic material developed and improved are tested through a number of on-station trials, but are finally targeted for the farmers' fields where the actual crop production takes place to feed the population of a country. Afghanistan needs to increase wheat production to support its domestic need of wheat consumption, reduce its imports and enhance the exports. The purpose of this study was to assess the effect of the improved varieties of wheat in the target domain in Afghanistan. The improved varieties with a package of practice were implemented in farmers' field through demonstration plots. A total of *223* farmers' fields were included in the trials implemented in eight districts in East Central Zone. Across all the locations, the improved varieties showed substantial increase of yield over local variety in range of 53-86% and yield stability across the locations. Consequently, the wide use of improved varieties with package of practice can result considerable gain to farmers to harvest more yield which motivated farmer to accelerate variety replacement up 100% and other hand, this increase will positively recover farmers economic status. As whole, increase in the yield would be contributed to meet current need of the country in wheat and improve the food security.

Key words: *on-farm trials, wheat, improved genotypes, food security, productivity risks, GGE bi-plot*

INTRODUCTION

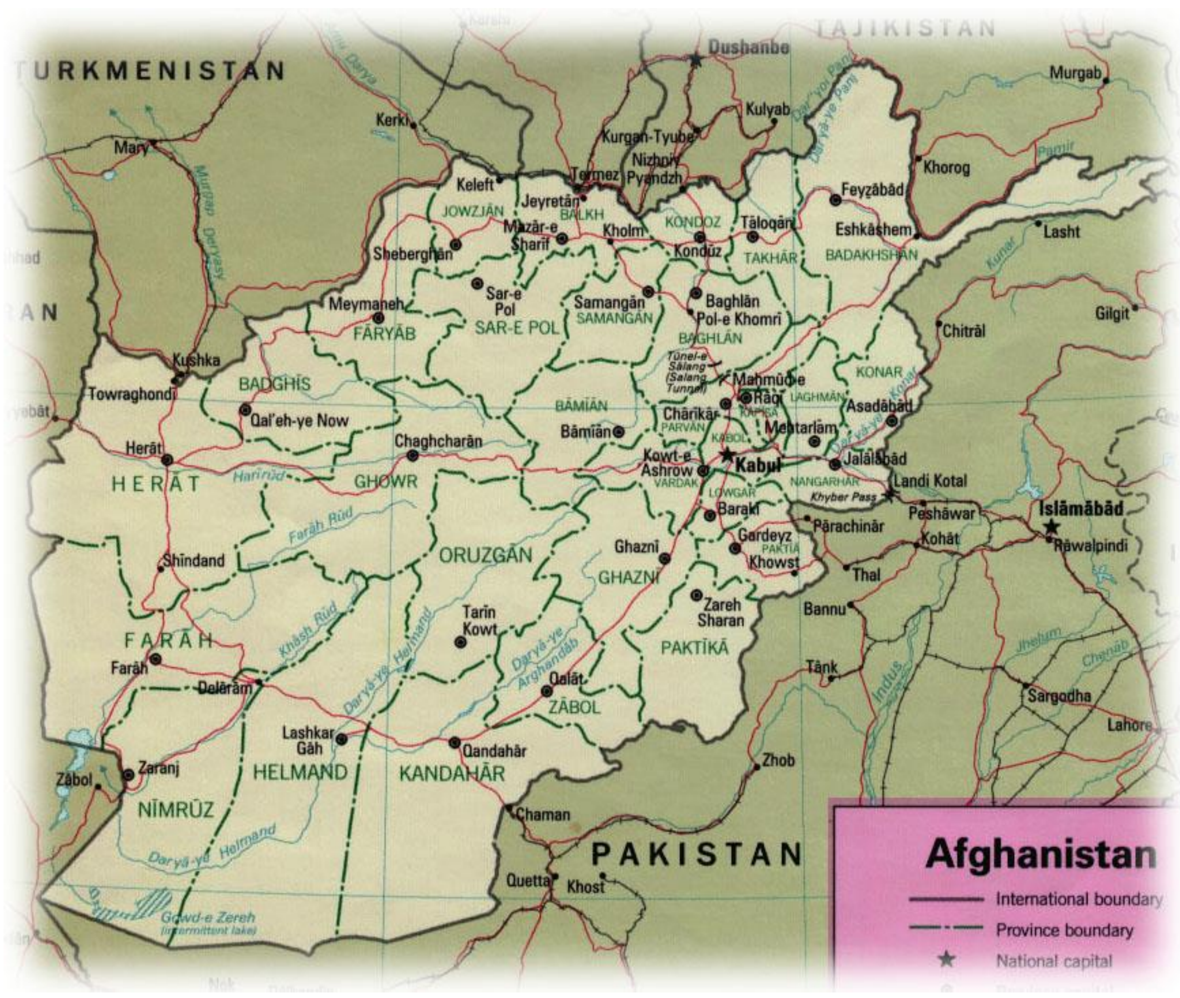
Afghanistan currently has a population of 33 million and wheat is the most stable food grain consumed by most families on daily base. Wheat is grown under either irrigated or rainfed conditions, where nearly 45 percent of Afghanistan's wheat area is irrigated and remaining 55 percent of area depends entirely on rain. Average wheat yield (without fertilizers) on irrigated land is about 2.7Mt ha^{-1}. Although a total of 12% of the Afghanistan land is under cultivation, where irrigated area is 5% and rainfed 7%, it still partially depends on an import of 1.7 million Mt annually. Extension agriculture and intensive agriculture are the only ways for increasing production but recently intensive agriculture is considered as immediate option as bringing land under irrigation will take time. Therefore, using improved varieties, improved crop production practices, soil and water management practices and agrochemical practices are the options for agriculture intensification for the crop production in the country. Since a long time, farmers have been cultivating the traditional varieties, most of which are susceptible to diseases, and have low production and economic gain. In the north part of the country, the farmers cultivate wheat under rainfed condition in hilly areas when rain is available. Besides the demand for improved wheat varieties, the production and distribution of improved seed has contributed to only 10%

