

Original Research Article

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Performance Assessment, Genetic Variability, Heritability, Genetic Advance and Correlation Coefficient Analysis for Yield and Some Agro -Morphological Traits in Faba Bean (*Vicia faba* L.) Genotypes in the Northern State, Sudan

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ABSTRACT

Field experiment were conducted during three successive winter seasons 2013/14, 2014/15 and 2015/16 at Merowe in the Northern state of Sudan, to study genetic variability, heritability, genetic advance, genetic advance as percent of mean and correlation coefficient for seven quantitative traits of faba bean. The field was laid down in a randomized complete block design with three replications. Analysis of variance revealed highly significant differences ($P \leq 0.001$) among the genotypes for all the morphological traits measured. All the tested genotypes gave significantly heavier seed weight than the check. High phenotypic coefficient of variation (PCV) coupled with high genotypic coefficients of variation (GCV) were observed for 100 – seed weight, plant height, days to 50% flowering and number of pods per plant, which indicates the presence of high genetic variation. The broad sense heritability estimates were high for all the characters. High heritability coupled with high genetic advance as percent of mean was observed for 100 – seed weight and number of seeds per pod and days to 50% flowering, indicating operation of additive gene action and the ample scope for improvement in these traits through simple selection. Significant positive correlations were detected between seed yield and each of number of pods per plant and plant height. These findings indicated that selection for number of pods per plant and plant height would be accompanied by high yielding ability under such conditions.

Keywords

Faba bean, Genetic variability, Heritability, Correlation, Seed yield.

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Introduction

Faba bean (*Vicia faba* L.) ($2n=12$), which is also known as broad bean, horse bean or field bean, belongs to the family leguminaceae. Its origin is still argued (Duc, 1997), but geographically it was the Near East. According to seed size faba bean is divided into three main types: major type, which is characterized by large seeds and originated in South Mediterranean countries and China; equina or medium-seed type, which is

originated in Middle East and North Africa; and minor or smallest-seed type, which is originated in Ethiopia (Witcombe, 1981). The main producing countries for Faba bean (*Vicia faba* L.), depending on acreage are Morocco, Tunisia, Algeria, U.K, Egypt, Ethiopia, China, Australia and Sudan (FAO, 2000). Faba bean is the most important food legume in the Sudan. It constitutes the main dish on the breakfast and dinner tables for a

large sector of the population, especially low income groups in the urban areas. In addition, it contributes to soil fertility through biological N₂-fixation. The crop is also an important source of income for farmers in northern Sudan. In some years the production falls below the demand and, thus, like in 1994, a sizeable amount needs to be imported to bridge the gap. The area under faba bean cultivation has increased from about 7,450 ha in 1965 to about 30,000 ha in the 1994/95 season. The main production zone of the crop is the Northern State where more than 70% of crop is produced, and the Nile State which produces about 20% of the crop. Small amounts are produced in Khartoum State, central Sudan and Jebel Marra area in western Sudan (Salih *et al.*, 1995).

The genetic improvement of crop desired traits depends on the nature and magnitude of genetic variability and interactions involved in the inheritance of these traits which can be estimated using experimental design techniques. Many researchers studied heritability for seed yield, yield components and the other agro-morphological traits in faba bean. Seed yield is a complex trait that is quantitatively inherited with low heritability value (Bond, 1966).

The low heritability and consequent limited genetic advance for yield in response to selection had led many scientists to search for characters which are associated with yield but which are more highly heritable (De Pace, 1979). Among secondary yield component significant positive correlation between seed yield and its component was reported in number of branches per plant by (Sindhu *et al.*, 1985). Significant negative correlation was reported between seed yield and plant height by (Abdelmula, 2002). Also, significant positive correlation was observed between seed yield and maturity, (Abdelmula, 2002).

The present study aimed to estimate the genetic variability, heritability and genetic advance for yield and yield components of four faba bean genotypes and correlation coefficients between seed yield and other traits were also investigated.

Materials and Methods

Experimental site

The data of this research experiment were collected from a study conducted over three consecutive seasons (2013/14, 2014/15 and 2015/16 during the winter season, at Merowe (The experimental farm of Merowe research station, Northern state of Sudan), which is located (Latitude: 18° 27' 0" N, Longitude: 31° 49' 59" E, Elevation: 258 meter.

Genetic materials

The genetic material used in this study comprised a total of 4 faba bean genotypes, which were selected from the national legume breeding program of the Agricultural Research Corporation (ARC), Sudan. Three genotypes are advanced breeding lines and one released faba bean variety; SM - L was included as check. The pedigree of the four faba bean genotypes used in the study were shown in Table 1.

