Advances in Crop Science and Technology

Tadele, Adv Crop Sci Tech 2021, 9:3

Research Article Open Access

Genetic Variability and Heritability of Agronomic Traits in Faba Bean (*Vicia faba l.*) Genotypes Evaluated under Soil Acidity Stress With and Without Lime Application

Mesfin Tadele[1*], **Wassu Mohammed**[2] **and Mussa Jarso**[1]

[1]*Holetta Agricultural Research Center, Ethiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia*

[2]*School of Plant Sciences, Haramaya University, P.O.Box 138, Dire Dawa, Ethiopia*

*__Corresponding author__: Dr. Mesfin Tadele, Holetta Agricultural Research Center, Ethiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia; E-mail: mesfintadele64@gmail.com

Received: February 04, 2021; **Accepted**: February 18, 2021; **Published**: February 25, 2021

Abstract

Faba bean is a multipurpose crop used as human food, animal feed, soil fertility restoration and income source for farmers and the country at large. However, the productivity of this crop is low as constrained by biotic and abiotic factors in which soil acidity takes the lions share in the highlands of Ethiopia. In order to estimate genetic variability on grain yield and related traits under soil acidity stress, 50 faba bean genotypes were evaluated in randomized complete block design with three replications at three locations, Holetta, Watebecha Minjaro, and Jeldu with and without lime application in 2017. The combined analysis of variance (ANOVA) over locations for each lime level showed the presence of significant differences among genotypes for agronomic traits except for the number of seeds per pod. The overall mean grain yields of tested faba bean genotypes were 62.93 (without) and 93.12 g/5plants (with lime). Hence, mean grain yield reductions of 32.34% were encountered due to soil acidity stress through a varied number of genotypes over locations. Computed genotypic coefficient of variations (GCV) ranged from 1.08%-23.05% and 0.94%-23.88% and phenotypic (PCV) from 1.20%-23.26% and 1.11%-24.07%, while heritability (H2) ranged from 24.63%-98.22% and 35.06%-98.45% and genetic advance as percent of the mean (GAM) from 2.0%-47.13% and 1.64%-48.89% without and with the lime application, respectively. The highest values for all components were recorded for 100 seeds weight (HSW), whereas the lowest values except for H2 were computed for days to maturity. Under both lime levels medium to high estimates of GCV, PCV, H2 and GAM were computed for HSW and the number of pod per plant and selection based on phenotypic expression of genotypes is possible to improve these traits. Selection based on mean would be successful in improving traits that have high H2. Furthermore, selection based on phenotypic performance of genotypes would be effective to improve traits that have high GAM coupled with high H2 estimates. Performances of variability components for different traits with and without lime application did not follow similar trends and higher values were recorded with lime as optimum environments allow for better genetic expression. Therefore, it is concluded that soil acidity affects the production and variability components of faba bean genotypes for yield, and yield related traits.

Keywords Heritability; Soil acidity; Variability components

Introduction

Faba bean is an important pulse crop produced throughout the world in which Ethiopia is the second largest producer next to the People's Republic of China. It is the leading pulse category of Ethiopia in terms of area coverage and volume of production sharing 0.44 million ha (27.34%) area coverage and about 0.92 million tons (30.95%) of the total pulse crops production (CSA, 2017/18). The crop is mainly cultivated in mid and high-altitude areas, with an elevation ranging from 1800-3000 meters above sea level [1].

Faba bean is used as a major source of protein rich foods in the developing countries for subsistence farmers and as animal feed in industrialized countries [2]. The crop is also a source of cash to the farmers and foreign currency to Ethiopia. Faba bean is widely used in rotation with cereals and other crops as it fixes atmospheric nitrogen. Realizing the potential importance of the crop, nationally 34 improved faba bean varieties have been released for production with appropriate management practices. Despite the diverse benefits and availability of high yielding faba bean varieties (>3 tha-1), the national average yield of faba bean about 2.11 tha-1 in Ethiopia (CSA, 2017/18), which very low compared to Egypt and United Kingdom 3.47 and 3.83 tha-1, respectively. However, the low average yield of this crop is attributed to its susceptibility to biotic (disease, weed and insects) and abiotic stresses such as waterlogging, low moisture stress, poor cultural practices and soil acidity. Currently, soil acidity is a major constraint of faba bean production in the highlands of Ethiopia as it associates with low nutrient availability. Hence, the productivity of acid soil needs to be improved as arable lands are shrinking and the demand of food and raw materials are increasing rapidly. Use of lime is a potential option for sustainable soil management for restoring soil health and fertility as a result it improves grain yield of faba bean. However, the use of acid tolerant varieties remains the first option and low cost due to unaffordable cost of lime for poor smallholder farmers [3-5].

