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Research Article

Grain Yield and other Agronomic Performances of Faba Bean (*Vicia faba* L.) Genotypes under Soil Acidity Stress Tested with and without Lime Application in the Central Highlands of Ethiopia

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ABSTRACT

The productivity of faba bean becomes reduced as compared to the potential due to soil acidity in the highlands of Ethiopia. Hence, this research was conducted to determine grain yield, other agronomic performance and relative yield reduction of faba bean genotypes at soil pH 4.66, 4.96 and 4.49 at Holetta, Watebecha Minjaro and Jeldu, respectively, with and without lime application in 2017. The experiment comprised 50 faba bean genotypes arranged in randomized complete block design with three replications. The analysis of variance (ANOVA) for each management over locations showed the presence of significant differences among genotypes for all agronomic traits except number of seeds per pod in both cases and number of pod per poding node under lime free condition. Moti and CS20DK were ranked first and second having a mean grain yield of 115.1 and 113.2 g/5plants with lime over locations, respectively. At both lime levels Wayu was the lowest yielder genotype whereas CS20DK in contrasting direction. Soil acidity caused a mean grain yield reduction (RR) ranged from 24.44 to 46.69% with an overall mean of 32.4% through varied number of genotypes produced higher mean grain yield under lime and without lime application over locations. Likewise, chocolate spot disease was aggravated by soil acidity stress as compared to lime treated once. Whereas, hundred seeds weight were less affected by soil acidity stress as compared to other traits implying that it is less affected by the growing environment. The genotypes Holetta-2, Hachalu, Numan, Obse and Wolki found less Susceptible to soil acidity stress having lower RR of 16.8, 18.8, 20.4, 20.6 and 22.1%, respectively, indicating genotypes released for water logging stress (Hachalu and Wolki) also tolerate to soil acidity stress too. Therefore, it is concluded that soil acidity affects the production and productivity of faba bean as it affects morpho-agronomic traits of this crop.

Key words: Chocolate spot, Faba bean, Grain yield, Lime, Soil acidity.

INTRODUCTION

Faba bean (*Vicia faba* L., 2n=2x=12) is among the oldest crops in the world (Singh *et al.*, 2013). It is produced throughout the world in different agro-ecological regions in which China followed by Ethiopia, Australia, United Kingdom, France and Egypt are the leading producers (FAOSTAT, 2018). In Ethiopia, faba bean shares 30% of area coverage and 34% of the total pulse crops production (CSA, 2019/2020).

Faba bean is a major source of protein rich foods in the developing countries for subsistence farmers (Asnakech *et al.*, 2016, Tadele, 2019). It has a potential to a good meat substitute in many parts of the world where there is demand for non-animal protein sources (Crépon *et al.*, 2010). It is a source of cash to the farmers and foreign currency to Ethiopia (Tewodros *et al.*, 2015; Asnakech *et al.*, 2016; Gemechu *et al.*, 2016). The crop is widely used in rotation with cereals and other crops because it fixes atmospheric nitrogen (Tadele, 2019).

Despite its diverse benefits and the availability of high yielding improved varieties in Ethiopia the national average yield of faba bean is about 2.16 tha^{-1} (CSA, 2019/2020) which is very low compared to United Kingdom 3.83 tha^{-1} (FAOSTAT, 2018). The low average yield of the crop is resulted from susceptibility to biotic and abiotic stresses (Gemechu *et al.*, 2016). Currently, soil acidity becomes the major production limiting factors of faba bean in the highlands of Ethiopia (Endalkachew *et al.*, 2018; Mesfin, 2020). It is a significant problem that agricultural

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producers in tropical and subtropical regions are facing and limit legume productivity (Bordeleau and Prevost, 1994). Soil acidity stress not only limits the growth of this crop due to shortage of soil nutrients but also aggravates chocolate spot infection that leads to yield reduction (Getachew *et al*., 2005). Faba bean is sensitive to soil acidity and grows successfully on slightly acidic soils (Chris and Stephen, 2009; Burns *et al.*, 2017). Hence, improving the productivity of acid soil is major priority as a demand of food and raw materials are increasing rapidly. Use of lime on acidic soil is a potential option which is effective and widespread practice to improve crop yields and maintain soil micro-organisms. Abebe and Tolera (2014) reported significant effect of lime application on grain yield of faba bean on acid soils of western highlands of Ethiopia.

The use of acid tolerant varieties remains the first option as cost of lime is not affordable by smallholder farmers. However, faba bean varieties released so far in Ethiopia were not tested and recommended for areas with soil acidity stress. Therefore, identifying genotypes with good agronomic performance under soil acidity stresses and non-stress environments is of a paramount importance for breeding faba bean genotypes adaptable to acidic soils. Hence, this study was initiated with the objective to determine the effect of soil acidity stress on grain yield and other agronomic trait performances of faba bean genotypes and quantify the relative yield reduction encountered.

MATERIALS AND METHODS

Description of the Study Sites

The experiment was conducted at three locations of two districts at Welmera (Holetta and Watebecha Minjaro) and Jeldu district during 2017 main cropping season under rain fed condition (Table 1 and Fig. 1).

Experimental Materials and Design

A total of 50 faba bean genotypes (22 released varieties and 28 pipe line) collected from Holetta and Kulumsa Agricultural Research Centers were used in the study (Table 2). The experiment was arranged in Randomized Complete Block Design with three replications using adjacent block technique (growing the two sets adjacent to each other). Each block was divided into two adjacent sub-blocks to accommodate both with and without lime plots. The spacing between adjacent and within blocks were 1.5 and 2m respectively. The experimental plots consisted of one row of 4m length and 40cm row spacing continuously and 10cm between plants (1.6m^2). Undamaged clean seeds of each genotype were selected to a reasonably uniform size by hand sorting and whole set of genotypes were planted separately in alternating adjacent sub-blocks with and without lime in side-by-side pairs.

One sub-block in each block were limed and not to the other sub-block one month ahead of planting whereas blended fertilizer NPS were applied at the rate of 121kg/ha during planting. One faba bean variety (Dosha) was planted as a border row in each block to avoid border effect. The other agronomic practices were carried out uniformly to all genotypes as per the recommendations made by the national research system for faba bean.

Experimental Procedure

Soil Sampling, Preparation and Analysis

Prior to planting, ten surface soil samples (20 cm depth) were taken randomly from representative spots of the entire experimental field using an auger and composited to one representative sample. The composite sample was air-dried at room temperature, thoroughly mixed and ground to pass through a 2mm sieve and then analyzed for: particle size distribution (soil texture), pH, organic carbon, cation exchange capacity, exchangeable bases (Na, K, Ca and Mg), total nitrogen, available Phosphorus, exchangeable acidity, extractable aluminium and micro nutrients (Zn, Fe, Mn and Cu). One soil sample for bulk density analysis at each location was taken by core sampler. Moreover, after harvesting, surface soil samples 0-20 cm were collected randomly from five spots in each lime treated blocks and analyzed to know the level of increment in parameters analyzed before planting with the exception of soil texture and bulk density.

Soil bulk density was determined using a core sampler and soil pH was determined by potentiometric method at 1:2.5 soils: water ratio (Van Reeuwijk, 1992). Cation exchange capacity was determined by 1M ammonium acetate method at pH 7 (Chapman, 1965) whereas organic carbon was determined by the Walkley and Black method (Walkley and Black, 1934) and total nitrogen by the micro-Kjeldhal method (Jackson, 1958), available P was determined by the Olsen method (Olsen *et al*., 1954). Soil particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). Exchangable Na, K, Mg and Ca were determined by Ammonium acete- AAS method and extractable Al, Fe, Zn, Mn and Cu by DTPA-AAS method. Analysis of all the soil parameters was done at Holetta agricultural research center soil and plant analysis laboratory.

Treatment Application and Field Activities

All field activities were done with standard production practices developed for faba bean. The land was cultivated by tractor at Holetta and Jeldu and by oxen plough at Watebecha Minjaro and pulverized by hand and rows were made to plant the seeds. As suggested by Temesgen *et al.* (2017) lime was applied one month ahead of planting to give time for incorporation on block bases at each location based on the lime requirement of the locations as a result of soil test. Planting of the experiment was done in July 2017 at all locations and harvesting was done in November 2017 at Holetta and Watebecha Minjaro and in December 2017 at Jeldu.