Cultural practices

Land preparation and sowing

The field prepared by disk ploughing, harrowing and leveling. After two days from leveling, the land was ridged. Sowing was on both sides of the ridge at a rate of two seeds per hole with intra row spacing of 20 cm between holes. The plot size was consisted of 5 ridges, 5 m long spaced 0.6 m. The sowing dates of the three seasons were usually within the third week of November. The plants were

irrigated equally at 12 – 14 days interval. The crop took a total of 10 irrigations during the growing period. Nitrogen was added as urea (46%) at a rate of 43 kg N/ha in the 3rd week from sowing. Weeds populations were kept to minimum by hand removal during the first month from sowing. In the first and third season, the crop was sprayed with folimat against the aphid (*Aphis fabae* sp.), when it appeared in the field. Seed yield was assessed from a net area of 9 m².

Experimental layout

The experiments were arranged in a randomized complete block design with three replications.

Parameters measures

During the three seasons, observations were taken on ten plants randomly selected in a plot. Data were recorded on the following vegetative and reproductive characters:

Days to 50% flowering: it was recorded as the number of days from sowing to the date when 50 % of the plants in a plot bore at least one flower.

Days to 90 % maturity: it was estimated as days from sowing to the date when 90% of the leaves in the row turned yellow and green pods became black.

Plant height: it was measured from ground level to the top of the plant at maturity. An average of ten plants was recorded in centimeters (cm).

Number of pods per plant: pods of 5 randomly taken plants were counted to estimate number of pods per plant.

Number of seeds per pod: it was calculated by dividing the total number of seeds per plant

(of the sample) by the total number of pods per plant.

100 - Seed weight (g) Hundred seeds were taken randomly from each plot and weighed using a sensitive balance namely, Sartorius.

Seed yield (kg ha⁻¹): At maturity, plots were harvested by hand and seed yield kg ha⁻¹ was determined.

Statistical analysis

Separate ANOVA in each environment was performed for grain yield and related traits before running the combined analysis.

The mean separation was done using Duncan's Multiple Range Test (DMRT) for the different characters collected from the field experiments at the level of $p \leq 0.05$. The correlation analysis was worked out according to the methods described by (Dewey and Lu, 1959) and (Falconer, 1964).

Phenotypic and genotypic variability

The variability present in the genotypes was estimated by simple measure, namely range, mean, standard error, phenotypic and genotypic variance and coefficient of variation. The phenotypic and genotypic variance and coefficient of variation were estimated according to the methods suggested by (Burton and Devane, 1953) as follows:

$$\sigma^2_g = (Mg - Me) / r$$

Where:

$$\sigma^2_p = \text{Phenotypic variance}$$

$$\sigma^2_g = \text{Genotypic variance}$$

$$\sigma^2_e = \text{Environmental (error) variance (Error mean square)}$$

Mg = mean square of genotypes

Me = mean square of error,

r = Number of replication

Phenotypic coefficient of variation, PCV = $(\sqrt{\sigma^2_g / x}) \times 100$

Genotypic coefficient of variation, GCV = $(\sqrt{\sigma^2_p / x}) \times 100$

Where x= population mean

Estimate of heritability

Heritability (H²) in broad sense for all characters was computed using the formula adopted by (Allard, 1960) as:

$$H^2 = (\sigma^2_g / \sigma^2_p) \times 100$$

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where:

σ^2_g = genotypic variance

σ^2_p = phenotypic variance

σ^2_e = error variance

Estimation of expected genetic advance

Genetic advance (GA) for each character was computed using the formula adopted from (Johnson *et al.*, 1955) and (Allard, 1960).

GA = (k) (σ_p)^{*} (H²), and

GA (as % of the mean) = $(GA / \bar{x}) \times 100$

Where, k= selection differential (k = 2.06 at 5% selection intensity)

σ_p = phenotypic standard deviation

H² = heritability (Broad sense)

\bar{x} = Grand mean

Results and Discussion

Analysis of variance and genotypes mean performance

Yield related traits

Mean squares of 7 traits of the four faba bean genotypes in the three environments (seasons) are shown in (Table 2). There were significant differences among genotypes, seasons and their interaction ($P \leq 0.01$) for most of the studied traits.

Results presented in (Table 3), showed highly significant differences for average number of days to 50% flowering, days to 90 % maturity and plant height (cm). The genotype Turkey was the earliest as it needs 97 days to reach maturity. On the other hand the two genotypes; Giza-843 and Otono were the latest as they required 109 and 112 days to mature, respectively.