Awareness about variability components, phenotypic (PCV) and genotypic coefficient of variation (GCV) helps to determine the type of breeding strategy to be followed. The magnitude of broad sense heritability (H2) also helps in predicting the behavior of succeeding generations by devising appropriate selection criteria and the genetic progress in the breeding program indicated by genetic gain expected from selection of the top 5% of the genotypes, as a percent of the mean (GAM). The high PCV and GCV is an indication of the less influence of environmental factors in the expression of traits and the higher chance to improve the traits through selection breeding. While, the higher PCV values than GCV implies greater influence of environmental factors for the phenotypic expression of these traits that make difficult or practically impossible to exercise selection based on phenotypic performance of the genotypes to improve the traits. Higher PCV values than GCV were reported for days to 90% maturity and plant height; for days to 50% flowering, days to 90% maturity and plant height; for days to 50% flowering and plant height [6].

Traits with high to moderate H2 respond moderate to high for phenotypic selection. High estimates of H2 were reported for hundred seed weight and grain yield in faba bean genotypes at varied environments and a number of genotypes. Also, high H2 was reported for chocolate spot disease. High GAM in faba bean was reported for number of pod per plant while low GAM for 100 seeds weight and grain yield. Considering both the GAM and H2 of traits together helps to determine how much progress can be made through selection and selection based on phenotypic performance of genotypes would be effective to improve traits that have high GAM coupled with high H2 as high H2 will not always be associated with high GAM.

The values of H2 and GAM did not show a similar trend under favorable and stressful environments. Favorable environments show higher estimates of H2 and GAM values than stress environment as stressed condition masked H2 and GAM due to a greater genotype by environment interaction. Genetic variability and H2 of faba bean genotypes for grain yield and other agronomic traits under soil acidity stress and non-stress environment are scanty. Therefore, genetic variability and H2 of traits under various environments is very important for breeders as the genetic advance achieved in each breeding cycle depends on how the additive gene effect is beneficial. Hence, this study was conducted to estimate genetic variability on grain yield and related agronomic traits of faba bean under soil acidity stress and non-stress environments [7,8].

Materials and Methods

Description of the experimental site

The experiment was conducted at three locations in the central highlands of Ethiopia during 2017 main cropping season under rain-fed condition. Descriptions of the experimental sites are given in Table 1.

Location	Longitude and latitude	Altitude (masl)	Annual rain fall (mm)	Temperature (C)	
				Min	Max
Jeldu	090 16'N, 380 05'E	2800	1200	2.06	16.9
Holetta	090 00'N, 380 30'E	2400	1072	6.6	24.1
Watebecha Minjaro	090 05'N, 380 36' E	2565	1100	8.7	23.3

Table1: Description of experimental locations.

Treatment and experimental design

A total of 50 faba bean genotypes were used of which 22 were released varieties and 28 pipe line genotypes. The materials were collected from Holetta and Kulumsa Agricultural Research Centers. Treatments were arranged in RCBD with three replications with and without lime using adjacent plot technique. The spacing between blocks was 2 m and within blocks 1.5 m. The experimental plots consisted of one row of 4 m length and 0.4 m row spacing continuously and 0.1 m between plants. Blended Fertilizer NPS was applied at the rate of 121 kg/ha at planting. One faba bean variety (Dosha) was planted as a border row in each block to avoid border effect. Weeding and other cultural practices were done as per the recommendations.

Data collection

Data were collected either from whole plot or from five sample plants from each plot. Days to 50% flowering, days to 90% physiological maturity, grain filling period, 100 seeds weight and chocolate spot disease severity were collected from whole plot. Plant height, number of poding nodes per plant, number of pods per poding node, number of pods per plant, number of seeds per pod, grain yield, economic growth rate and grain production efficiency were collected from five random sample plants from each plot. The mean values of these samples were utilized to estimate the performance of each genotype for the traits under consideration.

Data analysis

Homogeneity test

Before proceeding with the analysis of variance for each variable, tests were made for homogeneity of error variance using the F-max method based on the ratio of the larger mean square of error (MSE) from the separate analysis of variance to the smaller mean square of error (Gomez and Gomez, 1984).