Lime rate (LR) was calculated based on the results of soil analysis using the following formula:

$$LR\left(\mathrm{CaCo3}\left(\frac{\mathrm{kg}}{\mathrm{ha}}\right)\right)=\frac{\mathrm{EA}\left(\frac{\mathrm{cmol}}{\mathrm{kgsoil}}\right)*\ \mathrm{DS(m)}*\ \mathrm{A(m^2)}*\rho b\left(\frac{g}{cm^2}\right)}{2}*LF$$

Where: LR= Lime rate; EA= Exchangeable acidity; DS= Depth of soil; A= Area of land; ρb= Bulk density; LF= Liming factor/adjustment factor (LF= 2) is determined based on crop response (Kamprath, 1984).

Data Collection and Analysis

The agronomic data were recorded on the entire plot or on five randomly selected faba bean plants in each row. Accordingly, data for days to 50% flowering, days to 90% physiological maturity, rain filling period, hundred seeds weight (g) and chocolate spot disease severity were recorded on the entire plot. On the other hand, plant height, number of poding nodes per plant, number of pods per poding node, number of pods per plant, number of seeds per pod and grain yield (g/5 plants) were recorded on five randomly pre-tagged plants from each experimental plot. The average of the five plants in each experimental plot was used for statistical analysis. Chocolate spot disease was recorded using the scale of Bernier *et al.* (1993), as follows: 1 = no disease symptoms or very small spots (highly resistant), 3 = few small disease lesions (resistance), 5 = some coalesced lesions, with some defoliation (moderately resistant), 7 = large coalesced sporulating lesions, 50% defoliation some dead plants (susceptible), 9 = extensive, heavy sporulation, stem gridling, blackening and death of more than 80% of plants (heavily susceptible).

Analysis of Variance

The SAS computer package version 9.3 statistical software (SAS Institute, 2010) was used to test for presence of outliers and normality of residuals. Data based on disease score (1-9 scale data) were converted in to percentage as 0, 4, 15, 30, 50, 70, 86, 96 and 100 respectively (Mussa *et al.*, 2008) and percentage values were ARCSINE transformed for statistical analysis (Gomez and Gomez, 1984) and untransformed means were presented otherwise.

All data were subjected to analysis of variance (ANOVA) for RCBD as per the procedure indicated by Gomez and Gomez (1984) using SAS software version 9.3 statistical software package (SAS Institute, 2010). The SAS GLM (General Linear Model) procedure was employed for the analysis of variance. Analysis of variance was conducted for data collected from each location and management level (with and without lime application) separately and combined.

For combined analysis of variance, the homogeneity of error variance was tested using the F-max method from the separate analysis of variance mean square of errors. As per Gomez and Gomez (1984), if the larger error mean square is less than three-fold than the smaller error mean square, the error variance was considered homogeneous.

$$\mathrm{F-ratio} = \frac{\mathrm{Larger\ MSE}}{\mathrm{Smaller\ MSE}}$$

Accordingly, the error variances were homogenous for each with and without lime environments; therefore, combined ANOVA for data collected from with and without lime environments for each location were conducted. The error variances for separate management levels were homogeneous over locations and over locations and management levels. Therefore, overall combined ANOVA for with and without lime environments over locations and management levels were made and mean comparison of genotypes were on the basis of pooled means for the traits exhibited homogeneous error variances. For heterogeneous traits mean computed based on performance at each individual locations.

Existence of significant difference among the genotypes, locations, management level and their interaction were determined using the F-test in all the cases. Mean separation at 5% probability levels was done using Duncan's Multiple Range Test (DMRT) following Gomez and Gomez (1984), whenever genotype differences were significant.

The total variability for the traits was quantified using pooled analyses of variance over three locations using the following model:

$$P_{ijk} = \mu + B_i (L_k) + G_j + L_k + (GL)_{jk} + e_{ijk}$$

Where P_{ijk} = phenotypic observation on genotype j in block i (at location k) G, B, and L = number of genotypes, blocks and locations respectively, μ =grand mean, $B_i(M)_k$ = the effect of block i (within location k), G_j = the effect of genotype j, L_k = the effect of location k, $(GL)_{jk}$ = the interaction effect between genotype j and location k e_{ijk} = the residual or effects of random error.

RESULTS AND DISCUSSION

Soil Phsico-chemical Properties of Test Locations

The soils analysis results from the three test locations showed very strong acidic condition < 5 (Table 3). Practically, soils pH between 6.6 and 7.3 are considered as neutral; 5.6 to 6.5 are moderately acid and below 5.5 strongly acid (Alemu *et al*., 2016). Little modification of pH at each location in the lime treated blocks were observed indicating that lime improves the chemical properties of soils needs more time to bring to the required change. Likewise, it was reported that lime is slow acting, of long duration (Follet *et al*., 1981); at first year no significant increase in grain yield compared to the control but expected in the next planting season due to slow acting of lime (Adane, 2014).

Generally, applying calcium containing lime materials improve nutrient availability, particularly phosphorus; through reduction of phosphorus fixation thereby improving soil pH where maximum availability of the nutrient may be obtained. The result agrees with the reports of Abebe and Tolera (2014).

Analysis of Variance

The combined analysis of variance over three locations for each management indicated the presence of significant variations among genotypes, locations for all traits. The two-way interaction of genotype by location had significant effects for all traits of genotypes both under lime and without lime application except interaction of genotype by location had non-significant effect on number of pod per poding node without lime application and Number of seeds per pod in both cases (Table 4). The effect of genotype × location interaction being significant on most of the traits for each management over location indicated the differential performance of genotypes in different managements over locations. Partially agreement with this result, previously reported significant difference for plant height and grain yield while nonsignificant difference for number of pod per plant, number of seed per pod and hundred seeds weight as a result of lime application on acid soils (Abebe and Tolera, 2014). Other reports also confirmed the presence of significant effects of G × E interaction on grain yield in faba bean in different sets of environments in Ethiopia (Million and Habtamu, 2012; Tamene *et al*., 2015). Contrary to the current result Tamene *et al*. (2015) reported a non-significant interaction effect for chocolate spot disease resistance due to environmental variance.

The significant effects of G × L interaction indicated that the genotypes had differential performance over locations for agronomic traits and the effects of

Table 1: Description of three experimental environments

Location	Soil management	Longitude and latitude	Altitude (m.a.s.l.)	Annual rain fall (mm)	Temperature (°C)		Soil pH	
					Min	Max	Before lime	After lime
Jeldu	L_0, L_1	09^0 16'N, 38^0 05'E	2800	1200	2.06	16.9	4.66	5.03
Holetta	L_0, L_1	09^0 00'N, 38^0 30'E	2400	1072	6.6	24.1	4.49	4.80
Watebecha Minjaro	L_0, L_1	09^0 05'N, $38^0$36' E	2565	1100	8.7	23.3	4.94	5.08

L_0=without lime, L_1= with lime

Table 2: Description of 50 faba bean genotypes used in the study

No.	Genotypes	Year of release	No.	Genotypes	Year of release
1	Cool-0030	---	26	EKLS/CSR02017-3-4	---
2	Wolki$^{¥}$	2008	27	Kasa	1980
3	EKLS/CSR02012-2-3	---	28	Cool-0025	---
4	Obse	2007	29	EH06070-3	---
5	NC58	1978	30	EKLS/CSR02010-4-3	---
6	Ashebeka$^{¥}$	2015	31	Cool-0031	---
7	Hachalu$^{¥}$	2010	32	Cool-0018	---
8	Degaga	2002	33	EKLS/CSR02028-1-1	---
9	EH09031-4	---	34	EK 05037-4	---
10	Holetta-2	2001	35	Cool-0035	---
11	EH09007-4	---	36	KUSE2-27-33	1979
12	EH07023-3	---	37	EH07015-7	---
13	EK05006-3	---	38	Cool-0024	---
14	EKLS/CSR02014-2-4	---	39	Selale$^{¥}$	2002
15	Numan	2016	40	Moti	2006
16	Bulga 70	1994	41	EH06027-2	---
17	EK05001-1	---	42	EKLS/CSR02019-2-4	---
18	Dosha	2008	43	EH09002-1	---
19	Gora	2012	44	Tumsa	2010
20	EH08035-1	---	45	Gebelcho	2006
21	Wayu	2002	46	EK05037-5	---
22	EKLS/CSR02023-2-1	---	47	Didi'a$^{¥}$	2014
23	Mesay	1995	48	Cool-0034	---
24	EH09004-2	---	49	CS20DK	1977
25	EH06088-6	---	50	Tesfa	1995

