

Participatory variety selection and promotion of improved faba bean (*Vicia faba* L.) varieties in the highland areas of North Shewa, Ethiopia

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Abstract

Faba bean is the most important pulse crop in Ethiopia; however, its productivity has low and susceptible to biotic and abiotic stresses. The objective of this study was to select and promote varieties that most preferred by farmers and showed best agronomic performances. Participatory variety selection was conducted with seven improved and local faba bean genotypes using randomized complete block design with three replications. The agronomic data were collected from four central rows. The trial was conducted in Hagre Mariam woreda during 2019 and 2020 cropping seasons. Highly Significant variation was observed among the tested varieties in days to flowering (50 to 56), 100-seed weight (39.16 to 91.62 grams), grain yield (1.88 to 3.03 t ha⁻¹) and faba bean gall disease percent severity index (11.10 to 30.67%). Significant difference was also detected in days to maturity (135 to 141) and plant height (83.27 to 106.57cm). The highest grain yield was recorded by Hachalu (3.03 t ha⁻¹) followed by Walki (2.92 t ha⁻¹) and Numan (2.86 t ha⁻¹). Among the tested varieties Walki got farmers' high preference score indicating it fulfilled farmers' varietal selection criteria including, long plant height, high grain and straw yield, high no. of pods/plant and no of seeds/pod, big seed size, early maturity and better adaptability in the area. Accordingly, Walki was pre scaled up and widely disseminated. During the scaling up Walki gave an average grain yield of 2.64 t ha⁻¹ and showed about 107.9% grain yield advantage over the local cultivar.

Introduction

Faba bean (*Vicia faba* L) is a widely produced food legume in the world; Ethiopia is the second-largest faba bean producer next to [12, 13]. It is the most important pulse crop in Ethiopia, where it covers about 504,569.99 hectares annually, from which about 10,706,365.38 tons of grain yield was produced with the involvement of about 4,159,404.00 smallholder farmers [4]. Among the administrative zones in the Amhara region, the North Shewa zone ranks first in both area coverage and total production of faba beans and ranks third in the number of farmers involved in faba bean production [4, 5].

Faba bean is mainly cultivated in mid- and high-altitude areas of the country, whose altitude ranges from 1800 to 3000 meters above sea level [10, 2]. Faba bean has multiple uses. As a human diet, it is consumed as dry seeds, green vegetables, and processed food and is rich in high-quality protein. Its dry seeds, green haulm, and dry straw are used as animal feed. It is also one of the major exported legume crops, which provides the country with foreign currency [11, 14]. Faba bean plays a significant role in enhancing soil fertility through nitrogen fixation so that it is used as a rotational crop [7, 12].

Even though the faba bean has indispensable significance for the country. Amhara region in particular in terms of food and nutritional security, as a source of income for the farmers, as a source of foreign currency for the country, and its role in improving soil fertility, the productivity of the crop is far below its potential. Its national average grain yield is about 2.09 t ha⁻¹, while in the Amhara region it is about 1.9 t ha⁻¹ [4]. The productivity of faba bean has been constrained by a number of factors, among which wider use of local cultivars, which are low yielding and susceptible to both biotic and abiotic stresses coupled with traditional crop management practices, are the major ones [10].

Although about 38 improved faba bean varieties have been released through the research system [6], the farmers do not adopt most of them. Variety development by itself has nothing to bring a difference unless the

growers adopt it. Witcombe [17] summarized the reasons for low adoption of improved varieties by farmers as follow; many farmers may not have access to or information about seeds of new varieties; variety-testing programs are often conducted on-station, which does not represent farmers' fields; conventional breeding programs usually seek farmer input only at the very end of the process. furthermore, varietal release systems give more emphasis to grain yield whereas farmers consider other traits when selecting varieties. Wide agro-ecological variation due to differences in altitude, temperature, rainfall, and soil type also leads to the need for a wide range of varieties. As farmers are not consulted during the variety improvement process, many varieties are cultivated but never registered, while many registered varieties are never cultivated [3]. This needs to improve the communication between farmers and breeders so that farmers' concerns and preferences are incorporated earlier in the research process, research is accelerated, and the adoption rate improves.