Data were subjected to analyses of variance (ANOVA) and combined ANOVA over the environment for RCBD was performed using the SAS program. The total variability for the traits was quantified using pooled analyses of variance over three locations with and without lime separately using the following model:

Results and Discussion

Soil chemical properties of test locations

The physico-chemical properties of the soils from the three test locations showed a very strong acidic condition for all test locations with the pH values 4.49 to 4.94 (Table 2). It was observed little modification of pH and other soil parameters at each location in the lime treated blocks but the soil is still under very strong acidic category (pH<5.5) due to reduced basic cations. This may indicate that lime improves the chemical properties of soils but it needs more time to bring to the required level of change. Lime is slow acting, of long duration. At Jeldu the values of exchangeable acidity, Al3+, Mn and other micronutrients were high and low for K, Ca, Mg and Na. The levels of exchangeable cations were increased at lime treated plots except Na+ while decreased micronutrients. The level of soil P was increased at harvesting time except at Watebecha Minjaro (Table 2). All the three locations have clay soil and the high clay content at Watebecha Minjaro leads to high buffering capacity because the buffering capacity of the soil increases as the clay content increases; as a result high amount of lime will be required to alleviate acidity and increase the productivity of acid sensitive crops like faba bean [9,10].

Parameter		Holetta		Watebecha Minjaro		Jeldu	
		Before	After	Before	After	Before	After
Texture (%)	Clay	47.5	-	70	-	40	-
	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	4.8
TN (%)		0.14	0.14	0.14	0.21	0.29	0.3
Avail. P		7.96	9.57	12.74	12.74	13.17	15.14
CEC		18.18	19.04	17.38	18.8	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	0.5	0.58
Ex.Ca (ppm)		9.43	10.89	9.3	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	3.7	3.12	4.95	3.85
Ext.Fe (ppm)		180.77	164.45	245.7	231.07	341.13	327.43
Ext.Zn (ppm)		0.83	0.68	1.15	1.1	4.42	2.67
Ex. Acidity		1.01	0.61	0.98	0.62	3.36	1.3
Bulk density(gcm-3)		1.26	----	1.12	-----	1.05	----

Table 2: Parameters of experimental locations.

Applied lime improved the physico-chemical properties of acid soil and improved the availability of P as it fixed in acid soil. Liming reduces soil acidity, Al toxicity and increases P availability, which have a role in root development and energy transfer in nodule formation. Similarly, liming reduced Al3+ and H+ ions as it reacts with water leading to the production of OH-ions to form Al (OH)3 and H2O and the precipitation of Al3+ and H+ by lime causes the pH to increase which enhances microbial activity and nutrient availability.

Analysis of variance

The pooled analysis of variance over three locations with and without lime indicated the presence of significant differences ($P \leq 0.01$) among genotypes and locations for most of the traits studied like days to 50% flowering (DF), days to 90% maturity (DM), grain filling period (GFP), plant height (PH), number of poding node per plant (PNPP), number of pod per plant (PPP), number of pod per poding node (PPPN), chocolate spot (CS), 100 seed weight (HSW), grain yield (GY), grain production efficiency (GPE) and economic growth rate (EGR). Conversely, number of seed per pod (SPP) was not significantly different under both lime levels. This may show lack of sufficient genetic variation for these traits among the tested genotypes. The highly significant differences for GY with and without lime application indicated the existence of variations among genotypes under acid soil and limed condition. Similarly, a previous study on Ethiopian faba bean germplasm accessions also indicated that SPP often showed non-significant differences among genotypes; significant for DF, PH, PPP and HSW, significant effect ($P \leq 0.05$) of locations for HSW.

The two way interaction G x L had significant effects on most of the traits both with and without lime application except for PPPN and SPP without lime and for SPP with. The significant effects of G x L interaction indicated that the genotypes had differential performance over locations for agronomic traits and the effects of experimental plots with lime and without lime applications also exerted differential effects over locations on the performance of genotypes. Due to performance inconsistency of genotypes over locations such as with significant effects of G x L interactions, selection of genotypes for 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. This result partially agrees with the report for significant difference for PH and GY and non-significant difference for PPP, SPP and HSW as a result of lime application on acid soils of western highlands of Ethiopia. Many reports also showed the presence of significant effects of G x L for GY in faba bean in different sets of environments in Ethiopia. Contrary to the current result a non-significant interaction effect for chocolate spot disease resistance was reported due to environmental variance [11-14].