The genotypes; Turkey and Giza-843 gave 20 and 13 pods per plant, respectively compared to the check SM-L (18), while Otono resulted in the lowest number of pods (8). The genotype Giza-843 gave the highest number of pods per plant (Table 4) which may be one of the factors contributing to its outstanding performance in seed yield. The highest number of seeds per pod was given by the genotype Otono and the check. Whereas, the genotype Turkey recorded the lowest number of seeds per pod.

Seed yield and 100 - seed weight

The results presented in (Table 4), showed the average 100 - seed weight (g) and seed yield (kg ha^{-1}). Significant differences were

detected among the tested genotypes, season and their interactions for both characters. Also, (Waly and Abd El – Aal, 1986; Hanna, 1995; Salem, 1996); Abdel – Rahman, 2009 and Hassan, 2006) reported considerable variation among faba bean genotypes tested.

The three genotypes tested produced significantly heavier seed weight than the

check. The heaviest seed weight was obtained by Turkey (121 g) followed by Otono (98 g) and Giza-843 (68 g.). The genotype Giza-843 gave seed yields better to the check and surpassed the check (SM - L) by 2.8%, the other two genotypes; Turkey and Otono, which gave relatively seed yield (3179 kg/ha) and (2567 kg/ha), respectively less than the check.

Table.1 The pedigree of the four faba bean genotypes used in the study

No.	Genotype	Pedigree
1	Turkey	(Single plant selection from introduced unknown source grown at Dongola fields).
2	Giza – 843	(BPL710×R.S.P.S line to Orobanche from Giza429)
3	Luz de Otono	(Introduced from Spain)
4	SM – L (check)	(Released commercial variety)

Table.2 Mean squares of yield and some yield components of 4 faba bean genotypes grown during three seasons 2013/14, 2014/15 and 2015/16

Traits	Season (d.f = 2)	Genotype (d.f = 3)	Seas. X geno. (d.f = 6)	Pooled error (d.f = 18)
Days to flowering	101.694***	473.139***	41.583***	0.519
Days to maturity	239.694***	162.074***	5.657*	2.269
Plant height (cm)	533.581*	1110.585***	52.209n.s	60.243
No. of pods/ plant	181.308***	251.249***	36.462*	19.353
No. of seeds/pod	0.464n.s	4.606***	0.138n.s	0.142
100-seed weight	1427.111***	7400.407***	82.519*	29.509
Seed yield	2409633.444*	143353.667***	111512.556*	44110.593

* and *** Significant at 0.05 and 0.001 levels of probability, respectively.
n.s = non - significant difference at 5% probability level.

Table.3 Average performance for some Vegetative traits of 4 faba bean genotypes in the studies combined over three seasons

Genotype	DF	DM	PH
Turkey	37	97	87
Giza - 843	43	109	102
Luz de Otono	54	112	93
SM – L (check)	46	104	112
Mean	45	102	98
S.E_±	0.240***	0.502***	2.587***
C.V (%)	1.5	1.4	7.8

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm).
*** Significant at 0.001 probability level.

Table.4 Seed yield (kg ha⁻¹) and its primary components of 4 faba bean genotypes in the studies combined over three seasons

Genotype	SY	NPP	NSP	HSW
Turkey	3179	13	2.0	121
Giza – 843	3428	20	2.5	68
Luz de Otono	2567	8	3.7	98
SM – L (check)	3330	18	2.9	58
Mean	3126	15	2.8	86
S.E _±	70.0***	1.466***	0.125***	1.810***
C.V (%)	6.7	28.8	13.2	6.2

SY: seed yield (kg ha⁻¹), NPP: Number of pods per plant, NSP: Number of seeds per pod, HSW: hundred seed weight (g).

*** Significant at 0.001 probability level.

Table.5 Estimation of genetic parameters for different quantitative traits in faba bean genotypes combined over three seasons 2013/14, 2014/15 and 2015/16

Traits	δ ² _g	δ ² _{ph}	GCV (%)	PCV (%)	h ² (%)	GA	GAM (%)
Flowering	47.95	61.86	173.11	196.62	77.51	18.41	40.91
Maturity	17.37	19.51	104.19	110.42	89.03	9.80	9.60
Plant height	117.59	141.68	271.09	297.57	82.99	26.92	27.46
Pods / plant	23.86	38.16	154.43	197.67	62.52	16.10	107.33
Seeds / pod	0.496	0.557	17.60	18.65	89.04	1.62	57.85
100-seed weight	513.09	543.88	566.28	583.03	94.33	49.46	57.51

δ²_g = Genotypic variance, δ²_{ph} = Phenotypic variance, PCV = Phenotypic coefficient of variance, GCV = Genotypic coefficient of variance, h² (%) = Broad sense heritability, GA = Genetic advance, GAM = Genetic advance as percent of mean.