"---'' = pipeline genotypes, ¥ =Varieties released for areas with waterlogging problems

Table 3: Results of soil chemical analysis before and after liming at three locations

Parameter		Holetta		Watebecha Minjaro		Jeldu	
		Before lime	After lime	Before lime	After lime	Before lime	After lime
Texture (%)	Clay	47.50	---	70.00	---	40.00	---
	Silt	36.25	---	8.75	---	36.25	---
	Sand	16.25	---	13.75	---	23.75	---
pH		4.66	5.03	4.94	5.08	4.49	4.80
TN (%)		0.14	0.14	0.14	0.21	0.29	0.30
Avail. P		7.96	9.57	12.74	12.74	13.17	15.14
CEC		18.18	19.04	17.38	18.80	20.24	20.42
OC (%)		1.25	1.36	2.14	2.18	2.61	2.65
Ex. Na (ppm)		0.03	0.03	0.03	0.03	0.02	0.03
Ex.K (ppm)		0.57	0.58	0.53	0.54	0.14	0.23
Ex.Mg (ppm)		2.35	2.46	1.25	1.26	0.50	0.58
Ex.Ca (ppm)		9.43	10.89	9.30	10.95	6.35	11.82
Ex. Al (PPm)		0.49	0.28	0.55	0.33	2.39	0.85
Mn (ppm)		48.58	47.76	37.97	30.16	58.23	50.45
Cu (ppm)		4.07	3.92	3.70	3.12	4.95	3.85
Ext.Fe (ppm)		180.77	164.45	245.70	231.07	341.13	327.43
Ext.Zn (ppm)		0.83	0.68	1.15	1.10	4.42	2.67
Ex. Acidity		1.01	0.61	0.98	0.62	3.36	1.30
Bulk density(gcm^{-3})		1.26	----	1.12	-----	1.05	----

CEC= cation exchange capacity, OC= organic carbon, TN= total nitrogen, Ex. = exchangeable, Ext=extractables

experimental plots with lime and without lime applications also exerted differential effects over locations on the performance of genotypes. Due to the performance variation of genotypes over locations (with significant effects of G × L interactions), selection of genotypes based on superior performance under one set of environment may perform poorly under different environment. This implies that recommendation of genotypes for all locations and managements of soil acidity is hardly possible based on better performance of genotypes at one location and management. Likewise, Gemechu *et al.* (2015) reported that under significant G × L selection of genotypes that perform best under all sets of environments becomes less practical.

Table 4: Mean squares from combined analysis of variance without (above) and with lime application (below) over three locations for 12 traits of 50 faba bean genotypes in 2017 main cropping season

	Without lime application					
Trait	Rep (6)	Genotype (G) 49)	Location (L) (2)	G x L (98)	Error (294)	CV (%)
DF	11.54	22.67**	4730.67**	4.45**	1.22	2.05
DM	20.56	27.38**	4012.56**	5.20**	2.69	1.12
GFP (day)	28.59	37.51**	4401.98**	8.22**	3.69	2.09
PH (cm)	1855.06	175.01**	277083.56**	79.32**	31.67	5.06
PNPP	8.19	5.90**	242.89**	1.20**	0.78	13.49
PPP	4.62	21.55**	309.31**	2.86**	1.52	14.75
PPPN	0.11	0.09**	0.13**	0.02^{ns}	0.02	11.16
SPP	0.02^{ns}	0.03^{ns}	0.03^{ns}	0.02^{ns}	0.02	4.75
HSW (g)	110.15	2395.51**	715.23**	42.72**	11.99	4.94
CS (%)	1451.75	482.59**	2502.76**	344.07**	143.28	36.29
	(580.70)	(192.71)	(1044.86)	(145.24)	(57.63)	(22.08)
GYLD (g)	430.05	572.51**	15788.37**	190.83**	58.96	12.20
GPE (g)	2359.41	1858.03**	113609.25**	683.50**	207.49	13.26
EGR (g/day)	490.21	700.33**	27756.57**	232.64**	72.07	12.31
	With lime application					
DF	15.00	13.25**	4567.41**	4.12**	1.27	2.08
DM	15.27	23.54**	4438.82**	6.61**	2.31	1.04
GFP(day)	17.08	28.50**	5922.11**	9.26**	2.51	1.72
PH(cm)	1489.31	144.10**	243555.95**	85.82**	34.54	4.58
PNPP	3.64	6.04**	100.70**	1.33*	0.94	12.00
PPP	5.55	35.50**	237.27**	4.30**	2.24	12.84
PPPN	0.10	0.14**	3.69**	0.04**	0.02	10.15
SPP	0.05^{ns}	0.03^{ns}	0.04^{ns}	0.03^{ns}	0.03	5.91
HSW(g)	137.61	2690.63**	2305.57**	41.76**	12.96	5.01
CS (%)	873.28	573.40**	9065.48**	357.20**	78.09	32.17
	(387.65)	(251.76)	(3979.73)	(163.50)	(35.70)	(19.50)
GYLD(g)	376.50	1032.64**	1028.45**	281.20**	87.03	10.02
GPE(g)	2182.34	3853.17**	106043.51**	1069.63**	304.37	10.87
EGR(g/day)	347.55	1176.61**	3771.96**	330.84**	103.57	10.02

*and**, significant at P≤0.05 and P≤0.01, respectively. Numbers in parenthesis represent degree of freedom for the respective source of variation. Rep= replication, CV (%) = coefficient of variation in percent, DF= days to flowering(days), DM = days to maturity(days), GFP= Grain filling period(days), PH = plant height(cm), PNPP=Number of poding node per plant, PPP= Number of Pod per Plant, PPPN= Number of pod per poding node, SPP= number of seed per pod, HSW= hundred seed weight(g), GYLD= Grain yield per 5 plants(g), CS= Chocolate spot disease(%),GPE= Grain production efficiency(g), EGR= Economic growth rate(g/day).

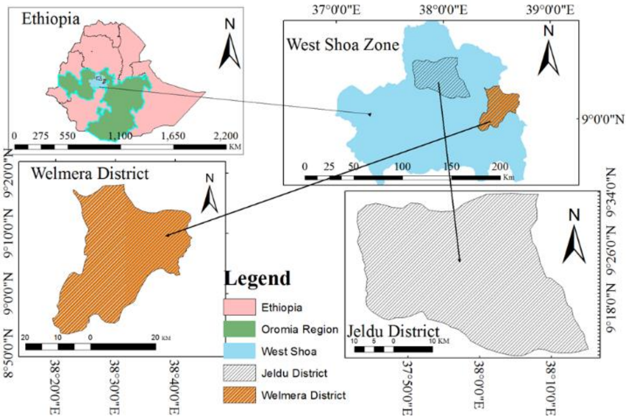

Fig. 1: The study area map of two districts.

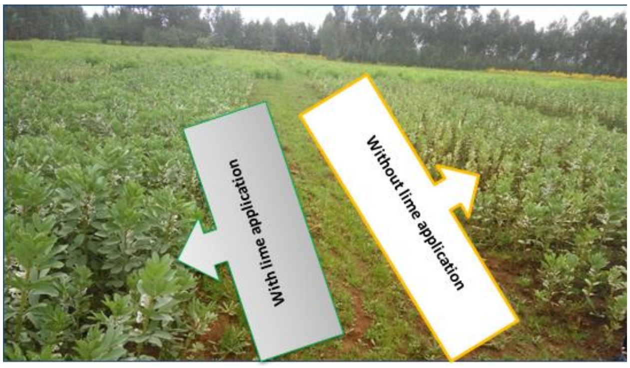

Fig. 2: Growth performance of genotypes with and without lime at Jeldu in 2017.