In order to address many of these problems in many crops, one approach that has been practiced is participatory varietal selection (PVS) [17]. PVS is the selection by farmers on their own fields of finished or near-finished products from plant breeding programs and involves a range of actors, including farmers, breeders, scientists, and other stakeholders. In PVS, farmers are provided with a basket of genotypes for matching with their selection criteria. Hence, this study was conducted to evaluate, select, and promote farmers' best preferred and biologically best performing improved faba bean varieties in the high-land areas of the North Shewa zone.

Materials and Methods

Description of the study area

The study was conducted at Debre Tsige kebele of Hagere Mariam woreda in the North Shewa zone. During the 2019 and 2020 main cropping seasons. The testing site was located between 9° 12' 50.75 N latitude and 39° 24' 59.93 E longitude at an altitude of 2754 meters above sea level. Debre Tsige receives about 1013.5 mm annual rainfall with the maximum and minimum mean temperature of 19.5°C and 9.4°C, respectively. The dominant soil type in the area is cambisol and has a waterlogging problem.

Experimental materials and trial management

Seven improved faba bean varieties and one local cultivar was included in the participatory variety selection (PVS) study in 2019. The passport data of the improved varieties is indicated in Table 1. The PVS was conducted in a mother-baby trial approach following ARARI's PVS guideline [1]. The mother trial was laid out in a randomized complete block design (RCBD) in three replications, executed at a farmers' training center (FRC), while the baby trial was executed on a farmers' farm, and laid out as a replication. The mother trial was used for biological data collection, while the baby trial was used for farmers' varietal evaluation and selection data collection. Each variety was planted in a plot size of 4 m by 2.4 m in six rows, of which four central rows were used for data collection. The spacing between replications, plots, and rows was 1 m, 0.5 m, and 0.4 m, respectively. Seeds were drilled in a row, and the spacing between seeds was 0.1 m. NPSB fertilizer at a rate of 121 kg ha⁻¹ was applied at planting. Weeding was done twice, two weeks after planting and before the flowering stage of the crop.

Table 1
Passport data of improved faba bean varieties included in the PVS study in 2019

No	Varieties	Altitude (m.a.s.l)	Rainfall (mm)	Year of release	Center of release	Yield t ha ⁻¹		Days to maturity
						Research center	Farmers field	
1	Numan	1800– 3000	700– 1100	2016	KARC	3.65	2.2–3.8	137–148
2	Ashebekka	1900– 2800	700– 1100	2015	KARC	3.0-5.4	2.8–4.7	128–156
3	Gora	1900– 2800	700– 1000	2013	KARC	2.2–5.7	2.0–4.0	151–158
4	Hachalu	1900– 2800	700– 1000	2010	HARC	3.2–4.5	2.4–3.5	122–156
5	Dosha	2050– 2800	700– 1000	2009	HARC	2.8–6.2	2.3–3.9	160–180
6	Walki	1900– 2800	700– 1000	2008	HARC	2.4–5.2	2.0-4.2	133–146
7	Dagim	2600– 3000	900– 1000	2002	DBARC	3.5	--	152
8	Local	--	--	--	--	--	--	--
Note: KARC = Kulumsa Agricultural Research Center, HARC = Holleta Agricultural Research Center, DBARC=								

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Agronomic data collection and analysis

Agronomic data were collected from the middle four harvestable rows on both plant and plot basis. Data on plant height (cm) no. of pods/plant and no. of seeds/pod were collected on plant basis while data on days to 50% flowering, days to 90% maturity, grain yield (g) and hundred seed weight (g) were collected on plot basis. The disease severity data on chocolate spot, ascochayta blight and faba bean gall disease were also collected using 0 to 9 scoring scale and converted into the percentage severity index (PSI) according to Wheeler [16].

$$\text{PSI} = \frac{\text{Sum of numerical rating}}{\text{number of plats scored} \times \text{maximum score on a scale}} \times 100$$

The collected data were subjected to analysis of variance using R software, and mean comparison was performed using LSD test at 5% level of significance.

