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Research paper

The Correlation and Path Coefficient Analysis for Yield and Some Yield Components of Faba Bean (*Vicia faba* L.) Genotypes in Northern Sudan

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ABSTRACT

The present study was carried out for two consecutive seasons; 2010/11 and 2011/12 at Merowe Research Farm to investigate the correlation coefficient and path coefficient with two released faba bean varieties; Basabeer and Hudeiba 93 as checks and ten advanced crosses. Field experiments were conducted in a randomized complete block design with three replications. Data were collected on number of days to 50% flowering, number of days to 90% maturity, plant height (cm), number of pods per plant, number of seeds per pod, hundred seed weight (g) and seed yield kg ha^{-1}. Statistical analysis was based on the combined data of the two seasons. Significant differences were observed among the tested genotypes for all traits. The genotypes: C.28\02, C.19\02, C.9\02 and C.98\02 produced significantly the highest seed yield and surpassed the first check (BB-7) by 16.5%, 15.1%, 9.6% and 8.0% and the second check (H.93) by 14.9%, 6.7%, 6.1% and 4.3%, respectively. Positive and highly significant relationships were observed for seed yield with hundred seed weight, number of seeds per pod and plant height. Direct and indirect effects of days to 50% flowering, number of days to 90% physiological maturity, plant height (cm), number of pods per plant, number of seeds per pod and hundred seed weight (g) upon seed yield were determined. Days to 90% physiological maturity, hundred seed weight, number of seeds per pod and plant height had the highest positive direct effects on seed yield (kg ha^{-1}). These traits could be used as selection criteria in faba bean breeding program.

Keywords: *Correlation, faba bean, path coefficient, seed yield, Sudan*

تحليل الارتباط ومعامل باث للإنتاجية وبعض مكوناتها لطرز من الفول المصري في شمال السودان

فتح العليم احمد حمزة[1] وجمال الخير خليفة[2]

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اجريت هذه الدراسة لموسمين متتاليين 11/2010 و12/2011 في مزرعة محطه بحوث مروي للتحقق من معامل الارتباط ومعامل المسار لاثنين من الاصناف المجازة وهما بسابير وحديبة 93 بالإضافة الى عشرة سلالات متقدمة. التجارب رتبت في تصميم القطاعات العشوائية الكاملة بثلاثة مكررات. البيانات المأخوذة هي عدد ايام الازهار 50 %، عدد ايام النضج الفسيولوجي 90 %، طول النبات، عدد القرون في النبات، عدد الحبوب في القرن، وزن ال 100 حبه، الغلة الحبيه كجم/هكتار. التحليل الإحصائي تم بناءً على جمع البيانات للموسمين. اوضحت النتائج وجود فروق معنوية بين السلالات في كل الصفات المدروسة. متوسط الإنتاجية للموسمين اوضحت ان اربعة من التهجينات وهي C.28/02، C.19/02، C.9/02، C.98/02 اعطت اعلى انتاجية وتفوقت على الشاهد الاول بسابير بنسبة 16.5، 15.1، 9.6، 8 % على التوالي وعلى الشاهد الثاني حديبه 93 بنسبه 12.9، 6.2، 5.7، 4 % على التوالي. لوحظ ارتباط موجب ومعنوي بين الغلة الحبيه وكل من وزن المائة حبة، وعدد الحبوب في القرن، وطول النبات. تم تحديد التأثير المباشر وغير المباشر لعدد أيام الازهار، عدد ايام النضج الفسيولوجي، طول النبات، عدد القرون في النبات، عدد البذور في القرن، ووزن المائة حبة على انتاج الغلة الحبيه. تحليل معامل المسار اشار الى ان عدد ايام النضج الفسيولوجي، وزن المائة حبة، وعدد الحبوب في القرن، وطول النبات كان لها تأثير مباشر وعالي الإيجابية على الغلة الحبيه. هذه الصفات يمكن ان تستخدم كمعيار للانتخاب في برنامج تربيه الفول المصري.

