Journal of Innovative Agriculture: 8(2) : 29-33, 2021
DOI: 10.37446/jinagri/rsa/8.2.2021.29-33
Research paper

On-farm assessment of the improved legumes

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Received: 6 January 2021
Accepted: 11 May 2021
Published: 30 June 2021

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Nutritional food security is essential for the growing population of Afghanistan. Legumes, such as chickpea, lentil and mung beans are important sources of food protein. Enhancing production of legumes is a natural option to provide health to its consumers and employment to agrarian families engaged in its cultivation. While developing the breeding methods for new seeds adapted to Afghanistan environments must continue, evaluation of a number of already improved varieties was found an immediate alternative to the low yielding farmer varieties. Over nine locations during 2014-15 and 2015-16, seven improved chickpea varieties were evaluated in 86 farmer fields, one improved lentil variety in 68 fields and one improved mung bean variety in 70 fields. The improved varieties were coupled with the recommended crop production practices. Of the seven improved chickpea varieties evaluated over the environments in the study, Australia was found having highest average yield mean of 1127 ± 107 kgha^{-1}(tested over three locations) followed by FLIP-92 (753 ±37 kgha^{-1}) while Sehat (372 ± 136 kgha^{-1}) yielded the lowest. Among the locations, Deh Sabz had highest yield level of 2341 kg ha^{-1}based on FLIP-92 and FLIP-95. The lentil Kushak-1 showed an average yield of 573 ± 260 kg ha^{-1} and mung bean variety Mash 2008 yielded 538 ± 273 kg ha^{-1}. This on-farm trial provided an appraisal of yield levels of the selected improved legume varieties. However, evaluation of new improved legume varieties is regularly needed through on-farm trials to provide an evidence-based recommendation to farmers.

Key words: on-farm trials, legumes, improved genotypes, food security, productivity risks

INTRODUCTION

Food insecurity and malnutrition is a big concern recently in Afghanistan and around five million people (20% consisted children within five years) are estimated to cope with it (FAO, 2015). At national level, malnutrition rates among children 0–59 months of age at national level were stunting 40.9%, severe stunting 20.9% and moderate 20.0% stunting and 9.5% wasting. Of girls between 10-19 years, 8.0% were thin and 1.5% was severely thin, while of the women between 15-49 years, 9.2% thin or undernourished (MPH, 2013). In consideration of 18.25 kg of annual capita requirement of pulses and the recommended pulse dietary requirement of 50 gm per capita per day, the current availability of 2.4 kg during 2013 is instigating in chronic malnutrition (FAO, 2016). The main factors perceived were the limited availability and accessibility to protein rich food sources, instability of food supplies and poor diets (FAO, 2015). Around 115-thousand-hectare land is under cultivation of pulses production and chickpea production contributes to 18.17% in country (MAIL, 2014). The total production of the food legume is estimated around 60,000 tons and the productivity is less 0.752 t ha^{-1} (FAO, 2016). Total population of the country was estimated 29.7 million people for 2017-18 (CSO, 2017). The main constraint in accessibility of protein sources was reported to be the huge demand-supply gap and suggested the need of crop diversification of improved varieties of legumes in cropping systems in Afghanistan (Tavva et al., 2019). He also pointed out some major constraints that were found responsible were low yield due to lack of improved varieties, related management practices and non-availability of quality seeds in pulses production. To meet the protein requirement of population in Afghanistan, high productive and widely and specifically adopted varieties of pulses are needed for rainfed and irrigated areas. Improvement in legume production as chickpea, lentil and mungbean in the country, is the only source to meet the requirement and need of protein. Therefore, varieties of pulses which are high yielding, resistance to biotic and abiotic stress, and suitable for adoption to rainfed and irrigated environments are required. A demonstration trial is a common practice in introduction and popularization of newly high yielding varieties by ICARDA and other NGOs conducted in the country. In Afghanistan, limited use of appropriate technology and social/cultural factors were the main issues affecting adopting of any new technologies in farmer fields (Erskine et al., 2009).

On-farm trials or demonstration used vary effectively for introduction of new technology or any other crop improved variety and management practices (Witcombe et al., 2005; Rizvi et al., 2012). A case study showed that the farmer field demonstration played important role in replacement of local rice variety by improved one by farmers in Nigeria (Okocha et al., 2004).This study assesses the impact, in terms of crop productivity, of recently introduced improved varieties along with their agronomic practices by on-farm trial, i.e., farmers' participatory demonstration in farmer's field.

