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Faba Bean Variety Development for Yield, Quality, and Disease Resistance for Water Logged Vertisol Areas-Registration of a Faba Bean Variety Named '*Ashebeka*'

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Abstract

A faba bean (*Vicia faba* L.) variety named *Ashebeka* with a pedigree designation of EH01075-4 has been released in 2015 by Kulumsa agricultural research center in Ethiopia. The variety is best adapted to waterlogging vertisol environments of Ethiopia with altitudes ranging from 1900 to 2800 meters above sea level. The variety was developed through hybridization between N86108-5 and BPL1297-1. The candidate variety has been tested at four locations (Arsi Robe, Sagure, Ambo and Inewari) representing major waterlogging vertisol environments of the country during 2012 and 2013 main cropping seasons making eight test environments. The variety is mainly characterized by its higher grain yield and heavier seed size (885g 1000 seeds^{-1}) than the standard checks and all the remaining genotypes in the trail. The variety *Ashebeka* showed 34% seed size advantage over *Hachalu*, the popular best standard check recently released for water logging vertisol production areas. Based on selected a parametric method that includes yield rank and stability, *Ashebeka* showed better performance stability across the test environments and over years than the standard checks, *Hachalu* and *Walki*. The variety showed better overall agronomic performance, and moderately resistance to major faba bean disease including root rot, rust and chocolate spot than the standard checks in the trial, and could be cultivated across mid to high altitude agro-ecologies with water-logging vertisol conditions of the country.

Keywords: Disease resistance, National yield trail, Water-logging, Variety development, Vertisol, Vicia faba L.

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Contribution of this paper to the literature
The study was conducted at four location (Arsi robe, Sagure, Enewari and Ambo) Agricultural Research Center to assess the genetic potential among the faba bean lines/ genotypes using RCBD designs.

1. Introduction

Faba bean (*Vicia faba* L.) is the most important pulse crop in terms of both area coverage and volume of annual production in Ethiopia. Presently, it occupies about 427,697 hectares of land with an annual national production of 878,011 tons, with a productivity of 2.05 tons ha^{-1} [1]. Ethiopia is the first producer of faba bean in Africa and the second in the world next to the People's Republic of China [2]. The crop is mainly cultivated in mid and high-altitude areas, with an elevation ranging from 1800-3000 meters above sea level [3, 4].

Faba bean were also known by N fixation crop which is considered as high among the grain legumes [5-7]. It is cultivated for the purpose of both human food and animal feed, especially for humans as nutritional and medicinal values [8, 9]. The crop contributes to the smallholder farmers as a source of protein in both rural and urban areas [8] and is an important source of income for farmers.

It is so far that, the commencement of faba bean breeding in Ethiopia was in the 1950's with the establishment of Arsi Rural Development Unit (ARDU) followed by the then Alemaya College of Agriculture, now Haramaya University [10]. Production of faba bean in the country couldn't attain the maximum yield potential of the crop because of biotic and abiotic stresses that collectively cause great yield losses. The major constraints to increased faba bean production are lack of improved varieties, chocolate spot (*Botrytis fabae*), root-rot, Faba bean gall and rust diseases, insect, pests, broad leaf and grass weeds, water-logging, and cold and drought weather conditions [11-14]. Therefore, faba bean research program in Ethiopia has been focused on increasing production and productivities of the crop through developing and promoting improved cultivars with high and stable yield, and resistant/tolerant to biotic and abiotic stresses [7, 15].

The potential of faba bean production in Ethiopia is its suitability as rotation crop in the cereal based system of not only potential production areas, but also in water-logged vertisol production environments of the country that has been mainly with a problems of root rot disease on faba bean. So considering the water-logged vertisol production environments alone, faba bean is among the most important pulse crop occupying 14.6% of the cultivated vertisols in the country. However, water logging due to a nature of soil and poor drainage are pre-dominant factor constraining an increase in production on this soil. Breeding of productive genotype under water logging was the only option to improving the productivity of faba bean under water logging condition. In order to convene the demand of the farmer' lived in comparable agro ecologies, considerable efforts have recently been paid by faba bean breeding program to develop a variety resistant/tolerant to water-logging conditions leading to a release of a number of varieties. The purpose of this paper is therefore; to describe the merits of recently released faba bean (*Vicia faba* L.) variety named '*Ashebeka*', developed for water-logging vertisol production environments of the country.