Farmers' participation in variety evaluation and selection

The participants of the testing kebele's Farmers Research and Extension Group (FREG) received improved faba bean production package training prior to the trial's execution. This training comprised both theoretical and practical sessions. Farmers' varietal evaluation and selection was done on both mother and baby trials, both at the vegetative and maturity stages. In consultation with kebele development agents, 20 (5 female) FREG members were invited to participate in variety evaluation and selection. Farmers were selected considering gender, experience in growing faba beans, and willingness to participate in the varietal evaluation and selection process. The participants were briefed on the purpose of the PVS and their involvement in the varietal evaluation and selection process before the evaluation and selection session in the field actually began. Then farmers were made to set their varietal preference criteria, and then they did varietal evaluation and selection based on their criteria (Fig. 1).

Ranking of farmers' varietal preferences

To find out the most preferred varieties by farmers, Garrett's ranking technique was employed [6]. As per this method, farmers were asked to rank each variety for each varietal selection criteria and the outcomes of such ranking were converted into score value with the help of the following formula:

$$\text{Percent position} = \frac{(R_{ij} - 0.5)}{N_{ij}} * 100$$

Where, R_{ij} =Rank given for the i^{th} variety by the j^{th} respondent, N = Number of varieties ranked by j^{th} respondents. With the help of Garrett's ranking conversion table (Appendix 1), the percent position is estimated and converted into scores (Table 2).

Table 2
The conversion of ranks of merits into units of amounts of scores

No	$100(R_{ij}-0.5)/N_j$	Calculated value (%)	Score
1	$100(1-0.5)/8$	6.25	80
2	$100(2-0.5)/8$	18.75	67
3	$100(3-0.5)/8$	31.25	60
4	$100(4-0.5)/8$	43.75	53
5	$100(5-0.5)/8$	56.25	47
6	$100(6-0.5)/8$	68.75	40
7	$100(7-0.5)/8$	81.25	33
8	$100(8-0.5)/8$	93.75	20

After that, the variety scores of each individual were added, and the total value and mean values of the score were calculated. Hence, the product of the performance score and the weight gave the preference value of the varieties for each selection criterion. The overall preference value of each variety was obtained by adding the preference values of each variety for each selection criterion. Hence, the rank of acceptability of the varieties

was done based on the total preference value of each variety. The lower the total preference value of a given variety, the higher the acceptability rank. A total of 36 farmers were interviewed for this preference analysis.

Pre scaling up of the selected faba bean variety

The pre-scaling of the selected variety was conducted in the study kebele in 2020. Host farmers were selected and supplied with seed of the variety. The success of a technology promotion program depends on appropriate prior orientation given to participants on technologies and the stepwise implementation of subsequent activities. Accordingly, prior to the commencement of the pre-scaling activity, training was given to the host farmers, kebele development agents, and woreda-level agricultural office experts on the recommended faba bean seed production and management package by a team of researchers. A multidisciplinary team of researchers and agricultural experts made regular field visits to observe the progress, fix problems, and give advice on proper field and crop management practices, starting from land selection to harvesting. Field day was organized at the physiological maturity stage of the crop to collect the reaction of host farmers and other field day participants on the performance of the improved faba bean variety being scaled up. Grain yield (kg ha^{-1}) data of the new variety was collected from the host farmers' farm, and for comparison purposes, grain yield data of the local cultivars was collected from the adjacent farms. The grain yield data was analyzed using simple descriptive statistics.