adoption by farmers. Tavvaet al. (2017) reported that for low yields, the major factors include narrow portfolio of improved varieties, poorly adopted varieties and the associated management practices and non-availability of quality seed. This situation has called for multi-environment evaluation of a number of prospective genotypes of wheat to examine genotype × environment interactions (GEI). A wide range of literature on techniques and tools for examination and exploitation of GEI are available (Basford and Cooper, 1998; Delacy et al., 1996; Eberhart and Russell, 1966; Finlay and Wilkinson,1963; Lin et al., 1986,; Sharma et al., 2010). In presence of GEI, genotype plus genotype × environment (GGE) interaction biplot analysis is another appropriate tool to represent the environments and specific adaptation of a genotype to an environment (Yan et al., 2000) and has been applied in several studies genotype (Kaya et al*.,* 2006; Asfaw et al*.,* 2009; Jambormias, 2011; Farshadfar et al*.,* 2012; Karimizadeh et al*.,* 2013) GGE biplot analysis provides an easy and comprehensive solution to genotype by environment data analysis, which has been a challenge to plant breeders, geneticists, and agronomists (Yan and Tinker, 2006). To increase the adoption rate of improved wheat varieties with crop production practices for increasing of agricultural production, implementation of the demonstration plot in farmer's field is an easy and effective extension method based on "seeing is believing' for introduction of newly improved variety with packages of practices given to the farmers to practice and realize more yield. In this study, the on-farm demonstration trials in wheat were set-up with objectives to assess on-farm performance of a number of improved wheat varieties and compare them with local varieties in terms of yield and risks of meeting specified production targets.

MATERIALS AND METHODS

Environments and the On-farm trials (OFT)

The three provinces, Kabul, Parwan and Logar, where the OFTs were conducted form substantial part of the East Central Zone of Afghanistan (Map). Although no weather data were collected on the farms, but for the zone, the average total annual precipitation in 2016 was 292 mm and mean temperature in this zone ranged between –5.9°C and 24.6°C. The elevation for locations under this zone ranges from 1800 – 2900 masl. The on-farm demonstration trials were conducted in eight districts of Kabul (3), Logar (2) and Parwan (3) provinces. Total of 223 farmers were representatively selected for implementation of on-farm trials jointly supervised with related departments of Agriculture and Extension in the Ministry of Agriculture, Irrigation and