2. Materials and Methods

2.1. Breeding Procedures

Crossing was done between N86108-5 x BPL1297-1 introduced from ICARDA and resulted pedigree designation of EH01075-4 at Holeta Agricultural Research Center during 2002 cropping season. Screen houses were routinely used in the early generations, i.e., F1, F2, F3 and F4, of a breeding cycle to prevent insects from causing cross-pollination. During these phases, pedigree selection was made for traits with high heritability such as seed size, grain yielding ability, plant habit, time of flowering and resistance to major diseases such as black root-rot, chocolate spot and rust.

Twenty-two elite individual lines selected from the F5 generation were promoted and evaluated at multi-locations for yielding ability, seed size, major disease reactions and stability in a preliminary variety trial (PVT) conducted during the 2010/11 cropping season. From this trial, 12 promising genotypes were promoted and evaluated in a national yield trial (NYT) along with two recently released standard checks *Walki* and *Hachalu* at four representative waterlogging vertisol production areas of the country during 2012 and 2013 main cropping seasons. The locations where the trials conducted include Sagure, Ambo, Arsi robe and Enewari. Each year at each location was considered as a separate environment, making a total of eight test environments for this study. Biophysical description of the four test locations are given in Table 1. Finally, *EH 00101-2* and *EH01075-4* were selected as the most promising candidate varieties and evaluated along with two best standard checks, *Hachalu* and *Walki*, on 10 m x 10 m plots by the national variety release technical committee at 4 water-logging vertisol locations, each one on-research station and two on-farm fields during the 2014 cropping season. Eventually, *EH01075-4* was recommended for commercial production and named *Ashebeka*.

2.2. Description of Experimental Site

Table-1. Biophysical description of the ten experimental locations used for national yield trial.

Test locations	Geographical position		Altitude (m.a.s.l)	Average rainfall (mm)	Temperature (°C)		Soil texture	Soil pH
	Latitude	Longitude			Min	Max		
Sagure	07°12'N	39°20'E	2300	620	5.8	23.6	Clay-loam	6.2
A/robe	08°05'N	39°10'E	2200	820	10.5	22.8	Dark-clay loam	6.0
Enewari	07°05'N	39°30'E	2780	1010	7.9	16.6	Clay-loam	5.0
Ambo	08°58'N	38°14'E	2400	975.5	6.05	22.41	Dark-clay	4.9

2.3. Experimental Layout

The experimental layout for multilocation national yield trial (NYT) was arranged in a randomized complete block design with four replications. Each experimental plot has 4 rows with 4 m long and arranged with inter and intra block spacing of 1.5 m and 0.6 m, respectively. The seeds were sown at the rate of 50 seeds per row with 8 cm plant to plant and 40 cm row to row spacing. Fertilizer was applied to each plot at the rate of 18 kg N and 46 kg P_2O_5 ha^{-1} in the form of diamonium phosphate at planting. Other agronomic practices were treated as non-experimental variables and applied uniformly to the entire experimental area. For data analysis, grain yield from net plot size of 3.2 m^2 was converted into kg ha^{-1} at 10% standard grain moisture contents.

2.4. Statistical Analysis

Data for grain yield and other important agronomic traits were subjected to analysis of variance (ANOVA) using the Proc GLM procedure of SAS version 9.0 [16] to determine the existence of significant differences between faba bean genotypes. Proc mean procedure of SAS was used to generate means of traits by genotypes and environments. Comparison of the main effect was performed using LSD at 5% probability level. Selected stability parameters that encompass both yield and stability were selected and computed to estimate the genotypic yield stability across test environments. For example, a new approach, known as genotypic selection index (GSI), was used by taking the AMMI stability value (ASV) and mean grain yield into consideration. Another nonparametric stability method, a stratified ranking technique of Fox, et al. [17] where a genotype usually found in the top third for mean performance compared to all genotypes tested across environments is considered. All the stability parameters were computed using c a comprehensive SAS stability program developed by Hussein, et al. [18].