Introduction

Faba bean (*Vicia faba* L.) is a diploid (2*n*= 12 chromosomes) crop which is one of the most important food legumes ranking fourth world wide after garden pea, chickpeas and lentil. It is cultivated in the temperate and subtropical regions of the world (Maxted and Bennett, 2001 and Torres *et al.,* 2006).

Faba bean is a grain legume and grown for its high protein content (25.4%) in the seed (Karadavut *et al.,* 2010). The green immature beans are boiled and eaten as vegetable. The mature seeds can be used for feeding livestock, swine, and equine and or poultry animals. The stock or haulms is used as animal feeding stuff. Faba bean also serves as a rotational crop which plays great role in controlling disease epidemics in areas where cereal mono-cropping is abundant (Yohannes, 2000).

In Sudan, faba bean is the most important pulse crop on basis of area cultivated and farm income. The boiled beans are considered as the main dish in breakfast and dinner meals for large population in the urban areas of Sudan (Ahmed, 1996). It is grown as a winter crop under irrigation mainly in the Northern and River Nile States in about 70% and 30% of the total cultivated area, respectively. Also it is grown to a limited extent in Khartoum State and Jabel Marra in Western Sudan due to the suitability of the environmental conditions (Salih and Salih, 1996). Lately, it was introduced to the larger irrigated schemes of Gezeira, Rahad and New Halfa.

Yield improvement is a major breeding objective of most crop improvement programs (Ghobary and Abdallah, 2010). Yield in faba bean, similar to the other crops, is a complex trait related to many morphological and physiological traits. Seed yield is a quantitative trait and affected by genotype and environmental factors. Using as selection criteria of characters, direct relationship with seed yield increases the success of selection in plant breeding (Karasu and Oz, 2010). Therefore, progress of breeding in such traits are primarily conditioned by the magnitude and nature of variation and interrelationships among them (Raffi and Nath, 2004).

Simple correlation analysis is not suitable to provide detailed and actual knowledge in the relation between dependent variable and predictor variables. Hence, the path analysis was also performed to determine the direct and indirect contribution of each character to seed yield (Chitra and Rajamani, 2010). For this reason Berhe *et al.* (1998); Ulukan *et al.* (2003) and Tadesse *et al.* (2011) determined the direct and indirect effects of various plant characters on yield and its components by using path analysis in faba bean. They indicated days to flowering,

days to maturity, number of pod per plants, seeds per pod, thousand seed weight and plant height had high positive direct effect on seed yield. They also indicated the direct and indirect effects of plant height, pod length, first pod height, pod number per plant and grain number per pod upon biological yield. In the other study, path analyses showed that number of seeds per plant and 100-seed weight were the major direct contributors to seed yield per plant. As in previous studies, breeders can release new varieties with certain characters by using path coefficients.

The objective of the present study was to estimate the correlations and partition of the coefficient of correlation between seed yield with its primary components, into direct and indirect effects to determine the relative importance of each one in faba bean seed yield in Northern Sudan.

Materials and Methods

The data of this research experiment were collected from a study conducted over two consecutive years (2010/11and 2011/12) during the winter season, at Merowe Research Station Farm- Northern state, which is located at Latitude: 18° 27' 0" N, Longitude: 31° 49' 59" E, Elevation: 258 meter above the sea level.

Ten faba bean promising crosses were selected from advanced material (Table 2) provided from Hudeiba Research Station-River Nile State. The material was compared to the two released varieties; Basabeer (BB-7) and Hudeiba 93(H.93). The design used was a randomized complete block with three replications. Planting was done manually at a seed rate of 120 kg/ha. The plot consisted of 5 ridges, 5 m long spaced at rate of 0.6 m**.** Two seeds were placed in holes spaced at 20 cm on the two sides of the ridge. The sowing dates of the two seasons were usually within the third week of November. The experiment was irrigated every 10– 12 days throughout the growing season. The crop was harvested manually 16 weeks after sowing. Seed yield was assessed from a net area of 8.28 m^2. Data was recorded on phenological characters (days to 50% flowering [DFF] and days to 90% physiological maturity [DPM]). With regard to plant height (cm), ten plants were randomly selected from each replicate and their height was measured from the tip to the ground level. Yield components were recorded by harvesting a sample of five plants, and then numbers of pods per plant, number of seeds per pod were calculated. Total weight of the whole plant cut was used to determine the biological yield. The pods per plant harvested were then threshed and weighed to calculate the seed yield per plant. Further, 100 - seed weight was recorded from the weight of 100 - seeds of bulk seeds.