Map: Map of Afghanistan with trial locations

Table 1: Number of farmers implemented wheat demonstrations for during 2014-15 and 2015-16

Provinces	District	2014-15							
		Gull96	Kohistan 013	Muqawim 09	PBW156	Solh 2002	Zaren 013	Gull 96	Kohistan 0
Parwan	Bagram	1	5	NT	2	1	6	8	NT
	Charikar	3	1	3	1	5	2	NT	NT
	Jabal Saraj	3	2	3	3	3	1	NT	NT
Kabul	Char Asyab	3	4	2	NT	3	3	NT	6
	DehSabz	3	4	2	NT	3	3	NT	7
	Qarabagh	NT	NT	NT	NT	NT	NT	NT	6
Logar	Mohammad Agha	4	3	NT	3	3	2	NT	12
	Pul-e-Alem	7	3	NT	2	3	NT	NT	14
Total		24	22	10	11	21	17	8	45

NT: No trial conducted

Livestock (MAIL), Afghanistan. The district development councils, or *Shuras*, played a vital role in introduction of the committed farmers to follow the instructions to implement the given package of practice during cropping season. The extension agent, representing the MAIL, facilitated the identification of selected farmers and implementation of the on-farm trials. Nearly equal number of the farmers, 13-15, were selected from each district except two districts, Mohammad Agha and Pul-e-Alem of Logar province (Table1). The improved varieties of wheat were Gull 96, Kohistan 013, Muqawim 09, PBW-156, Solh 2002 and Zaren 013 and the package of practice comprised of seed rate, 120kg/ha and optimum fertilizer, 250kg/ha urea and 125 Kg/ha diammonium phosphate (DAP). The plot area for each of the improved package and local practice, *i.e.* farmer practice, was 0.2 ha in the same land. The seed rate for local variety, generally unknown and varying with farmer, was 210kg/ha and fertilizer application for local was kept same as that for the improved. The improved varieties were cultivated in rows with 25cm row to row distance, while seeds of local varieties were broadcast. The yield data was collected from three representative areas of 1 m x 1 m and then converted to kg/ha for statistical analysis.

Statistical methods

The improved varieties yields were modelled as mixed linear model accounting for the effect of varieties, districts, year within districts and their interactions with variety. Furthermore, the effects of varieties and districts were assumed as fixed, while that of their interactions involving year were assumed random. The models were fitted using REML (restricted maximum likelihood) procedure to estimate fixed effects with their standard errors and variance components of the random effects. The model can be described as in the following using the directives of GenStat software (VSN International, 2015).

VCOMPONENTS [FIXED= District + Variety + District.Variety]

Random model=District.Year + District.Year.Variety

REML [PRINT=MODEL, COMP, MEANS, DEVI, WALD; PSE=E]Yield

Where the factors denoted as Variety, District, and Year stand for improved variety (six levels), districts (8) and years (2) respectively, and Yield stands for response variable wheat grain yield. If random terms did not show variation, then they were ignored. In every district, some farmers planted the improved variety under recommended practice as well as a local variety using his own cultivation practice. The assessment of an overall means of locals within a district and overall the district was carried out using a model in terms of district and years within district effects. Specific adaptation of the improved varieties to locations (districts) was carried out using its GGE bi-plot (Yan et al., 2000; Yan 2011) in GenStat software environment (VSN Inc., 2015).

A comparison of improved varieties was also carried out in terms of risk measured by the probability of obtaining a targeted amount of yield using the underlying distribution (Anderson, 1974; Haddad et al., 2005; Tavva et al., 2017).Using an estimate of mean (M) and its standard errors (S) for a given variety, the risk for a given target (T) was computed as follows. Under the assumption that the estimated mean yields are normally distributed, the risk can be computed as probability Prob $[Z>z_0]$ where $z_0 = (T - M)/S$ and the random variable Z has approximately standard normal distribution. The risk curves were drawn by plotting the risks against a range of the target yield values.

RESULTS AND DISCUSSION

Variety and district interaction

We observed non-significant interaction between improved varieties and year and also low variance component for the years (Table 2). We revised the model without these two random terms and significance of variety and interactions with district are given in Table 2. Also table 3 shows significant interaction (P=0.001) between improved variety and district. In the presence of this interaction, the main effect of variety (*i.e.* varieties performances averaged over districts) is not significant (0.154), which may be due to crossover type interaction. Akbarzai et al. (2017) reported significant genotype × location interactions (GLI) while evaluated 35 wheat lines at three locations and Mohammadi et al. (2017) also reported significant genotype × location interactions in chickpea.