3. Result and Discussions

Result of analysis of variance shows highly significant differences ($p \leq 0.01$) among genotypes for gain yield, seed size, pods plant-1 to significant ($p \leq 0.05$) for plant height Table 2. Likewise, test environments exerted highly significant ($p \leq 0.01$) effects on the important agronomic traits including grain yield, 1000 seed weight, number pods $plant^{-1}$ and plant height. The interaction effects of environments and genotypes were highly significant ($p \leq 0.01$) for grain yield and seed size and significant at ($p \leq 0.05$) probability level for number of pods $plant^{-1}$ and plant height Table 2. Significant differences were observed between genotypes across environments for chocolate spot ($p \leq 0.01$), root rot ($p \leq 0.01$), and rust ($p \leq 0.05$). Moreover, highly significant differences ($p \leq 0.01$) observed among the test environments for all fusarium root-rot, chocolate spot and rust diseases Table 2 indicating that the test environments were differently influenced the reaction of the test genotypes towards the diseases.

Table-2. Mean square significance of grain yield, 1000 seed weight, number of pods $plant^{-1}$, plant height, and root-rot, chocolate spot and rust diseases of 12 faba bean genotypes tested across four locations during 2012 and 2013 cropping seasons.

Source of variation	Mean squares						
	Grain yield (kg ha^{-1})	Seed weight (g)	Pod per plant	Plant height (cm)	Root rot	Chocolate spot	Rust
Environment	86956763**	103324**	2130**	29552 **	25.9**	11.6**	58.6**
Block(Environment)	810897**	5149^{ns}	134**	486**	1.6**	2.4**	0.8^{ns}
Genotype	919193**	278879**	84**	258*	1.6**	3.3**	1.2*
Genotype x Environment	774559**	6210**	24*	140*	0.7^{ns}	0.7*	0.5^{ns}
Mean	3455	855	13.3	123	2.5	4.5	2.9
CV (%)	16.9	7.1	31.2	8.0	32.2	15.2	28.2
R^2	0.89	0.85	0.82	0.90	0.62	0.65	0.73

3.1. Varietal Characteristics

The newly released faba bean variety *Ashebeka* is characterized by an indeterminate growth habit having white with black spots flower color. The seed coat and cotyledon colors are light green and ceramic respectively. Its average seed weight is 885g 1000 $seeds^{-1}$, which is heavier than the seeds of all other improved faba bean varieties released so far for water logging vertisol production areas of the country Table 3. The average number of days required by the variety to reach its 50% flowering and 95% physiological maturity were 58 and 151, respectively Table 3. The average plant height and number of pods $plant^{-1}$ of *Ashebeka* are 125 cm and 13, respectively Table 3. The appropriate planting date for this variety would range from mid-June to early July. For a better harvest the variety must receive 46 kg ha^{-1} P_2O_5 and 18 kg ha^{-1} N at sowing.

Table-3. Mean performance of selected agronomic traits of 12 faba bean genotypes tested across eight environments during 2012 and 2013 cropping seasons.

Genotypes	DTF	DTM	PHT	PPL	TSW	CHS	R	RR
EH 01075-4	58	151	125	13	885	4.48	2.71	2.13
EH 00098-2	58	151	126	13	856	4.96	3.04	2.46
EH 00131-3	57	150	120	13	882	4.92	3.08	2.75
EH 00101-2	57	145	123	14	905	4.63	2.92	2.58
EH 01036-2	58	152	121	12	806	4.63	2.83	2.50
EKCSR 010	57	150	123	13	901	4.75	2.75	2.88
EKLS 0101	58	151	124	13	894	4.83	3.29	2.92
EKLSS 020	57	144	127	13	857	4.38	2.79	2.17
EH 06007-4	60	145	124	10	1075	3.83	2.46	2.33
EH 06028-1	59	149	116	14	861	3.83	2.63	2.71
Hachalu	58	151	124	16	662	4.58	3.04	2.42
Walki	58	149	123	17	677	4.63	2.83	2.46
Mean	58	149	123	13	855	4.54	2.86	2.52
LSD (<0.05)	1.32	3.0	4.81	2.04	34.66	0.39	0.46	0.46
CV (%)	4.3	3.8	7.9	31.1	7.1	15.2	28.2	32.2