Mean Performances of Genotypes for Morpho-Agronomic Traits

Phenological and Growth Traits

The genotypes had days to 50% flowering (DF) in the range between 51.4 days (EH09004-2) and 58.9 days (Wayu) and overall mean of 54.1 days without lime application over the three locations. Without lime application, the genotypes showed significantly early flowering (6.3 days) for EH07023-3, EH09002-1, EH06088-6, EH08035-1 and EH09004-2 compared to the late flowering Wayu and Gebelcho (Table 5). DF varied in the range between 47.64, 4786 days at Holetta and 58.04, 58.45 days at Watebecha Minjaro without and with lime over the three locations, respectively (Table 7). The genotypes had days to 90% maturity (DM) in the range between 142.1 days (Degaga) and 149 days (EKLS/CSR02014-2-4) and 142.7 days (KUSE2-27-33) and 148.8 days (EH07023-3) with overall mean of 145.9 days without and with lime application over the three locations, respectively. A total of 13 genotypes including EKLS/CSR02014-2-4 took longer days to attain DM over locations without lime applications with non-significant difference among the mean values of genotypes and a total

Table 5: Mean phonological, plant height and number of poding node per plant Performances of 50 faba bean genotypes evaluated without and with lime application across three locations in 2017

Genotype	DF		DM		GFP		PH		PNPP	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
Cool-0030	55.8^{ef}	54.3	147.3^{a-g}	147.3^{a-h}	91.6^{g-l}	93.0^{b-h}	112.1^{b-l}	127.7^{c-m}	6.0^{i-p}	8.6^{a-g}
Wolki¥	56.1^{de}	55.2	145.1^{h-n}	144.4^{m-r}	89.0^{m-r}	89.2^{r-v}	114.0^{a-h}	130.0^{b-k}	7.8^{abc}	9.6^{a}
EKLS/CSR02012-2-3	53.0^{o-r}	53.2	147.0^{b-h}	148.0^{a-d}	94.0^{a-f}	94.8^{ab}	117.3^{ab}	128.7^{b-l}	6.0^{i-p}	7.3^{h-l}
Obse	53.0^{o-r}	52.8	145.7^{g-m}	145.9^{g-n}	92.7^{c-j}	93.1^{b-h}	119.0^{a}	132.2^{a-g}	6.4^{e-m}	7.1^{i-l}
NC58	53.4^{k-r}	53.3	143.2^{o-r}	143.9^{p-s}	89.8^{k-q}	90.6^{l-t}	115.7^{a-e}	130.3^{b-j}	8.3^{a}	9.1^{ab}
Ashebeka¥	57.1^{cd}	55.9	147.6^{a-g}	148.4^{ab}	90.4^{j-p}	92.6^{d-j}	118.9^{a}	134.6^{abc}	6.9^{c-j}	8.1^{b-i}
Hachalu¥	56.1^{de}	56.3	146.8^{c-i}	146.3^{d-k}	90.7^{j-p}	90.0^{p-t}	118.9^{a}	132.6^{a-e}	6.9^{c-j}	8.0^{b-j}
Degaga	54.3^{h-n}	53.7	142.1^{r}	143.7^{p-s}	87.8^{qr}	90.0^{p-t}	106.2^{k-p}	127.2^{d-m}	7.6^{a-d}	9.2^{a}
EH09031-4	53.3^{l-r}	53.0	147.7^{a-f}	147.3^{a-h}	94.3^{a-d}	94.3^{bcd}	107.2^{i-o}	124.6^{h-o}	5.2^{op}	6.7^{kl}
Holetta-2	53.6^{j-r}	53.7	146.6^{c-j}	146.1^{f-m}	93.0^{b-i}	92.4^{e-k}	106.8^{j-p}	120.1^{no}	6.1^{h-p}	7.9^{c-j}
EH09007-4	52.7^{p-s}	53.2	145.7^{g-m}	146.3^{d-k}	93.0^{b-i}	93.1^{b-h}	104.0^{nop}	123.2^{k-o}	5.1^{p}	6.7^{kl}
EH07023-3	52.6^{q-t}	52.8	147.3^{a-g}	148.8^{a}	94.8^{abc}	96.0^{a}	113.7^{a-i}	137.1^{a}	5.7^{k-p}	7.7^{e-l}
EK05006-3	53.7^{i-q}	55.0	148.4^{abc}	147.6^{a-g}	94.8^{abc}	92.6^{d-j}	109.3^{d-o}	129.7^{b-k}	6.2^{g-o}	8.0^{b-j}
EKLS/CSR02014-2-4	53.7^{i-q}	54.0	149.0^{a}	147.1^{a-h}	95.3^{a}	93.1^{b-h}	111.2^{b-m}	128.7^{b-l}	6.0^{i-p}	7.2^{i-l}
Numan	54.7^{f-k}	53.7	146.8^{c-i}	147.2^{a-h}	92.1^{e-j}	93.6^{b-g}	114.4^{a-g}	127.4^{d-m}	5.3^{nop}	6.6^{l}
Bulga 70	53.1^{n-r}	53.6	143.9^{m-r}	144.6^{l-r}	90.8^{j-o}	91.0^{i-r}	110.4^{c-n}	125.4^{f-o}	7.1^{b-h}	8.9^{a-d}
EK05001-1	53.2^{m-r}	52.7	147.0^{b-h}	144.4^{m-r}	93.7^{a-g}	91.8^{g-p}	113.8^{a-i}	129.6^{b-k}	6.7^{d-k}	8.0^{b-j}
Dosha	53.4^{k-r}	54.7	145.7^{g-m}	146.4^{c-k}	92.2^{d-j}	91.8^{g-p}	118.8^{a}	130.0^{b-k}	7.0^{b-i}	8.7^{a-f}
Gora	54.2^{h-o}	54.2	147.6^{a-g}	146.3^{d-k}	93.3^{a-h}	92.1^{e-m}	114.6^{a-f}	131.2^{a-h}	6.0^{i-p}	7.0^{i-l}
EH08035-1	51.7^{st}	52.3	143.9^{m-r}	144.0^{p-s}	92.2^{d-j}	91.7^{h-q}	105.9^{l-p}	124.4^{h-o}	5.4^{m-p}	8.0^{b-j}
Wayu	58.9^{a}	58.1	146.1^{e-k}	145.8^{h-o}	87.2^{r}	87.7^{v}	100.8^{p}	119.0^{o}	6.4^{e-m}	7.9^{c-j}
EKLS/CSR02023-2-1	52.7^{p-s}	53.4	146.8^{c-i}	147.2^{a-h}	94.1^{a-e}	93.8^{b-e}	109.1^{e-o}	131.1^{a-h}	5.7^{k-p}	7.3^{h-l}
Mesay	53.3^{l-r}	53.4	142.9^{pqr}	144.2^{n-s}	89.6^{l-q}	90.8^{j-s}	111.1^{b-m}	128.8^{b-l}	7.3^{b-f}	9.0^{abc}
EH09004-2	51.4^{t}	52.4	142.3^{qr}	142.9^{rs}	90.9^{i-n}	90.4^{m-t}	109.1^{e-o}	123.7^{j-o}	6.1^{h-p}	8.1^{b-i}
EH06088-6	52.3^{rst}	53.1	145.7^{g-m}	146.0^{g-m}	93.3^{a-h}	92.9^{c-h}	106.2^{k-p}	122.3^{l-o}	5.6^{l-p}	7.7^{e-l}
EKLS/CSR02017-3-4	52.7^{p-s}	53.4	145.9^{f-l}	146.6^{c-k}	93.2^{a-h}	93.1^{b-h}	107.0^{j-p}	130.6^{a-j}	5.4^{m-p}	7.4^{g-l}
Kasa	53.7^{i-q}	53.7	142.8^{pqr}	143.6^{qrs}	89.1^{m-r}	89.9^{q-t}	109.9^{c-o}	125.7^{e-n}	7.4^{a-e}	8.4^{a-h}
Cool-0025	54.4^{g-m}	54.2	145.8^{f-l}	144.9^{k-q}	91.3^{h-l}	90.7^{k-s}	114.1^{a-h}	130.0^{b-k}	7.0^{b-i}	8.4^{a-h}
EH06070-3	54.9^{f-i}	54.1	147.9^{a-e}	147.9^{a-e}	93.0^{b-i}	93.8^{b-e}	108.4^{f-o}	124.3^{h-o}	5.6^{l-p}	6.9^{jkl}
EKLS/CSR02010-4-3	53.3^{l-r}	53.1	146.6^{c-j}	146.3^{d-k}	93.2^{a-h}	93.2^{b-h}	112.7^{a-k}	132.3^{a-f}	5.9^{j-p}	7.2^{i-l}
Cool-0031	55.6^{efg}	54.2	147.2^{a-g}	146.7^{c-j}	91.7^{g-l}	92.4^{e-k}	114.7^{a-f}	130.1^{b-k}	6.6^{d-l}	9.0^{abc}
Cool-0018	53.9^{h-p}	53.9	143.8^{n-r}	144.1^{o-s}	89.9^{k-q}	90.2^{n-t}	108.4^{f-o}	131.2^{a-h}	7.2^{b-g}	9.1^{ab}
EKLS/CSR02028-1-1	53.7^{i-q}	54.1	148.8^{ab}	147.9^{a-e}	95.1^{ab}	93.8^{b-e}	106.9^{j-p}	126.2^{d-n}	6.1^{h-p}	7.3^{h-l}
EK 05037-4	53.0^{o-r}	53.0	146.7^{c-i}	146.7^{c-j}	93.7^{a-g}	93.7^{b-f}	112.9^{a-j}	132.7^{a-d}	7.1^{b-h}	8.8^{a-e}
Cool-0035	53.4^{k-r}	54.1	144.9^{i-o}	143.7^{p-s}	91.4^{g-l}	89.6^{r-u}	113.0^{a-j}	129.9^{b-k}	7.3^{b-f}	9.3^{a}
KUSE2-27-33	53.0^{o-r}	53.8	144.1^{l-q}	142.7^{s}	91.1^{h-m}	88.9^{tuv}	107.9^{g-o}	127.6^{d-m}	7.6^{a-d}	9.6^{a}
EH07015-7	53.2^{m-r}	54.6	148.1^{a-d}	146.9^{b-i}	94.9^{ab}	92.3^{e-l}	113.7^{a-i}	127.8^{c-m}	6.3^{f-n}	7.6^{f-l}
Cool-0024	53.3^{l-r}	53.7	145.2^{h-n}	144.6^{l-r}	91.9^{f-k}	90.9^{j-s}	114.4^{a-g}	131.1^{a-h}	8.0^{ab}	9.6^{a}
Selale¥	54.6^{g-l}	54.3	145.1^{h-n}	146.2^{e-l}	90.6^{j-p}	91.9^{f-o}	104.1^{nop}	121.2^{mno}	7.1^{b-h}	7.8^{d-k}
Moti	53.3^{l-r}	53.4	143.9^{m-r}	145.1^{j-q}	90.6^{j-p}	91.7^{h-q}	115.9^{a-d}	130.8^{a-i}	7.3^{b-f}	8.4^{a-h}
EH06027-2	54.9^{f-i}	54.3	146.8^{c-i}	147.1^{a-h}	91.9^{f-k}	92.8^{c-i}	111.6^{b-m}	131.8^{a-g}	6.0^{i-p}	7.4^{g-l}
EKLS/CSR02019-2-4	53.6^{j-r}	53.7	148.1^{a-d}	148.1^{abc}	94.6^{abc}	94.4^{bc}	113.8^{a-i}	135.2^{ab}	6.1^{h-p}	8.0^{b-j}
EH09002-1	52.6^{q-t}	52.8	144.9^{i-o}	145.3^{i-p}	92.3^{d-j}	92.6^{d-j}	105.6^{m-p}	124.8^{h-o}	6.0^{i-p}	7.9^{c-j}
Tumsa	57.6^{bc}	56.2	147.3^{a-g}	147.9^{a-e}	89.8^{k-q}	91.7^{h-q}	112.7^{a-k}	129.3^{b-k}	6.9^{c-j}	8.0^{b-j}
Gebelcho	58.6^{ab}	57.7	147.2^{a-g}	147.8^{a-f}	88.7^{o-r}	90.1^{o-t}	112.8^{a-j}	130.2^{b-j}	6.2^{g-o}	7.3^{h-l}
EK05037-5	53.3^{l-r}	53.1	144.8^{j-o}	144.9^{k-q}	91.4^{g-l}	91.8^{g-p}	107.8^{h-o}	123.9^{i-o}	5.7^{k-p}	7.7^{e-l}
Didi’a¥	54.8^{f-j}	55.2	146.2^{d-j}	147.2^{a-h}	91.4^{g-l}	92.0^{e-n}	116.4^{abc}	131.0^{a-h}	6.7^{d-k}	7.9^{c-j}
Cool-0034	53.9^{h-p}	53.6	144.9^{i-o}	146.3^{d-k}	91.0^{i-n}	92.8^{c-i}	113.2^{a-j}	127.2^{d-m}	7.4^{a-e}	8.7^{a-f}
CS20DK	55.8^{ef}	55.4	144.3^{k-p}	144.6^{l-r}	88.6^{pqr}	89.1^{s-v}	112.1^{b-l}	125.3^{g-o}	8.0^{ab}	9.3^{a}
Tesfa	55.0^{e-h}	54.9	143.9^{m-r}	143.0^{rs}	88.9^{n-r}	88.1^{uv}	103.4^{op}	120.2^{no}	7.0^{b-i}	8.6^{a-g}
Mean	54.1	54.1	145.9	145.9	91.8	91.9	111.2	128.2	6.5	8.1
CV (%)	2.1	2.1	1.1	1.0	2.1	1.7	5.1	4.6	13.5	12.0
R^2	0.97	0.97	0.93	0.94	0.91	0.95	0.98	0.98	0.80	0.70