Table 2. Estimates of variance components due to year within districts and its interaction with improved varieties

Variance components	Estimates	Standard Error	F pr
Year within districts	1891572	1167640	0.053
Variety × Year within districts interaction	317358	288905	0.136
Residual	370657	40154	

Table 3. Significance of improved variety and district interaction and main effect of varieties

Fixed term	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
District	7	20.83	183	<0.001
Variety	5	1.63	183	0.154
District.Variety	27	2.19	183	0.001
Random term	Component	Standard error		
Variance	954499	99785		

n.d.f: Numerator degrees of freedom. d.d.f = Denominator degrees of freedom. Fpr= P-value (Probability of F – random variable values exceeding the F statistic observed value when the respective main effect or interaction is absent).

Mean performance of varieties and winners in mega environments for crop production

The mean performance of varieties is given in Table 4. The improved varieties averaged over all the districts yielded in the range 4254 – 5169 kg/ha compared to local 2781 kg/ha indicating an additional yield from 53 - 86% over the local (Table 4). The highest yielding varieties in the districts were Kohistan 013 (3037 – 5967 kg/ha) in Charikar, Jabal Saraj, DehSabz and Qarabagh, PBW 156 (5383 – 5533 kg/ha) in Bagram and Mohammad Agha, Gull 96 (6044 kg/ha) at Pul-e-Alem and Zaren 013 (5490 kg/ha) at Char Asyab. To examine if the districts could be grouped into mega environments, we present GGE biplot in Fig. 1. The eight districts in the East Central Zone form three mega environments (ME): DehSabz, Charikar, Bagram, Qarabagh, and Mohammad Agha (ME1, say); Jabal Saraj and Char Asyab (ME2, say) and Pul-e-Alem (ME3). ME 1 comprises districts from all the three provinces and ME2 from Kabul and Parwan. The first two principal axes explained over 81% of variation in GGE. The highest yielding varieties in these ME are PBW 156 (5345 kg/ha) for ME1 (5 districts), Zaren 013 (5606 kg/ha) for ME3 (2 districts) and Gull 96 (6044 kg/ha) for ME 1 (Pul-e-Alem). Similarly, Akbarzai et al. (2017) observed the formation of two different mega-environment (Baghlan and Nangarhar; Mazar and Baghlan). Mohammadi et al. (2017) also reported the formation of mega-environment of two locations (Kabul and Baghlan).

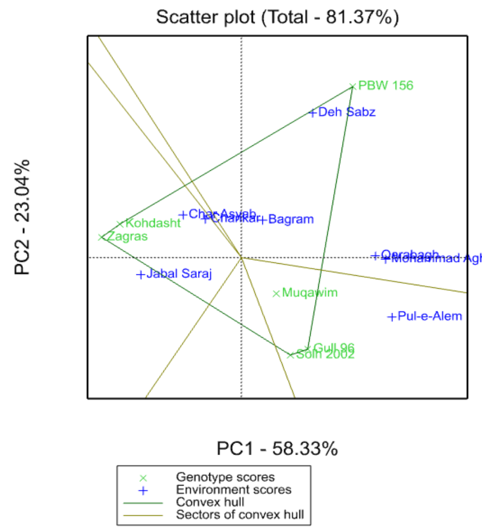


Fig 1. GGE biplot of the seven improved wheat varieties to eight locations in Afghanistan

Table 4. Predicted means of improved varieties and an averaged-over-locals in the eight districts of Afghanistan averaged over the two years, 2014-15 and 2015-16.