Results and Discussion

Agronomic performance of the tested faba bean varieties

The result of the analysis of variance showed highly significant differences among the tested faba bean varieties in days to flowering, no. of pods/plant, 100-seed weight, grain yield, and faba bean gall disease severity index, while significant differences were detected in days to maturity and plant height. On the other hand, there was no significant difference observed among the tested faba bean varieties in the number of seeds per pods, chocolate spot, and ascochyta blight disease severity index (Table 3). However, in the number of seeds/pods, chocolate spot and ascochyta blight disease severity was not observed as a significant difference at the p-value 0.05 significance level (Table 3). The days to flowering and maturity ranged from 50 to 56 and 135 to 141 days, respectively. Numan, Hachalu, and Walki were found early maturing varieties and took 135 days to mature, while Dagim was late maturing and took 141 days to mature. Mulualem [9] noted that early maturing genotypes have the advantage over late-maturing genotypes in environments where rainfall begins late and ends early.

Plant height ranged from 83.27 cm to 106.57 cm, with a grand mean of 96.08 cm. The highest plant height (106.57 cm) was recorded for the Numan variety, while the lowest (83.27 cm) was measured for the Gora variety. Walki gave the highest number of pods/plants (9.68), followed by Dosha (11.53) and Hachalu (11.20), and while the lowest number of pods per plant (6.33) was recorded by Gora. In contrast to the result of this study, Getnet & Yehizbalem [8] and Tiringo [15] reported that Gora recorded the highest plant height and number of pods per plant who conducted a similar study, indicating varietal performance variation from environment to environment.

Among the tested faba bean varieties, Numan gave the highest 100-seed weight (91.62 g), followed by Gora (77.06 g), and Ashebeka (75.22 g), while Dagim recorded the lowest 100-seed weight (39.16 g) (Table 3). The result of a similar study, which was conducted by Yirga and Zinabu [20], showed that Gora gave the highest 100-seed weight (85.50 g), followed by Dosha (77.17 g). The grain yield ranged from 1.88 t ha⁻¹ to 3.03 t ha⁻¹, with a grand mean of 2.53 t ha⁻¹. The highest grain yield (3.03 t ha⁻¹) was recorded by Hachalu, followed by Walki (2.92 t ha⁻¹) and Numand (2.86 t ha⁻¹) while the least grain yield (1.88 t ha⁻¹) was obtained from Gora (Table 3). The grain yield performance of the tested varieties in this study is in agreement with the research findings reported by Aliyi [2].

Regarding faba bean disease percent severity index, significant variation was detected among the tested faba bean varieties in faba bean gall disease, while no significant variation was observed in both chocolate spot and ascochyta blight severity index among tested varieties. The faba bean gall disease percent severity index ranged from 11.10%, which was recorded by Dosha, Numan, and Hachalu, to 30.67%, which was recorded by the local cultivar (Table 3). The result of the percent disease severity index of the three reported diseases in this study was found to be in agreement with the findings reported by Tiringo [15].

Table 3
Mean performance of the tested faba bean varieties for the measured agronomic traits

Variety	Traits									
	DF	DM	PH	PPP	SPP	HSW	GY	FG	CS	AB
Ashebeka	52 ^{de}	136 ^{bc}	98.67 ^{ab}	8.80 ^{bcd}	2.57	75.22 ^b	2.48 ^{bc}	22.63 ^b	16.30	12.67
Dagim	56 ^a	141 ^a	94.67 ^b	12.07 ^a	2.40	39.16 ^e	2.40 ^c	18.83 ^{bc}	14.13	13.07
Dosha	50 ^{ef}	136 ^{bc}	92.53 ^b	11.53 ^{ab}	2.50	64.19 ^c	2.37 ^c	11.10 ^d	10.73	11.20
Gora	54 ^{bcd}	137 ^{bc}	83.27 ^c	6.33 ^d	2.50	77.06 ^b	1.88 ^d	22.93 ^b	12.20	13.03
Hachalu	50 ^f	135 ^c	99.53 ^{ab}	11.20 ^{ab}	2.50	61.92 ^c	3.03 ^a	11.10 ^d	11.47	12.30
Local	54 ^{abc}	138 ^b	93.67 ^b	10.73 ^{abc}	2.40	49.23 ^d	2.29 ^{cd}	30.67 ^a	14.43	13.57
Numan	55 ^{ab}	135 ^{bc}	106.57 ^a	7.67 ^{cd}	2.60	91.62 ^a	2.86 ^{ab}	11.10 ^d	14.80	13.17
Walki	52 ^{cd}	135 ^{bc}	99.73 ^{ab}	13.60 ^a	2.30	62.84 ^c	2.92 ^a	14.97 ^{cd}	16.63	13.07
GM	53	136	96.08	10.24	2.47	65.16	2.53	17.92	13.84	12.76
LSD(5%)	1.85	2.79	7.92	3.18	0.35	3.57	0.43	6.868	6.948	2.96
CV(%)	2.0	1.2	4.7	17.7	8.0	3.1	9.7	21.9	28.7	13.2
P-level	**	*	*	**	NS	**	**	**	NS	NS