L_0= without lime, L_1= with lime, CV (%) = coefficient of variation in percent, R^2= coefficient of determination, DF= days to 50% flowering (days), DM = days to 90% maturity (days), GFP= Grain filling period (days), PH = plant height (cm), PNPP=Number of poding node per plant. Mean values followed by similar letter(s) in each column had non-significant difference at $P<0.05$

of nine genotypes found as early maturity significantly different from other genotypes mean maturity days over locations (Table 5). The genotypes had mean values of 91.8 and 91.9 days for grain filling period (GFP) with the range spanning between 87.2 and 95.3 days for Wayu and EKLS/CSR02014-2-4 and 87.7 and 96 days for Wayu and EH07023-3 without and with lime, respectively over locations (Table 5).

The observed variations among genotypes for DF and DM over locations with different management may be due to the inherent characteristics of genotypes and the influence of locations. The GFP of the genotypes associated with days to DF and DM. Therefore, short GFP resulted from short DF and DM which is an advantage if any terminal moisture stress encountered in the location(s). It was reported that faba bean genotypes took 61 to 65 days for DF and 130-143 DM

Table 6: Combined mean performance of 50 faba bean genotypes for grain yield (g/5plants) and other yield components evaluated without and with lime over three locations in 2017

Genotype	PPP		PPPN		HSW		CS		GYLD		
	L$_0$	L$_1$	L$_0$	L$_1$	L$_0$	L$_1$	L$_0$	L$_1$	L$_0$	L$_1$	RR
Cool-0030	7.9^{h-o}	12.1^{f-l}	1.33^{b-j}	1.42^{f-p}	68.5	69.0^{o}	37.3^{a-g}	31.2^{e-i}	59.3^{i-q}	95.9^{c-j}	38.2
Wolki[¥]	10.4^{b}	14.9^{abc}	1.33^{b-i}	1.56^{a-i}	59.2	59.8^{p}	29.9^{e-i}	26.3^{h-k}	75.6^{abc}	97.0^{c-j}	22.1
EKLS/CSR02012-2-3	7.1^{l-r}	9.6^{qrs}	1.22^{e-l}	1.31^{m-p}	84.3	86.8^{efg}	28.6^{ghi}	25.1^{i-l}	61.5^{g-o}	98.5^{b-g}	37.6
Obse	8.1^{f-m}	9.8^{p-s}	1.28^{c-k}	1.36^{k-p}	78.4	77.5^{jkl}	36.0^{a-h}	32.4^{d-h}	77.6^{ab}	97.7^{b-i}	20.6
NC58	12.0^{a}	14.2^{bcd}	1.47^{ab}	1.59^{a-f}	47.7	45.2^{x}	43.7^{a}	35.0^{b-f}	61.6^{g-o}	82.2^{k-n}	25.0
Ashebeka[¥]	8.6^{d-k}	11.7^{g-o}	1.25^{e-l}	1.43^{e-o}	79.4	84.7^{fgh}	33.7^{b-i}	30.0^{e-i}	69.3^{b-h}	98.8^{b-g}	29.8
Hachalu[¥]	9.2^{b-h}	11.8^{g-n}	1.34^{b-g}	1.49^{c-l}	70.9	73.6^{mn}	34.7^{b-i}	31.2^{e-i}	72.9^{a-e}	89.7^{e-k}	18.8
Degaga	9.3^{b-g}	13.6^{c-f}	1.25^{e-l}	1.48^{d-m}	53.1	54.0^{rst}	38.5^{a-f}	31.3^{e-i}	59.6^{i-q}	87.3^{i-m}	31.7
EH09031-4	6.1^{rs}	8.6^{rs}	1.21^{e-l}	1.29^{nop}	93.2	93.6^{bc}	29.7^{f-i}	22.5^{jkl}	61.6^{g-o}	88.6^{g-l}	30.5
Holetta-2	8.3^{e-l}	11.0^{j-q}	1.34^{b-g}	1.39^{i-p}	53.5	54.7^{q-t}	31.1^{d-i}	28.6^{f-j}	53.3^{n-r}	64.0^{o}	16.8
EH09007-4	5.6^{s}	8.4^{s}	1.09^{l}	1.27^{op}	84.8	91.7^{bcd}	28.9^{ghi}	25.1^{i-l}	54.8^{l-r}	89.3^{e-k}	38.7
EH07023-3	6.7^{n-s}	10.0^{o-s}	1.18^{g-l}	1.33^{l-p}	90.8	94.4^{b}	29.9^{e-i}	34.8^{b-f}	65.7^{d-k}	102.6^{bc}	35.9
EK05006-3	8.0^{g-n}	11.1^{i-q}	1.30^{c-k}	1.41^{h-p}	74.1	79.9^{ij}	36.1^{a-h}	32.4^{d-h}	70.0^{b-g}	99.1^{b-g}	29.3
EKLS/CSR02014-2-4	6.8^{m-s}	9.6^{qrs}	1.16^{jkl}	1.33^{l-p}	84.6	84.4^{gh}	37.4^{a-g}	32.4^{d-h}	62.8^{f-l}	89.0^{f-l}	29.5
Numan	6.8^{m-s}	8.6^{rs}	1.27^{d-k}	1.33^{l-p}	93.9	98.5^{a}	35.1^{a-i}	25.1^{i-l}	72.8^{a-e}	91.3^{d-k}	20.4
Bulga 70	9.4^{b-f}	14.1^{bcd}	1.36^{b-f}	1.59^{a-e}	47.6	45.4^{x}	36.1^{a-h}	34.8^{b-f}	55.4^{l-r}	89.1^{e-l}	37.9
EK05001-1	7.8^{i-p}	10.3^{m-q}	1.18^{g-l}	1.31^{m-p}	75.4	75.7^{klm}	35.0^{a-i}	30.0^{e-i}	62.6^{f-m}	87.8^{h-m}	28.7
Dosha	8.6^{d-k}	12.3^{e-k}	1.23^{e-l}	1.44^{e-n}	70.4	70.6^{no}	41.1^{abc}	38.5^{a-d}	74.1^{a-d}	98.1^{b-h}	24.5
Gora	7.7^{i-p}	9.7^{qrs}	1.26^{d-k}	1.42^{g-p}	84.9	89.9^{cde}	42.4^{ab}	33.7^{c-g}	71.0^{b-f}	99.9^{b-e}	29.0