MATERIALS AND METHODS

Evaluation environments

Afghanistan has both arid and semi-arid climates. The summers with temperatures up to 49 °C (120 °F) is considered hot and winters can be severe cold temperatures as low as -9 °C (15 °F). Maximum precipitation falls between the months of October and April. The precipitation is high (1000 mm or 40 in) in the in highest part (mountains) mostly as snow and low (100 mm or 4 in) in the desert areas. In total, 120 farmers (53 for chickpea, 30 for lentil and 37 for mungbean) were selected for the implementation on-farm trials with proper guidance of responsible extension departments. Farmers, extension agent and ICARDA field staff were the main implementer in the field based on pre-prepared field layout and the fields are monitored regularly for advice to farmers and data collection. Although the selection of equal number of farmers per district for each crop was set initially but it finally differed through the damages at with stages such as crop germination, field management and bio-physical parameters (Table 1).

Statistical analysis

The dataset was unbalanced for variety, location named by the district and year. The yield therefore, was modelled using a mixed linear model accounting for the effect of varieties, districts, year within districts and their interactions with variety. Variety effects and district effects were assumed as fixed and the interactions involving year were assumed random. The REML (restricted maximum likelihood) procedure was used to estimate fixed effects with their standard errors and variance components of the random effects and can be illustrated in terms of key directives of GenStat software (VSN International, 2015), as follows.

VCOMPONENTS [FIXED= District + Variety + District.Variety]
Random model= District.Year + District.Year.Variety
REML[PRINT=model,components, means, deviance, Wald; PSE=e] Yield

Where the factors denoted as Variety, District, and Year stand for improved variety (7levels), districts (9) and years (2) respectively, and Yield stands for response variable chickpea seed yield.

There was only one improved variety for each of lentil and mung bean, so yields distribution across the environments (district – year combinations) was presented as boxplots and descriptive summaries. The variations in average yields between and within environments were estimated as variance components.

Table 1: Number of farmer fields where the demonstration trials in chickpea, lentil and mung bean were implemented during 2014-15 and 2015-16

Province	District	Chickpea		Lentil		Mung bean	
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Kabul	Chara Asyab	5	4	5	5	3	5
	Deh Sabz	3	5	0	5	0	1
	Qara Bagh	5	5	3	5	5	4
Parwan	Bagram	6	5	2	2	5	5
	Charikar	5	4	2	2	5	4
	Jable Seraj	5	3	3	4	5	5
Logar	Baraki Barak	0	4	0	1	0	3
	Pul-e-Alam	8	4	6	5	7	4
	Mohammad Agha	8	7	9	9	7	2
Total		45	41	30	38	37	33

The trials

The demonstration plots were implemented during the two growing seasons (2014-15 and 2015-16) in a total of nine districts from the three provinces, particularly in the central part of the country. In the case of chickpea, the improved varieties experimented were: Australia, FLIP - 92, FLIP - 93, FLIP - 94, FLIP - 95, FLIP - 96, Madad and Sehat. Lentil and mungbean trials included only one available varietyeach, Kushak-1 for lentil trials and Mash 2008 for mung bean trials. With the improved seed were package of practices, for example, seed rates of 100, 35 and 25 kg ha^{-1}, chemical fertilizer, 55, 55 and 25kg Urea ha^{-1} and the same rate of 100 DAP kg ha^{-1} for chickpea, lentil and mungbean respectively. The field area implemented was $1000m^2$ covering all the improved practices. The row to row distance was 30 – 40cm for chickpea and lentil and mung bean. But the genotype of available local variety was not known nor the details of package of practices were available for comparison. The data is collected from the whole plot and then converted to $kgha^{-1}$ for statistical analysis.

RESULTS AND DISCUSSION

Since it was the first time of introduction of these new improved varieties (Table 2) to the farmer fields in these locations for adoption, therefore more focus was on production as obtained by the farmers. In this consideration there were no local practices or variety for compression of difference in all over the study. As estimation of mean yield over the year and location, the top high yielding chickpea variety was Australia with average yield mean of1127 ±107$kgha^{-1}$ followed by FLIP-92 (average: 753 ±37 $kgha^{-1}$), FLIP-95 (650 ± 60 $kgha^{-1}$), FLIP-94 (560 ±235 $kgha^{-1}$), Madad (446 ± 118 $kgha^{-1}$), FLIP-96 (440 ±235 $kgha^{-1}$) and Sehat (372 ± 136 $kgha^{-1}$) over tested locations. The variance component estimated for the random effects of the years within districts and variety × year interactions within districts (Table - 3). The variance component estimate for the temporal interaction of variety was found zero which indicates the stability of the varieties over the years across the districts. Although there is substantial variation between the chickpea varietymeans, 372 - 1127 $kgha^{-1}$, a threefold difference, but variety means were not significantly different (P =0.872). Obviously, the field plot variation was very high and mask the variety differences as indicated by a high coefficient of variation (CV = 38%).