District	Variety						Local (average)	Av. SE
	Gull 96	Kohistan 013	Muqawim 09	PBW 156	Solh 2002	Zaren 013		
Bagram	4999	4827	4600	5383	4633	4798	2443	630
Char Asyab	4803	5181	4110	NA	4420	5490	4229	471
Charikar	4300	5967	5010	5100	4965	4626	2690	627
DehSabz	2644	3037	3017	NA	2599	2807	1924	465
Jabal Saraj	4522	5933	4778	4478	5578	5722	2776	515
Mohammad Agha	5413	3588	NA	5553	4997	3894	2595	451
Pul-e-Alem	6044	4371	NA	5330	5773	3555	2497	445
Qarabagh	NA	3389	NA	NA	NA	3144	2010	318
Means	4675	4537	4303	5169	4709	4254	2781	
Av. SE	189	180	314	319	236	114	93	
ME1	4339	4162	4209	5345	4299	3854		
ME2	4663	5557	4444	4478	4999	5606		
ME3	6044	4371	NA	5330	5773	3555		

ME1= Mega-environment: DehSabz, Charikar, Bagram, Qarabagh, and Mohammad Agha. ME2= mega-environment= Jabal Saraj and Char Asyab. ME3= Pul-e-Alem. NA: The cases were not in the trial. Av.SE= average standard error estimate of the means.$Value in bold is the highest yield at the given location.

Risk analysis

The risk curves for achieving target yields in the range 2500 – 6000 kg/ha are presented in Fig. 2 for the six improved varieties and averaged locals. As expected local is the most risky for wheat production for any target set. The least risky variety out of the six is the PBW 156. The risk curves for Gull 96 and Solh 2002 are very close and these two could be on second rank. Kohast 3rd, Muqawim 09 4th, Zaren 013 5th. There is a crossover between Zaren 013 and Muqawim 09 around 4200 kg/ha above which Zaren 013 is riskier compared to Muqawim 09. Investment on breeding is often assessed in terms of breeding progress measured as performance of best lines relative to the local checks as discussed in Tadesse et al. (2013) using the data collected from 1997 to 2010 in irrigated environments across different countries including Afghanistan. As the on-farm trials progress over years, it would be worth estimating the progress due to best of the improved lines in Afghanistan agro-climates. Since the present study is based on only two years of data and there is no significant variety × year interaction, the temporal progress approach can be laterally expressed in terms of the spatial suitability for wheat production. Table 4 shows that the yield of the best lines relative the locals exceeds 200% at Pul-e-Alem, Bagram, Jabal Saraj and Mohammad Agha while at the remaining locations the relative yield is in the range 130 – 169%. This assessment also could be used for a geographical preference for large scale commercial production. For successful adoption of winter wheat varieties in Central and West Asia, Sharma et al. (2012) highlighted that the resistance to stripe (yellow) rust is also among the most important traits. The neighboring countries, Iran, Turkey and Uzbekistan locations were used to identify stripe rust resistant winter wheat lines. In future on-farm trials, we plan to include varieties resistant to current yellow rust race, as the older varieties lose their resistance potential with time.

CONCLUSION

The result of on-farm trials showed the substantial yield increase of improved varieties along with package of practice over local in the farmers' field. In total 223, on-farm trials were conducted in eight districts in East Central Zone. For the improved variety over the local, positive gain in yield was shown by the risk assessment. Over all the locations, the improved varieties showed substantial increase of yield over local variety in rang of 53-86% and yield stability across the locations. Consequently, the wide use of improved varieties with package of practice resulted in considerable yield gain which motivated the farmers to accelerate variety replacement up 100%. Such an increase will be uplifting the economic status of the farmer. As whole, increase in the yield would be contributed to meet current need of the country in wheat and improve the food security.

AUTHOR CONTRIBUTIONS

Darya Khan Akbarzia, Omar Jan Mangal, Suhilla Nisar and Lina Mohammdi were carried out the experiment and collect data for analysis from different locations including writing the full manuscript. This research was funded by Community Livestock and Agriculture Project (CLAP) - Sub-Component 2.3: Improved Food, Fodder and Vegetable Crops (IFFVC) and implemented by ICARDA, Kabul, Afghanistan.

ACKNOWLEDGMENTS

Authors thanks to related Department of Agriculture, Irrigation and Livestock (DAIL) in Kabul, Parwan and Logar provinces including ICARDA field technical staff Mssrs. Khalilurahman, Shafiullah Qarishi, Nisar Ahmad for and providing technical support and implementation and collecting the data from the trials presented.

COMPETING INTERESTS

The authors declare that they have no competing interest

ETHICS APPROVAL

Not applicable

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