EH08035-1	6.2^{qrs}	10.8^{k-q}	1.16^{i-l}	1.34^{l-p}	84.9	85.9^{fgh}	39.9^{a-d}	39.8^{abc}	57.7^{j-r}	99.3^{b-g}	41.9
Wayu	9.6^{b-e}	12.9^{d-h}	1.46^{ab}	1.68^{ab}	35.4	36.7^{y}	40.1^{abc}	31.2^{e-i}	40.7^{s}	61.6^{o}	33.9
EKLS/CSR02023-2-1	6.4^{p-s}	10.0^{o-s}	1.16^{jkl}	1.36^{k-p}	84.6	90.3^{cde}	33.7^{b-i}	30.0^{e-i}	53.8^{m-r}	91.5^{d-k}	41.2
Mesay	9.7^{b-e}	13.6^{c-f}	1.32^{b-k}	1.52^{b-k}	49.5	55.8^{qrs}	37.3^{a-g}	32.5^{d-h}	55.2^{l-r}	78.8^{lmn}	30.0
EH09004-2	7.6^{j-q}	10.4^{l-q}	1.23^{e-l}	1.29^{nop}	75.8	79.0^{ijk}	33.8^{b-i}	27.6^{g-j}	60.2^{i-q}	99.2^{b-g}	39.4
EH06088-6	6.8^{m-s}	9.8^{p-s}	1.20^{e-l}	1.30^{nop}	89.9	89.8^{cde}	33.5^{b-i}	28.8^{f-j}	60.0^{i-q}	95.9^{c-j}	37.4
EKLS/CSR02017-3-4	6.4^{p-s}	9.6^{qrs}	1.20^{e-l}	1.27^{nop}	85.7	93.2^{bc}	28.8^{ghi}	35.0^{b-f}	59.7^{i-q}	101.1^{bcd}	40.9
Kasa	10.6^{b}	13.3^{c-g}	1.44^{bc}	1.58^{a-g}	45.0	47.3^{wx}	41.4^{abc}	36.4^{b-e}	51.4^{qr}	75.7^{n}	32.1
Cool-0025	9.9^{bcd}	12.8^{d-i}	1.42^{bcd}	1.52^{b-k}	55.3	56.7^{pqr}	42.4^{ab}	41.2^{ab}	62.5^{f-m}	98.5^{b-g}	36.6
EH06070-3	6.6^{o-s}	8.6^{rs}	1.21^{e-l}	1.25^{p}	86.7	87.6^{efg}	28.9^{ghi}	22.7^{jkl}	57.3^{k-r}	84.5^{k-n}	32.2
EKLS/CSR02010-4-3	7.2^{k-r}	9.9^{p-s}	1.18^{g-l}	1.38^{j-p}	85.4	95.0^{b}	34.8^{b-i}	32.4^{d-h}	62.0^{g-n}	108.5^{ab}	42.8
Cool-0031	9.6^{b-e}	13.9^{b-e}	1.46^{ab}	1.56^{a-h}	48.6	49.7^{uvw}	41.1^{abc}	43.8^{a}	59.9^{i-q}	98.4^{b-h}	39.1
Cool-0018	9.3^{b-g}	14.0^{b-e}	1.31^{b-k}	1.57^{a-h}	54.9	53.8^{rst}	31.1^{d-i}	32.4^{d-h}	61.5^{g-o}	97.7^{b-i}	37.1
EKLS/CSR02028-1-1	7.2^{k-r}	10.9^{k-q}	1.19^{f-l}	1.48^{d-m}	85.5	85.3^{fgh}	37.4^{a-g}	32.5^{d-h}	64.8^{e-k}	98.7^{b-g}	34.4
EK 05037-4	8.7^{d-j}	11.8^{g-n}	1.22^{e-l}	1.35^{k-p}	78.0	75.7^{klm}	32.5^{c-i}	25.2^{i-l}	66.8^{d-i}	100.9^{bcd}	33.8
Cool-0035	9.8^{bcd}	14.0^{b-e}	1.34^{b-g}	1.52^{b-k}	57.1	56.4^{pqr}	41.2^{abc}	38.6^{a-d}	68.2^{c-i}	97.4^{c-j}	29.9
KUSE2-27-33	9.9^{bcd}	15.3^{ab}	1.34^{b-h}	1.62^{a-d}	47.0	48.3^{vwx}	38.8^{a-e}	32.5^{d-h}	54.5^{l-r}	95.9^{c-j}	43.2
EH07015-7	7.3^{j-r}	9.7^{qrs}	1.17^{h-l}	1.30^{nop}	91.6	88.3^{def}	29.9^{e-i}	25.0^{i-l}	66.3^{d-j}	100.6^{bcd}	34.1
Cool-0024	10.3^{bc}	15.3^{ab}	1.33^{-j}	1.62^{a-d}	52.7	51.0^{t-w}	33.8^{b-i}	32.5^{d-h}	68.0^{c-i}	103.3^{bc}	34.1
Selale[¥]	9.3b^{-g}	13.0^{d-h}	1.36^{b-f}	1.65^{abc}	44.6	45.8^{x}	35.1^{a-i}	36.1^{b-e}	50.1^{r}	74.9^{n}	33.2
Moti	9.0^{c-i}	12.0^{f-m}	1.26^{d-k}	1.43^{e-o}	70.8	74.7^{lm}	37.4^{a-g}	30.0^{e-i}	72.7^{a-e}	115.1^{a}	36.8
EH06027-2	7.3^{j-r}	10.9^{k-q}	1.23^{e-l}	1.48^{d-m}	82.7	85.4^{fgh}	27.4^{hi}	28.9^{f-j}	62.1^{g-n}	86.8^{j-m}	28.4
EKLS/CSR02019-2-4	7.4^{j-r}	10.2^{n-r}	1.22^{e-l}	1.27^{nop}	87.7	91.6^{bcd}	35.0^{a-i}	32.5^{d-h}	66.7^{d-i}	97.7^{b-i}	31.8
EH09002-1	7.0^{l-r}	10.6^{l-q}	1.15^{kl}	1.33^{l-p}	78.5	82.3^{hi}	27.7^{hi}	25.1^{i-l}	60.9^{h-p}	86.8^{j-m}	29.9
Tumsa	8.7^{d-j}	12.1^{f-l}	1.29^{c-k}	1.54^{b-j}	71.8	71.9^{mno}	26.2^{i}	22.6^{jkl}	70.9^{b-f}	101.2^{bcd}	29.9
Gebelcho	8.7^{d-j}	11.4^{h-p}	1.43^{bc}	1.57^{a-h}	75.2	77.7^{jkl}	28.7^{ghi}	20.3^{kl}	65.2^{e-k}	86.9^{j-m}	25.0
EK05037-5	6.7^{n-s}	10.4^{l-q}	1.18^{g-l}	1.37^{k-p}	76.7	74.1^{lmn}	32.5^{c-i}	28.6^{f-j}	53.0^{o-r}	81.8^{k-n}	35.2
Didi'a[¥]	8.6^{d-k}	11.9^{f-n}	1.25^{e-l}	1.49^{c-l}	73.4	71.0^{no}	31.1^{d-i}	26.3^{h-k}	74.5^{a-d}	100.8^{bcd}	26.1
Cool-0034	10.1^{bc}	13.9^{b-e}	1.37^{b-e}	1.62^{a-d}	55.4	57.8^{pq}	32.5^{c-i}	33.7^{c-g}	67.0^{c-i}	99.8^{b-f}	32.8
CS20DK	12.7^{a}	16.0^{a}	1.59^{a}	1.72^{a}	51.9	51.8^{tuv}	27.6^{hi}	19.0^{l}	79.6^{a}	113.2^{a}	29.7
Tesfa	9.0^{c-i}	12.7^{d-j}	1.29^{c-k}	1.47^{d-m}	50.0	52.1^{stu}	32.6^{c-i}	28.7^{f-j}	52.3^{pqr}	77.8^{mn}	32.8
Mean	8.4	11.7	1.3	1.4	70.1	71.8	34.4	30.64	62.9	93.1	32.4
CV (%)	14.8	12.8	11.2	10.2	4.9	5.0	22.1	19.5	12.2	10.0	--
R^2	0.82	0.80	0.57	0.75	0.97	0.97	0.63	0.79	0.82	0.76	--