The overall mean grain yield of tested faba bean genotypes was 62.93 without and 93.12 g with lime that resulted a mean grain yield reduction of 32.34% due to soil acidity stress through varied number of genotypes over locations. Moreover, the result suggested the importance of lime for yield improvement. Soil acidity associates with low nutrient availability and major yield-limiting factor for pulse production.

Estimates of heritability and expected genetic advance

The broad sense heritability (H2) values ranged from 24.63% to 98.22% and 35.06% to 98.45% and the genetic advance as percent of mean (GAM) values ranged from 2.0% to 47.13% and 1.64% to 48.89% without and with lime, respectively, over locations. Low and high H2 values were calculated for CS and HSW, respectively, with and without lime applications over locations. Also low and high GAM computed for DM and HSW, respectively, under both managements. This result implied that H2 and GAM values were higher under stress free condition than stressed environments. In contrary to the current result moderate GAM were reported for number of seeds per plant (12.32%) and high for GY (35.46%).

It was suggested that the importance of considering both the genetic advance and heritability of traits rather than considering separately in determining how much progress accompanied with high to moderate genetic advance was observed for number of poding node per plant, number of pod per plant, hundred seed weight and grain yield under both managements. This indicated that these traits were highly heritable and selection of high performing genotypes is possible to the improvement of the traits. Thus, selection based on phenotypic performance of genotypes would be effective to improve traits that have high genetic advance as percent of mean coupled with high heritability estimates. Likewise, traits with high to moderate heritability may respond moderate to high for phenotypic selection. The high H2 and GAM value of traits indicates the high possibility of transferring traits from parents to the next progeny. Many authors also reported high estimates of broad sense heritability for hundred seed weight and grain yield in faba bean genotypes at varied environments and number of genotypes. In agreement with this result high GAM were reported for number of pod per plant. In contradict to this finding low GAM was reported for hundred seed weight and grain yield.

Low GAM values were calculated for days to 50% flowering, days to 90% maturity, grain filling period and plant height under lime and additionally for chocolate spot without lime applications over locations. Low heritability coupled with low GAM was calculated for chocolate spot without lime application over locations. The result indicated that low heritability values for chocolate spot limit possibility of improvement for this trait through selection. In contradict to this result high heritability for chocolate spot disease was reported. The probable reason for the variation of traits low to high GAM and vice versa with this result and others were due to the difference in the genetic makeup of the evaluated genotypes [7,14].

Generally, medium to high estimates of GCV, PCV, H2 and GAM were computed for hundred seed weight and number of pod per plant under both lime levels. Traits with high PCV, GCV, H2 and GAM indicated that these traits are controlled by genetic factor and a higher chance for improvement of these traits through selection. The present results showed that heritability and genetic advance values did not show a definite trend with and without limed applications. For most of the traits heritability under lime free condition is less than limed condition while genetic advance is in contrasting direction. It was reported that favorable environments show higher estimates of heritability and genetic advance values than unfavorable environment. Hence, heritability and genetic advance value may be masked due to a greater genotype by environment interaction under unfavorable conditions. Likewise, it was reported that heritability and genetic advance values varied in the presence or absence of phosphorus in chick pea. In contrary, to the current result and the reports of others, heritability and genetic advance values were influenced by the nature of the genetic material and not evaluated by the growing environment [8,12,15-18].

Conclusion

This research was conducted to estimate genetic variability in faba bean genotypes under soil acidity stress and non-stress conditions. As soil acidity becomes one of the major production constraints of faba bean in the highlands of Ethiopia. As a result of this stress the tested genotypes encountered a mean grain yield reduction of 32.34%; suggesting the importance of lime application on acid soil for yield improvement.

The computed variability components were ranged between 1.08%-23.05% and 0.94%-23.88% for GCV, between 1.20%-23.26% and 1.11%-24.07% for PCV, between 24.63%- 98.22% and 35.0%-98.45% for H2 and between 2.0%-47.13% and 1.64%-48.89% for GAM without and with lime application, respectively. The result indicated that the performance of variability components will not follow similar trends for different traits with and without lime. However, for all variability components higher values were recorded in the presence of lime. The results, allowed to conclude that the presence of variability in faba genotypes with wide genetic distance both under lime and without lime application which is a good opportunity to identify genotypes of interest. The differential performances of traits evaluated with and without lime application indicate a future breeding activity to identify soils acid tolerant genotypes.