Table 2. Estimated mean yields of chickpea varieties over the tested locations and years

Number of farmer fields	Variety	Mean ± SE (kg ha^{-1})	95% Confidence interval
5	Australia	1127 ± 107	(916, 1337)
53	FLIP-92	752.5 ± 37.4	(679, 826)
1	FLIP-94	560 ± 235.2	(99, 1021)
19	FLIP-95	649.9 ± 59.9	(532, 767)
1	FLIP-96	440 ± 235.2	(0, 901)
4	Madad	446.2 ± 117.6	(216, 677)
3	Sehat	371.7 ± 135.8	(106, 638)

SE: Standard error

Table 3. For chickpea yield, estimates of variance components due to year within districts and interaction with varieties

Variance components	Estimates	Standard Error (SE)
Year within Districts	822294	420136
Year ×Variety interaction within Districts	0	Bound
Residual	55327	10951

Further, the distribution of yield observed from the individual fields are presented as boxplots. The yield distribution of chickpea varieties, shown in Figure. 1, exhibits a much wider spread for varieties FLIP-92 and FLIP-95 with extremely favorable yields in some environments compared to the others.

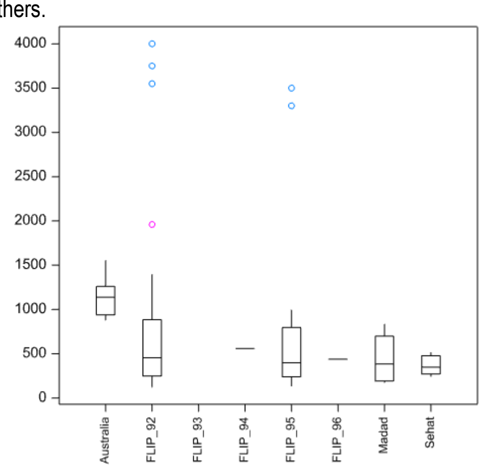

Figure 1: Boxplot of chickpea yields

Distribution of average yield over the farms tested for district × varieties are presented in Table 4 which provides a geographical option for chickpea production. The yield of given improved varieties fluctuated due to environment affect. The number of varieties per location ranged from 2 to 5. In Bagram, where only three chickpea varieties were tested namely FLIP-92, FLIP-96 and Madad. FLIP-96 was the high yielded one with mean of 297.5 kgha^{-1}. Over all the varieties tested in a given district, Deh Sabz was highest yielding location (average 2341 kg ha^{-1}) followed by Baraki (1125 kg ha^{-1}), thus most suitable for large scale production with any of the FLIP - 92 and FLIP - 95**.** The low yielding locations are Bagram, Char Asyab, Charikar and Jabal Saraj yielding in the range: 305 – 436 kg ha^{-1}. The remaining three locations, Mohammad Agha, Pul-e-Alem and Qarabagh yielded in the range: 599 – 782 kg ha^{-1}. In case of the lentil and mung bean, where only one improved variety was tested over all targeted locations, the distribution over the districts are presented in Table 5.

Table 5. District-wise mean yields for the lentil and mung bean varieties

District	Lentil Kushak-1 (kg ha^{-1})	Mung bean Mash 2008 (kg ha^{-1})
Bagram	115	289.5
Baraki	1300	1053.3
Char Asyab	456	582.9
Charikar	140	394
Deh Sabz	1930	1400
Jabal Saraj	125.6	420.5
Mohammad Agha	521.7	461.8
Pul-e-Alem	861.4	848.9
Qarabagh	393.6	712.6
All districts	573.2 ±259.5 (68)$	537.8± 273 (70)$

$Number of fields

For lentil Kushak-1, the average yield varied over locations in the range 115 – 1930 kg ha^{-1} and such a wide range shows that the lentil variety is very sensitive to environment factor. The mean yield of improved lentil variety, Kushak -1, was 573 ± 260 kg ha^{-1}. The highest yielding location for lentil was Deh Sabz with average mean of 1930 kgha^{-1} followed by Baraki and Pul-e-Alem with mean of 1300 kgha^{-1} and 861.4 kgha^{-1}. These mentioned locations were also the best location for chickpea production as well. Parwan province is not at all good for lentil production as it has very low mean (115 – 140 kg ha^{-1}) among studied locations/province. The average mean yield of the mungbean variety, Mash 2008, across the locations ranged 289.5– 1400 kgha^{-1} and yielded 538 ± 273 kg ha^{-1} overall the locations. Deh Sabz, Baraki and Pul-e-Alem were the productive locations with average mean in the range: 849 - 1400 kg ha^{-1}. In general, Kabul and Logar showed to be legume