Note- Means followed by the same letters are not significant at 5% probability level, DF = days to flowering, DM = days to maturity, PH = plant height (cm), PPP = pod per plant(no), SPP = seed per pod(no), HSW = 100-seed weight (gram), GY = Grain yield (t ha⁻¹), FG = faba bean gall severity (%), CS = chocolate spot severity (%), AB = Ascochyta blight severity (%), GM = grand mean, LSD = Least significant differences at 5%, CV = coefficients of variation, P = probability, ** = highly significance, * = significance, NS = non significance.

Farmers' varietal preferences

The results of farmers' varietal preference analysis based on their varietal selection criteria are indicated in Table 4. Farmers set seven varietal selection criteria, including plant height, number of branches, adaptability, resistance to disease, number of pods per plant, number of seeds per pod, and seed size (Table 4). The results of farmers' varietal preference analysis showed that Dosha was found to be the tallest variety among the tested varieties. In terms of seed size, both Numan and Ashebeka were found to be large seeded varieties. However, farmers preferred Walki first, followed by Dosha and Ashebeka (Fig. 2). Farmers preferred Walki as first for its branching ability, adaptability to their environment, high number of pods per plant, and number of seeds per pod.

Table 4
Farmers' varietal preference value (%) of each variety and final acceptability rank (N = 36)

Varieties	PH	NB	DR	AD	NPP	NSPP	SS	Mean	Rank
Numan	50	12.5	62.5	62.5	62.5	50	100	57.1	4
Ashebeka	87.5	25	75	75	75	37.5	87.5	66.1	3
Gora	37.5	37.5	37.5	25	37.5	62.5	50	41.1	7
Hachalu	75	75	50	37.5	25	12.5	62.5	48.2	5
Dosha	100	62.5	87.5	87.5	87.5	87.5	75	83.9	2
Walki	62.5	100	100	100	100	100	37.5	85.7	1
Dagim	12.5	87.5	12.5	50	50	75	12.5	42.9	6
Local	25	50	25	12.5	12.5	25	25	25	8

Note: PH = plant height, NB = number of branches, DR = Disease resistance, AD = adaptability, NPP = no. of pods per plant, NSPP = No. of seeds per pod, SSL = Seed size

Pre scaling up of farmers' preferred improved faba bean variety

One of the key elements of participatory varietal selection (PVS) is to scale up the varieties that are most preferred by farmers and have shown the best biological performance to reap their benefits. Based on the results of the biological data and farmers' varietal preference analysis from the PVS trial, Walki was selected and recommended for pre-scaling up. Consequently, it was pre-scaled up in Debre Tsige kebele during the main cropping season of 2020. Seed of Walki was distributed to 13 host farmers, and a total of 5.4 hectares of land were covered.

Field day

Field day was organized to create awareness among farmers and other stakeholders (Fig. 3). The event was held at the physiological maturity stage of the crop, and 34 participants attended. During the event, farmers and stakeholders shared their experiences and knowledge. Finally, a group discussion was conducted to gather feedback on the strengths and weaknesses of the variety. All of the participants acknowledged the host farmers who produced the seed following the right protocol. They also appreciated the variety's best

performance, including its longer plant height, high grain yield, straw yield, and high number of pods and seeds. The variety was also noted for its overall adaptability in the area. Every participant recommended the variety for further scaling up, particularly male and female farmers who were inspired by its performance and suitability for their needs. The farmers agreed with the host farmers to obtain seeds of the variety for further scaling up in their kebele.