Separate analysis of variance for each season was performed for seed yield and its component before running the combined analysis. Means were separated using Duncan′s

multiple range test (DMRT). The correlation and path coefficient analysis were worked out according to the methods described by Dewey and Lu (1959) and Falconer (1964). General analysis was done using a computer program of GenStat, 12th edition.

Results

Analysis of variance and genotypes mean performance

The results presented in Tables (1) and (2) show the combine analysis of variance, in which the genotypes under study were significantly different for all characters. In season 2010/11 the genotypes, C.4/02, C.8/02 and C. 28/02 were the latest as they required 97 days to mature. The rest of the tested material needed 93-95 days to reach maturity. Most of the tested genotypes gave significantly heavier seed weight than the two checks. The genotypes C.98/02 and C.28/02 gave the heaviest seed weight, 50.6 and 50.3 g, respectively.

In season 2011/12, the genotypes C.28/02 and C.9/02 produced higher seed yield than the two checks. The respective increases in seed yield of the two genotypes over the check BB-7 were 20.0% and 15.2%, respectively. Results summarized in table 2 indicated that the seed yields of the three genotypes C.98/8, C.14/02 and C.8/02, were significantly higher than those of the two checks, B B-7 and H.93.

On the average over the two seasons the four crosses: C.28\02, C.19\02, C.9\02 and C.98\02 produced better seed yield than the two checks and surpassed the first check (BB-7) by 16.5%, 15.1%, 9.6% and 8.0% and the second check (H.93) by 14.9%, 6.7%,6.1% and 4.3%, respectively.

Correlation coefficient analysis

The simple correlation coefficients determined at the end of the research between the characteristics investigated are presented in Table (3) for mean values of the two seasons. Highly significant positive correlation values were detected between seed yield and plant height (r= 0.469**), number of seeds per pod (r= 0.572**) and hundred seed weight (r= 0.573**). The strong association of these characters can be used during selection to improve the yield potential of the crop. Positive and significant correlation was observed between number of seeds per pod and plant height (r= 0.302). Positive correlation also was observed between 100- seed weight and plant height (r= 0.294) and between 100-seed weight and number of seeds per pod (r= 0.163). Similarly, positive and highly significant correlation was recorded between days to 90 % maturity and days to 50% flowering (r= 0.539**) but significantly correlated with number of pods per plant and plant height (r= 0.060). There is a negative and highly significant correlation

between number of seeds per pod and number of pods per plant (r= -0.523**), 100-seed weight and days to 50 % flowering (r= -0.547**) and between seed yield and number of pods per plant (r= -0.522**). Number of pods per plant exhibited a negative correlation with days to 50 % flowering (r= -0.181) and days to 90 % maturity (r= -0.081). Also the hundred seed weight recorded a negative correlation with days to 50 % flowering (r= -0.236) and days to 90 % maturity (r= -0.182). Thus, correlation helps breeders to identify the characters that could be used as selection criteria in breeding program. These results suggested that improvement of grain yield in faba bean is linked with these traits and selection of these traits might have good impact on seed yield.