L$_0$= without lime, L$_1$= with lime, CV (%) = coefficient of variation in percent, R^2= coefficient of determination, PPP= Number of Pod per Plant, PPPN= Number of pod per poding node, HSW= hundred seed weight (g), CS= Chocolate spot disease (%), GYLD= Grain yield per 5 plants (g), RR= relative reduction. Mean values followed by similar letter(s) in each column had non-significant difference at $P<0.05$.

(Tewodros *et al.*, 2015). Million (2012) also reported 57-63 and 137-146 DF and DM, respectively. This study result partially agrees with the previous findings of Million (2012) and Tekle *et al.* (2016) that GFP of faba bean genotypes ranged from 78-87 and 75-88 days, respectively. In contradict to this study result, Hirpa *et al.* (2013) reported that application of lime hastened flowering and maturity in common bean.

The genotypes had overall mean plant height (111.2 and 128.2 cm) with the range between 100.8 and 1119 cm for Wayu and Obse and 119 and 137.1 cm for Wayu and EH07023-3 without and with lime application, respectively, over locations (Table 5). The mean number of poding node per plant (PNPP) of genotypes over locations was between 5.1 and 8.3 for EH09007-4 and NC58 and between 6.6 (Numan) and 9.6 (KUSE2-27-33 and Wolki) with the mean

Table 7: Mean performance of 13 Traits of faba bean evaluated without and with lime application across three locations in 2017

Traits	Without lime (L_0)				With lime (L_1)			
	Holetta	W/M	Jeldu	Mean	Holetta	W/M	Jeldu	Mean
Days to 50% flowering	47.64^{c}	58.04^{a}	56.51^{b}	54.06	47.86^{c}	58.45^{a}	55.85^{b}	54.05
Days to 90% maturity	142.21^{c}	143.60^{b}	151.78^{a}	145.86	142.45^{c}	143.13^{b}	152.19^{a}	145.92
Grain filling period(days)	94.57^{b}	85.55^{c}	95.27^{a}	91.80	94.59^{b}	84.69^{c}	96.34^{a}	91.87
Plant height(cm)	148.29^{a}	121.30^{b}	64.12^{c}	111.24	159.59^{a}	142.25^{b}	82.76^{c}	128.20
Number of poding node plant^{-1}	7.03^{b}	7.49^{a}	5.09^{c}	6.54	7.87^{b}	8.98^{a}	7.38^{c}	8.08
Number of pod plant^{-1}	8.84^{b}	9.49^{a}	6.74^{c}	8.36	10.28^{c}	12.75^{a}	11.94^{b}	11.66
Number of pod poding nod^{-1}	1.26^{b}	1.27^{b}	1.31^{a}	1.28	1.30^{c}	1.42^{b}	1.61^{a}	1.44
Number of seed pod^{-1}	2.98^{a}	3.00^{a}	2.97^{a}	2.98	2.99^{a}	2.95^{a}	2.97^{a}	2.97
Hundred seed weight(g)	72.63^{a}	68.56^{b}	69.22^{b}	70.13	76.14^{a}	68.46^{c}	70.90^{b}	71.83
Chocolate spot disease	35.24^{a}	31.43^{b}	36.49^{a}	34.39	30.25^{b}	25.69^{c}	35.97^{a}	30.64
Grain yield(g/5plants)	69.98^{a}	67.66^{b}	51.16^{c}	62.93	92.62^{b}	90.80^{b}	95.96^{a}	93.13
Grain production efficiency	139.49^{a}	99.64^{b}	86.69^{c}	108.61	183.89^{a}	131.61^{c}	166.20^{b}	160.57
Economic growth rate	74.10^{b}	79.23^{a}	53.53^{c}	68.95	98.01^{b}	107.32^{a}	99.44^{b}	101.59

W/M=Watebecha Minjaro

values of 6.5 and 8.1 without and with lime, respectively. The genotypes KUSE2-27-33, Wolki, Cool-0024, Cool-0035, CS20DK and Degaga followed by other thirteen genotypes had significantly high PNPP and EH09007-4, EH09031-4, Numan followed by fifteen other genotypes had less PNPP that are significantly different from the other genotypes with lime over locations (Table 5).

The significant difference in plant height and number of poding node per plant of genotypes over locations and managements indicated the existing variation among the evaluated faba bean genotypes which were mainly attributed to genotype and their growing environment. Soil acidity stress reduced plant height and number of poding node per plant of genotypes as compared to lime treated plots (Table 5). The result indicated that stressed environments hinder the growth performance of faba bean genotypes (Fig. 2). In harmony with this result Tewodros *et al.* (2015) reported longer plant height under optimum environments than stress environments. Similarly, lime application improved plant height of faba bean genotypes on acid soil (Ouertatani *et al.*, 2011; Abebe and Tolera, 2014). Partially in agreement with this result a plant height of 119-137cm were reported under optimum environment (Million, 2012). As reported by Mussa and Gemechu (2006) faba bean has a problem of flower abortion consequently this reduces the number of poding node per plant.

Yield Components

The genotypes had mean number of pod per plant (PPP) that ranged between 5.6 (EH09007-4) and 12.7 (CS20DK) without and 8.4 (EH09007-4) and 16.0 (CS20DK) with lime application with an overall mean value of 8.1 and 11.7, respectively. The genotypes CS20DK and NC58 without lime and Wolki, KUSE2-27-33, Cool-0024 and CS20DK with lime had high PPP that is significantly different than other genotypes over locations (Table 6).