Table 4. Average yield distribution of chickpea varieties across districts

Variety	Australia	FLIP- 92	FLIP-94	FLIP-95	FLIP-96	Madad	Sehat	All varieties
District				Mean (number of farmer fields)				
Bagram	*	374.4 (8)	*	297.5 (2)	*	175 (1)	*	342.3 (11)
Baraki	1060 (2)	1190 (2)	*	*	*	*	*	1125 (4)
Char Asyab	*	423.3 (3)	560 (1)	346.7 (3)	440 (1)	*	520 (1)	425.6 (9)
Charikar	*	494.3 (7)	*	220 (1)	*	*	245 (1)	436.1 (9)
Deh Sabz	*	2347.5 (5)	*	2330.8 (3)	*	*	*	2341.2 (8)
Jabal Saraj	*	389 (5)	*	142.5 (2)	*	210 (1)	*	305 (8)
Mohammad Agha	*	886.7 (12)	*	367.5 (2)	*	*	350 (1)	781.7 (15)
Pul-e-Alem	1193.3 (3)	380.6 (8)	*	*	*	560 (1)	*	598.8 (12)
Qarabagh	*	696.7 (3)	*	704.2 (6)	*	840 (1)	*	715.5 (10)
All districts	1140 (5)	746.5 (53)	560 (1)	741.7 (19)	440 (1)	446.2 (4)	371.7 (3)	735.5 (86)

***: Not tested.**

productive area rather than Parwan. In the three legumes, the limitation has been to stay with the improved varieties developed in other environments. However, more focus on research is needed to develop crosses, selections and evaluation, all in the Afghanistan's agro-ecologies, as the crop products developed are likely to break the bottle neck of the limited yield level.

Increases in yield due to an improved variety and associated technology of crop production must be examined for the level of adoption and factors determining it. As found in (Shiyani *et al*., 2002), adoption of improved chickpea varieties in tribal villages in Gurajat, India was replacing a local prominent variety and the factors that influenced the adoption were crop maturity, farm size, yield risk, and farmers' experience of growing chickpea crop. To study the impact of adoption of improved legume technology, (Asfaw *et al*., 2012) used consumption expenditure as an indicator of the impact in rural Ethiopia and Tanzania estimated from the cross-sectional farm household level data. In this study, while substantial increases were observed in yield due to improved varieties of chickpea compared to the locals, follow-up studies are needed to assess the impact of their adoption by Afghanistan farmers and the factors determining the impact, using various approaches including the above two approaches.

CONCLUSION

On-farm trials were conducted in three legumes, chickpea, lentil and mung bean, on a total of 224 farms, over nine locations during 2014-2016. The chickpea improved variety Australia yielded the highest of the seven improved varieties (mean: 1127 ± 107 kgha^{-1}) followed by FLIP-92 (mean: 753 ±37 kgha^{-1}), while the popular varieties Madad (446 ± 118 kgha^{-1}), and Sehat (372 ± 136 kgha^{-1}) yielded around 30% of the best varieties (86 farms). The lentil variety Kushak-1 gave an overall mean of 573 ± 260 kg ha^{-1} (68 farms) and mung bean variety Mash 2008 yielded an average of 538 ± 273 kg ha^{-1} (70 farms). For chickpea, the Australian variety clearly shows an advantage in supporting the food security and increasing the farmers' income in comparison to the other varieties. Among the chickpea growing locations, Deh Sabz shows the option of large scale production. The on-farm trials must be regularly continued to keep the better varieties identified for enhancing the production.

AUTHOR CONTRIBUTIONS

Darya Khan Akbarzia and Lina Mohammdi were carried out the experiment and collect data for analysis as well as 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 the Department of Agriculture, Irrigation and Livestock (DAILs) in Kabul, Parwan and Logar provinces including ICARDA field technical staff Mssrs. Khalilurahman Fazli, Shafiullah Qarishi and Omid Arman for providing technical support and collecting the data from the trials presented.

COMPETING INTERESTS

The authors declare that they have no conflicts of interest associated with the publication of this article.

ETHICS APPROVAL

Not applicable.

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