Note: Keys: DTF= days to flowering, DTM= days to maturity, PHT= plant height, PPL= number of pod per plant, TSW= thousand seed weight (g), GYDH= grain yield (kg ha^{-1}), CHS = chocolate spot (1-9 scale), R=rust (1-9 scale), and RR= root rot (1-9 scale)

3.2. Yield and Quality Performance

The average grain yield performance across environments of *Ashebeka* is ranged from the lowest of 1245 kg ha^{-1} at Arsi-robe in 2012 to the highest of 6438 kg ha^{-1} at Enewari in 2013 cropping season, with mean overall environment of 3756kg ha^{-1} which is significantly higher than the best standard check, *Hachalu* (3470kg ha^{-1}), in the trial Table 4. The newly released variety has yield advantage of 286 kg ha^{-1} (8%) and 393 kg ha^{-1} (12%) over the two standard checks, *Hachalu* and *Walki*, respectively Table 4. *Ashebeka* has produced 223g (33%) and 208g (31%) seed size advantage over the best standard checks, *Hachalu* and *Walki*, respectively Table 4.

Table-4. Mean grain yield (kg ha^{-1}) of the released faba bean variety *Ashebeka* tested over 8 environments during (2012-2013) cropping season as compared to the two standard checks.

Genotypes	Sagure 2012	Arsi-robe 2012	Inewari 2012	Ambo 2012	Sagure 2013	Arsi-robe 2013	Inewari 2013	Ambo 2013	Mean
Ashebeka	4652	1245	3610	3274	4597	2965	6438	3264	3756
Hachalu	3890	1345	2983	3505	4154	2816	5440	3627	3470
Walki	4249	1281	2514	3406	4073	2980	5074	3327	3363
Mean	4392	1313	2932	3164	4298	2697	5723	3007	3455
LSD (< 0.05)	791	437	864	623	1226	780	869	890	287
CV (%)	12.2	23.1	20.5	13.7	19.8	20.1	10.6	20.6	16.9

3.3. Performance Stability and Adaptation Domain

The variety *Ashebeka* was released for the mid-to-high altitude agro-ecologies of the country with water logged vertisol condition and receiving 700-to-1100 mm average annual rainfall. It is well adapted to water logging areas with an altitude range of 1900 to 2800 meters above sea level such as Ambo, Arsi-robe, Inewari, Sagure and similar agro-ecologies. Based on parameters that comprise both yield rank stability, *Ashebeka* showed relatively better performance stability across a range of water logging environments.

Additive main effect and multiplicative interaction (AMMI) is gaining popularity and is currently the main alternative multivariate approach to determine genotypic performance stability in many breeding programs. Another approach called the AMMI stability value *(ASV)*, which is based on the first and second interaction principal component axis *(IPCA)* scores of the AMMI model for each genotype, has also been developed recently. AMMI stability value *(ASV)*, genotypic stability index *(GSI)*, and a stratified ranking *(FT3)* of Fox, et al. [17] has been generated to evaluate performance stability of the genotypes across test environments. Genotypes with the lowest *ASV* and *GSI* values are considered as having stable performance across the test environments. Accordingly, upon its tremendous seed size advantage, the newly released variety *Ashebeka* revealed lowest values of *ASV* and *GSI* Table 5 and identified as the most stable variety among the tested genotypes. Similarly, Fox, et al. [17] proposed that genotypes which are ranked in the top third of the genotypes in largest proportion of the test environments as having most stable performance than the remaining. Based on the stratified ranking technique of the top third *(FT3)* parameter, *Ashebeka* was ranked as top yielding variety in the top third of the test genotypes in 50% of the test environments Table 5, hence considered as the most stable variety.