The performance of pre scaled up improved faba bean variety for different parameters

On farm performance, Walki for grain yield and other yield parameters in comparison with the local cultivar (Table 5). Statistically significant difference was observed between Walki and the local cultivar for all measured parameters. The performance of Walki for all parameters was much better than the local cultivar did. For instance, Walki gave an average grain yield of 2639.4 kg ha⁻¹ and showed 107.9% grain yield advantage over the local cultivar.

Table 5
On farm performance of Walki vs the local cultivar

	Walki		Local variety		
Parameters	Mean	Std. Deviation	Mean	Std. Deviation	t-test
Plant height (cm)	111.2	12.39206	80.1	14.86952	7.197***
No. of branches	1.9	0.5228	1.4	0.59824	2.486**
No. of pods per plant	21.1	4.71296	11.2	3.57292	7.511***
No. of seeds per pod	2.7	0.31286	2.2	0.69585	2.784***
Biomass yield (t ha ⁻¹)	4.73	254.2467	3.49	668.9379	7.774***
Grain yield (t ha ⁻¹)	2.64	299.3943	1.27	311.8974	14.17***

***** and **. The mean difference is significant at p < 0.01, and p < 0.05, respectively**

Conclusion and Recommendation

Significant variation was detected among the tested faba bean varieties in most of the measured agronomic traits, including grain yield. Hachalu, followed by Walki (2.92 t ha⁻¹), recorded the highest mean grain yield (3.03 t ha⁻¹). Among the tested varieties, Walki was preferred by farmers for its merits, including long plant height, high grain and straw yield, high number of pods/plant, high number of seeds/pod, big seed size, early maturity, and better adaptability in the testing area. The preference for Walki by farmers signifies that farmers could adopt necessarily not all improved varieties. Hence, evaluating the existing improved crop varieties with farmers' participation in each agro-ecology is a prerequisite for adoption and scaling up and out of the crop.

The result of the pre-scaling up indicated that Walki gave about 107.9% grain yield advantage over the local cultivar. Once they recognized the significant benefits of Walki, farmers and other stakeholders expressed a strong desire to obtain this variety. Accordingly, it was extending very rapidly through farmer-to-farmer seed exchange approach. Since farmers are the ones who ultimately decide whether to adopt a particular variety, it is imperative to include farmers' knowledge in the selection of promising varieties. It is advice that plant breeders anticipate that it may be challenging to determine which traits, or combinations of traits, are most important for a certain target group of farmers based on the lessons acquired from this study. Therefore, future breeding programs should include the participation of farmers' and their selection preferences early during the varietal development program. Participatory variety selection is found to be cost-effective and fast track delivery of new and existing technologies.

Declarations

Ethics Approval and Consent to Participate

This study involved human participants, and the Amhara Agricultural Research Institute review board approved the experimental protocols. Survey respondents were informed that they have the right to privacy, anonymity, confidentiality, voluntary participation, and withdrawal to ensure ethical standards. Before participating in this study, all persons provided written informed consent, and all personal identifying information for participants was omitted from the data presented in this manuscript.

Conflicts of Interest

The authors declare that they have no competing interests.

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Author Contribution

Simegnew Aniley and Yehuala Kassa conceived and designed the experiment, including the selection of experimental treatments, plot lay-out, and conducting the fieldwork, overseeing the implementation of the experiment, and monitoring the data collection process, analysis, and interpretation of the data and played a major role in writing the manuscript. Nigussie Kefelegn collaborated in the conception and design of the experiment, providing valuable insights and expertise in actively participated in the data collection process, including analyzing and interpreting the data. Worku Zikarge was involved in during plot layout and conducting the fieldwork, data collection phase, and writing up and reviewing the manuscript. All authors review and approved the final manuscript.

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Data Availability

Data will be available upon request from the corresponding author.