Acknowledgments

Authors are especially grateful to acknowledge staff members of Holetta Agricultural Research Center, particularly highland pulse breeding program and soil laboratory unit for their valuable contribution for successful accomplishment of this research work. We are thankful to the Ethiopian Institute of Agricultural Research for financial support.

Conflict of Interests

The authors declare that they have no conflict of interests.

References

1. Abebe Z, Tolera A (2014) Yield response of faba bean to fertilizer rate, rhizobium inoculation and lime rate at Gedo highland, western Ethiopia. Glob J Crop Soi Sci Plant Breed 2: 134-139.
2. Buni A (2014) Effects of liming acidic soils on improving soil properties and yield of haricot bean. J Environ Anal Toxicol 5: 1-4.
3. Alemu L, Tekalign M, Wassie H, Hailu S (2016) Assessment and mapping of status and spatial distribution of soil macronutrients in Kambata Tembaro Zone, Southern Ethiopia. Adv Plants Agric Res 4: 1-14.
4. Allard RW (1960) Principle of plant breeding. John Wiley and Sons Inc.
5. Ashenafi M, Mekuria W (2015) Effect of Faba Bean (*Vicia faba L.*) Varieties on yield attributes at Sinana and Agarfa districts of Bale Zone, Southeastern Ethiopia. Jordan J Biol Sci 4: 281-286.
6. Asnakech T, Derera J, Sibiya J, Asnake F (2016) Participatory assessment of production threats, farmers' desired traits and selection criteria of faba bean (Vicia faba L.) varieties: Opportunities for faba bean breeding in Ethiopia. Indian J Agric Res 50: 295-302.
7. Asnakech T (2014) Genetic analysis and characterization of faba bean (*Vicia faba*) for resistance to chocolate spot (Botrytis fabae) disease and yield in the Ethiopian highlands.
8. Bakhiet MA, El-Said RA, Raslan MA, Abdalla NG (2015) Genetic variability, heritability and correlation in some faba bean genotypes under different sowing dates. World Appl Sci J 33: 1315-1324.
9. Ceccarelli S, Grando S (1996). Importance of specific adaptation in breeding for marginal conditions. Barley research in Ethiopia: Past work and future prospects. Addis Ababa: 34-58.
10. CSA (Central Statistical Agency of Ethiopia) (2017/18). Report on Area and Production of Major Crops (Private peasant holdings, meher season). Addis Ababa, Ethiopia 1: 10-29.
11. Duc G, Bao S, Baum M, Redden B, Sadiki M, et al. (2010) Diversity maintenance and use of Vicia faba L. genetic resources. Field Crops Res 115: 270-278.
12. Ejigu E, Wassu M, Berhanu A (2016) Genetic variability, heritability and expected genetic advance of yield and yield related traits in common bean genotypes (Phaseolus vulgaris L.) at Abaya and Yabello, Southern Ethiopia. Afr J Biotechnol 17: 973-980.
13. El-Badawy NF, Abo-Hegazy SR, Mazen MM, El-Menem HA (2012) Evaluation of some faba bean genotypes against chocolate spot disease using cDNA fragments of chitinase gene and some traditional methods. Asian Journal of Agricultural research, 6: 60-72.
14. Endalkachew F, Kibebew K, Asmare M, Bobe B (2018) Yield of faba bean (Vicia faba L.) as affected by lime, mineral P, farmyard manure,

compost and rhizobium in acid soil of lay gayint district, northwestern highlands of Ethiopia. Agric Food Secur 7: 1-11.

15. Fageria NK, Baligar VC, Melo LC, de Oliveira JP (2012) Differential soil acidity tolerance of dry bean genotypes. Commun in Soil Sci Plant Anal 43: 1523-1153.
16. FAOSTAT (2018) Statistical database of agricultural production.
17. Follet RH, Murphy LS, Donahue RL (1981) Fertilizers and soil amendments. New York Prentice Hall Incorporation.
18. Jarso M, Keneni G (2009) Comparison of Two Approaches for Estimation of Genetic Variation for Two Economic Traits in Faba Bean Genotypes Grown under Waterlogged Verisols. East Afr J Sci 3: 95-101.