The mean number of pod per poding node (PPPN) of genotypes ranged from 1.09 (EH09007-4) to 1.59 (CS20DK) and 1.25 (EH06070-3) to 1.72 (CS20DK) without and with lime application, respectively. The genotypes CS20DK had high number of pod per poding node significantly different from other genotypes over locations both with and without lime (Table 6). The genotypes had different PPP as affected by management, location, genetic makeup of genotypes and the interaction of them. Both PPP and PPPN increased in case of lime application indicating that reduction without lime were due the sensitivity of this trait to soil acidity. The result agreed with the reports of Tamene (2008) and Million (2012) who reported 10 to 16 and 6 to 10 pods per plant, respectively; and also Tamene (2008) reported that the PPPN was significantly different across locations. It was reported that more PPP under limed than lime free condition in acidic soil in faba bean (Ouertatani *et al.*, 2011) and common bean (Hirpa *et al.*, 2013). In contradict to this `study result it was reported that no variation in PPP as a result of lime application (Abebe and Tolera, 2014) and 19 to 22 PPP (Tekle *et al.*, 2016).

The genotypes had hundred seed weight (HSW) that ranged between 36.7g (Wayu) and 98.5g (Numan) and with overall mean of 71.8g with lime application over the three locations. In this case Numan showed larger and Wayu smaller HSW which was significantly different from other genotypes. Likewise, HSW of genotypes varied in the range between 35.4g (Wayu) and 93.9g (Numan) without lime application over the three locations (Table 6). The variation in HSW over location was due to the genetic potential of the genotypes rather than soil acidity of test locations because there were no rank order changes of the lowest and highest HSW of genotypes. The result implied that HSW was less affected by soil acidity stress of test sites as compared to the other traits. Tamene *et al.* (2015) reported that HSW in faba bean was less variable than grain yield. Likewise, Abebe and Tolera (2014) also reported that HSW was not changed as a response of lime application under acidic soil.

Grain Yield Performance of Genotypes

The genotypes had mean grain yield (GYLD) in the range between 40.7g (Wayu) and 79.6g (CS20DK) and overall mean of 62.3g without lime application over the three locations. In case of without lime application over the three locations, CS20DK, Obse, Wolki, Didia, Dosha, Hachalu, Numan and Moti were high yielder while Wayu was low yielder significantly different from other genotypes. Likewise, the GYLD of genotypes ranged between 61.6g (Wayu) and 115.1g (Moti) with the mean value of 93.1g with lime application over the three locations. The genotypes Moti, CS20DK, EKLS/CSR0200104-3 were high yielder whereas Wayu and Holetta-2 were low yielder with significantly different from other genotypes (Table 6). The grain yield of Wayu was the least under each management level, location and their interaction due to its smaller hundred seeds weight. In agreement with this result the older varieties (Kuse2-27-33, NC-58, Wayu and Selale) were consistently low yielder over environments (Tamene, 2008) and CS20DK was high yielder genotype over locations under optimum environments (Tamene *et al.,* 2015*).*

Jeldu was the lowest and highest yielder environment without and with lime application, respectively. The variation in the highest and lowest yield at each location was a result of significant genotype by management interaction. The variety Wayu was the least yielding at separate and over locations. The soil acidity problem of test locations leads to a relative reduction in GYLD of genotypes 24.44, 25.48 and 46.69%, at Holetta, Watebecha Minjaro and Jeldu, respectively (Table 7) with a mean values of 32.4% (Table 6). The grain yield difference with and without lime application indicated the sensitivity of genotypes to soil acidity stress and the growing environment more contributed for GYLD in addition to genotype. In line with this result previously reported that, faba bean varieties gave better seed yield per plant on soil pH 7.7 than on soil pH 4.7 indicating that acid soil affects grain yield (Elliott and Whittington, 2009). Similarly, previously reported that liming significantly increased grain yield (Ouertatani *et al*., 2011) and 32% yield increment as a result of lime application reported in faba bean at pH 5.1 (Endalkachew *et al*., 2018), 26% in common bean (Hirpa *et al.,* 2013). Furthermore, faba bean varieties gave lower yield compared to the national average yield in Ethiopia due to strong acidic status of the soil (pH 5.1) (Degife and Kiya, 2016). Conversely, CS20DK was reported as the lowest yielder variety as compared to Gora, Walki and Geblecho (Degife and Kiya, 2016). Different authors reported that low yields in acid soil could mainly be either due to the deficiency of P, Ca and Mg and toxicity of Al, Fe and Mn (Dodd and Mallarino, 2005; Endalkachew *et al*., 2018) while grain yield increment on lime treated soil is related to reduction of toxic levels of soil Al^{3+} and H^{+} ions (Fageria *et al.,* 2012). Generally, genotypes showed inconsistent performance of seed yield across environment under both management regimes indicating the presence of environmental influence on the performance of the genotypes.

Disease Reaction Response of Genotypes

The overall mean performances of genotypes for chocolate spot disease reaction across locations with and without lime application were between 19.0 - 43.8% (for CS20DK and Cool-0031) and 26.2 - 43.7% (for Tumsa and NC58) with mean value of 30.6 and 34.4%, respectively. The genotypes CS20DK, Tumsa, Gebelcho, Numan EH06070-3, EH09002-1, EKLS/CSR02012-2-3, EH09007-4, EH07015-7, EH09031-4 and EK05037-4 showed less susceptibility to chocolate spot whereas Cool-0031, Cool-0025, Cool-0035 and EH08035-1 were susceptible with significant difference from other genotypes over locations with and without lime application (Table 6).

The result indicated the presence of higher chance of selecting disease resistant genotypes for disease stress which is one of the faba bean production problems in the study areas. Lime application brought a reduction in severity of chocolate spot which implied that stress condition aggravate disease susceptibility. Genotypes that become susceptible to chocolate spot disease gave lower grain yield as compared to genotypes relatively resistant. It was reported that soil acidity of growing environments expose faba bean to greater chocolate spot infection (Getachew *et al.,* 2005). Likewise, chocolate spot infection was higher in lower pH 4.8 than higher soil pH 7.0 thereby reduced plant vigor and consequently increased disease susceptibility (Elliott and Whittington, 2009). Furthermore, chocolate spot is the most widespread and destructive faba bean disease in Ethiopia, with estimated yield reductions of up to 68% on susceptible cultivars (Samuel *et al.,* 2010) and contributes to low productivity (Asnakech *et al*., 2016).

Conclusion

Currently, soil acidity becomes one of the major production constraints of faba bean in the highlands of Ethiopia. Therefore, this research was conducted to assess the effect of soil acidity on grain yield and other agronomic traits of faba bean genotypes and determine yield reduction encountered. A total of 50 faba bean genotypes were evaluated in randomized complete block design with three replications at Holetta, Watebecha Minjaro and Jeldu without and with lime application in 2017.

The combined analysis of variance (ANOVA) for each management over locations showed the presence of significant ($P\leq0.01$) differences among genotypes for all agronomic traits except number of seeds per pod. Similarly, the mean squares due to genotype × location were significant for all traits except number of pod per poding node under lime free condition and number of seed per pod in both cases. The significant differences among locations, the significant effects of G × L interactions on grain yield and other traits showed the differential response of genotypes over locations and managements and the test locations were different each other. Higher mean grain yield of 115.1 and 113.2 g/5 plants were obtained from Moti and CS20DK, respectively across locations with lime while 79.6 g/5 plants obtained from CS20DK without lime. The lowest (51.2) and highest (96.0 g/5plants) overall means grain yield were recorded at Jeldu without and with lime applications, respectively leading a relative yield reduction of 46.69% whereas the overall mean grain yield reduction were 32.4% as a result of soil acidity stress indicated the importance of lime application to obtain higher yield in each locations. Under lime free condition, the severity of chocolate spot disease was more severe than lime treated ones. Moreover, the great variability in grain yield performance and other traits of the 50 faba bean genotypes indicated a good potential to screening genotypes for soil acidity and to develop tolerant cultivar.

The results allowed concluding that lime application was a good management to increase yield of faba bean. However, due to unaffordable cost of lime by most smallholder farmers use of acid tolerant variety becomes the best option. Thus, the differential performance of genotypes over locations for both managements suggested the evaluation of genotypes over locations with and without lime application in a future breeding activity to identify genotypes tolerant to acid soils with minimal yield gap.

Conflict of Interests

The authors declare that they have no conflict of interests.

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