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Figures



Figure 1

Farmers at variety evaluation and selection session

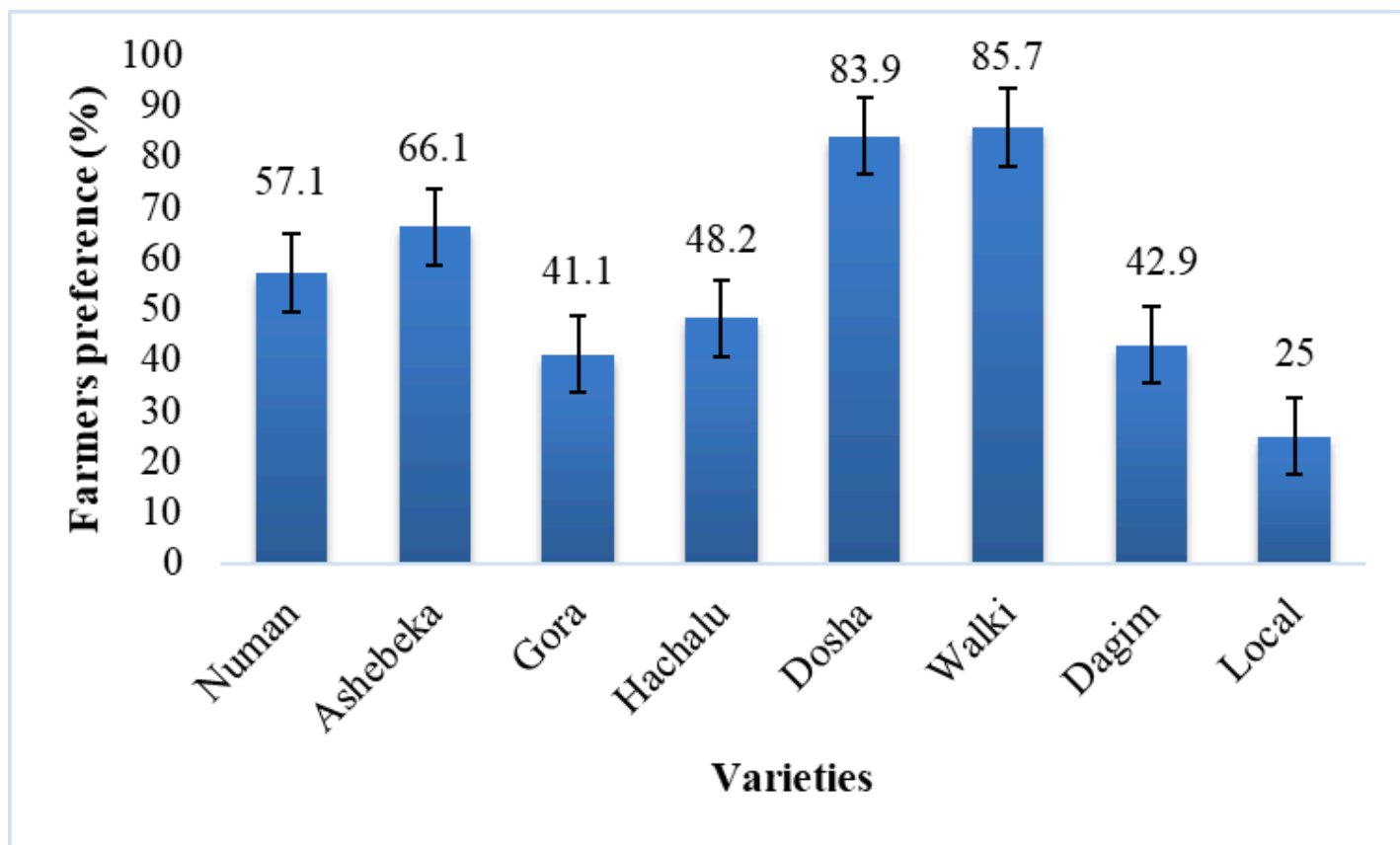


Figure 2

Over all farmers' varietal preferences (%)



Figure 3

Field day event on Walki variety

Supplementary Files

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