Table-5. Stability status of the genotypes as revealed by *ASV*, *GSI* and *FT3* stability parameters.

No	Entry	Yield	ASV	RY	RASV	GSI	TOP	VIPC1	VIPC2
1	EH 01075-4	3756	9.5	1	2	3	50.0	3.624	-8.113
2	EH 00098-2	3403	21.1	8	7	15	25.0	14.670	-6.606
3	EH 00131-3	3480	35.9	5	10	15	50.0	26.179	1.531
4	EH 00101-2	3671	8.2	2	1	3	62.5	5.455	-3.371
5	EH 01036-2	3363	36.1	10	11	21	37.5	-21.466	-20.876
6	EKCSR 010	3492	13.5	4	4	8	12.5	9.374	-4.301
7	EKLS 0101	3191	22.5	12	9	21	12.5	-10.289	-17.555
8	EKLSS 020	3596	21.7	3	8	11	50.0	-14.627	8.225
9	EH 06007-4	3480	41.6	6	12	18	25.0	-22.826	27.487
10	EH 06028-1	3197	10.0	11	3	14	0.0	-6.270	-5.109
11	Hachalu	3470	20.0	7	6	13	37.5	10.177	14.307
12	Walki	3363	16.6	9	5	14	37.5	6.000	14.379

Note: Key: ASV = AMMI stability value, RY = yield rank, RASV = AMMI stability value rank, GSI = genotypic stability index, FT3 = % of the environments where genotypes fall in in the top third high yielding genotypes, VIPC1 = varietal interaction principal component one, VIPC2 = varietal interaction principal component two.

3.4. Reaction to Major Diseases

Black root-rot caused by *Fusarium solani* complex is the most destructive faba bean disease causing up to 70% yield losses under sever condition in water logging production areas. Agronomic practices such as use of raised seedbed, crop rotation, planting date adjustment, fungicide applications and use of certified seeds may provide partial protection against the foliar and root diseases of faba bean. However, the most effective and eco-friendly disease control method is through developing resistant or tolerant cultivars. Developing resistant or tolerant varieties to major diseases such as chocolate spot *(Botrytis fabae)*, black root-rot *(Fusarium solani)*, and rust *(Uromyces viciae-fabae)* are among the major objectives of the national faba bean breeding program. Chocolate spot, fusarium root-rot, and rust diseases have been scored using on (1-9) scale and were analyzed to determine the reaction of the released variety *Ashebeka* to these diseases as compared to the recently released standard checks.

Consequently, the released variety *Ashebeka* showed an average reaction of 4.48, 2.13 and 2.71 compared to 4.58, 2.42 and 3.04 for that of the best standard check, *Hachalu*, in the trial for chocolate spot, *Fusarium* root-rot and rust, respectively Table 3, and is characterized as moderately resistant to these major diseases.

4. Variety Maintenance

The breeder and foundation seed will be maintained by Kulumsa and Holeta Agricultural Research Centers.

5. Conclusion

As Fusarium root-rot of faba bean is reported highly relevant pathogen causing significant yield losses in water logging vertisol production areas that covers 13% of the country potential highland arable land, increasing grain yield along with seed size is a recent prime objective in faba bean breeding programs of the country. So far, large scale field phenotyping of the host reactions to *Fusarium* root-rot disease using sick plots has been done and resulted in the development of highly resistant breeding materials among which only few small-to-medium seeded varieties has been released and recommended for commercial use. The current variety, *Ashebeka*, has combined high yield with heavier seeds has produced 33% and 8% seed size and yield advantage, respectively, over the best standard check, *Hachalu*, in the trial and believed to meet the seed quality required for export market. Therefore, wide cultivation of *Ashebeka* variety will enhance productivity and marketability of the crop and believed to play significant role in improving farmers' livelihood in water logging agro-ecologies.

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