Table.6 Correlation coefficients among studied traits of faba bean genotypes, combined over three seasons 2013/14, 2014/15 and 2015/16

Traits	Flowering	Maturity	Plant height	Pods/plant	Seeds/pod	100 – sw
Maturity	0.848**					
Plant height	0.211	0.251				
Pods/plant	-0.473*	-0.146	0.679**			
Seeds/pod	0.997**	0.810**	0.193	-0.511		
100 – sw	-0.269	-0.425*	-0.967**	-0.707**	-0.235	
Seed yield	-0.714**	-0.438*	0.496*	0.950**	-0.739**	-0.480*

* Significant at p ≤ 0.05 and ** Significant at p ≤ 0.01.

Genetic parameters

Estimates of phenotypic and genotypic variances, phenotypic coefficient of variance, genotypic coefficient of variance, broad sense

heritability (h²), genetic advance and genetic advance as percent of mean are presented in Table 5. The phenotypic coefficients of variation (PCV) were generally higher than the genotypic coefficients of variation (GCV)

for all traits studied, indicating more or less equal genetic effect on the trait. Here, the environmental effect is generally negligible, which is an agreement with the observation of (Babar *et al.*, 2002). Broad sense heritability (h^2) estimates were generally high to moderate for all of studied traits. The highest estimates of broad sense heritability was inscribed as 94.33 % for 100 – seed weight, 89.04% for number of seeds per pod and 89.03% for days to 90% maturity. High estimates of heritability indicated that selection based on mean would be successful in improving these traits. The lowest value of (h^2) was observed for number of pods per plant with 62.52%. The moderate value of heritability for days to 50% flowering and seed yield were 77.52% and 76.48%, respectively. In agreement with the results of this work, (Toker, 2004) recorded high to moderate heritability for traits containing days to flowering and seed yield and low heritability for number of pods per plant. The results of this research are also similar to the results of Bora *et al.*, (1998), Kalia and Sood (2004) Alghamdi (2007) and Ibrahim (2010).

Number of pods per plant was recorded the highest genetic advance as percent of mean 107.33% followed by number of seeds per pod 57.85% and 100 – seed weight 57.51%. The moderate genetic advance as percent of mean was recorded by days to 50% flowering (40.91%) followed by seed yield (31.87%). On the other hand, the days to 90% maturity recorded the lowest genetic advance as percent of mean.

Correlation coefficient analysis

Simple correlation coefficients among the examined characters are shown in Table 6. Obtained linear relations among investigated characters (correlations) are insufficient in used faba bean genotypes in our research. However, Number of pods per plant could be

useful selection criteria for this study because jointed or bilateral relations with this character have been given almost biggest value. Significant positive correlation values were detected between seed yield and number of pods per plant (0.950**) and plant height (0. 0.496*). Similar results were also obtained by (Bora *et al.*, 1998). There is strong association of these characters can be give importance during selection to improve the yield potential of the crop. While there are negative and highly significant phenotypic relationships for seed yield and seeds per pod, days to 50% flowering, hundred seed weight and days to 90% maturity. Positive and highly significant correlation was observed between number of seeds per pod and days to 50% flowering (0.997**) and with days to 90% maturity (0.810**). There is a negative but significant correlation was observed between 100 – seed weight and plant height (-0.967**), pods per plant (-0.707**) and days to 90% maturity (-0.425*). Plant height had a positive and highly significant correlation with pods per plant (0.679**). Days to 50% flowering had recorded positive and highly significant correlation with days to 90% maturity (0.848**). Thus, correlation helps breeders to identify the characters that could be used as selection criteria in breeding programmed. These results suggested that improvement of grain yield in faba bean is linked with these traits (number of pods per plant and plant height) and selection of these traits might have good impact on yield.

The mean squares due to seasons were high significant for all traits studied except number of seeds per pod. Similarly, except the plant height and number of seeds per pod, the mean squares due to season x genotype were significant for all traits. The mean squares due to genotypes were highly significant for seed yield, indicating existence of sufficient genetic variability for seed yield. Genotypic coefficient of variation (GCV) values were

lower than phenotypic coefficient of variation (PCV) values for all the traits which reflect the influence of environment on the expression of traits. High genotypic coefficient of variation observed for 100 - seed weight followed by plant height. High heritability estimates were recorded for 100 – seed weight (94.33 %) and number of seeds per pod (89.04%). The result of genetic advance as percent of mean an increase of 9.60% to 107.33% magnitude made by selection. Positive and highly significant correlation were observed for seed yield with number of pods per plant and plant height. So, it is concluded that these two traits may be considered as the selection criteria for the improvement of seed faba bean.

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