Path coefficient analysis

In order to determine the relationships between yield and the other examined traits, path correlation coefficients were calculated. The path coefficients were partitioned into direct and indirect effects by using grain yield as a dependent variable. Direct and indirect effects are given in Table (4). Days to maturity had the greatest direct effect on seed yield (p.c= 0.531). Also its indirect effect on seed yield was more positive through number of pods per plant but negative and low through days to flowering, plant height, number of seeds per pod and hundred seed weight. The second highest direct effect on seed yield was the hundred seed weight (p.c= 0.452). Number of seeds per pod was the third highest positive direct contributors to seed yield following days to maturity and hundred seed weight. The number of pods per plant had the highest negative indirect effect on seed yield via number of seeds per pod (p.c= -0.230). The indirect effects via hundred seed weight (p.c= -0.082), days to maturity (p.c= -0.010), plant height (p.c= 0.016) and days to flowering (p.c= 0.017) were negligible.

The results of correlation and path analysis indicated that number of pods per plant, hundred seed weight and plant height were the major yield contributing characters as they showed positive and significant association with seed yield and also had high positive effects. Thus these characters could be considered as the most important for selection in order to improve the seed yield in faba bean.

Discussion

The analysis of variance showed that the twelve faba bean genotypes had significant differences among genotypes, seasons and their interaction ($P \leq 0.01$) for most of the studied traits. These results confirmed the results of Hassan (2006) and Abdel-Rahman (2009), who reported considerable variation among faba bean cultivars tested.

The results of the correlation coefficients between traits and path analysis indicated that the 100-seed weight, number of seeds per pod and plant height exhibited positive and significant correlation with seed yield. Similar results were reported by Badolay *et al.,* (2009) who found that the seed yield exhibited positive and significant correlation with clusters per plant, pod length, plant height, branches per plant, pods per plant and hundred seed weight. These results were also in conformity with Alghamd (2007) who detected significant positive correlations between seed yield and each of number of seeds per pod, seed weight and biological yield.

Path coefficient analysis indicated that the traits containing, days to 90 % maturity, number of seeds per pod and hundred seed weight play major role in seed yield determination of faba bean. This result concur with Berhe *et al.* (1998) who indicated that number of seeds per plant and 100-seed weight were the major direct contributors to seed yield. These results also agree with those of Tadesse *et al.* (2011) and Ulukan *et al.* (2003) who found out number of pods per plant, seed per pod, thousand seed weight, pod length, and grain number per pod had high positive direct effect on seed yield per plot. Whereas seed yield had maximum negative direct effect on number of pods per plant (p.c= -0.233). These results are in agreement with those obtained by Peksen and Gulumser (2005) and Cokkizgin (2007).

Conclusion

Conclusively, attention should be paid to some of characters such as plant height, number of seeds per pod and hundred seed weight, for increasing of seed yield and these traits could be used as selection criteria in faba bean breeding programs. These findings indicate that selection for each or full of the above traits would be accompanied by high yielding ability under such conditions. These results suggest that the mentioned traits are the most important seed yield components in the development of high yielding varieties.

Results showed that the genotypes C.28/02, C.19/02 and C.9/02 possessed the high values of traits. It could be concluded that the high yielding genotypes, such as C.28/02, C.19/02 and C.9/02 could be used to improve faba bean and making possibilities of extending its production. Moreover, the traits that exhibited strong and positive association with yield could be used as selection criteria for improving faba bean.

Table 1: Some vegetative traits of 12 faba bean genotypes over two seasons

Genotype	Days to 50% flowering		Mean	Days to 90% maturity		Mean	Plant Height (cm)		Mean
	2010/11	2011/12		2010/11	2011/12		2010/11	2011/12	
C.98/02	38	35	37	95	94	94	85.3	94.5	89.9
C.98/8	36	35	36	93	97	95	82.1	100.5	91.3
C.1/02	38	37	37	94	94	94	75.3	96.7	86.0
C.4/02	39	37	38	97	93	95	72.7	90.1	81.4
C.8/02	39	37	38	97	95	96	76.7	92.0	84.4
C.9/02	38	34	36	93	94	94	82.8	91.4	87.1
C.14/02	38	37	38	94	96	95	80.7	97.2	88.9
C.15/02	38	37	37	94	94	94	84.9	97.8	91.3
C.19/02	39	37	38	94	96	95	84.3	102.7	93.5
C.28/02	38	37	38	96	96	96	80.5	98.4	89.5
BB7 (check)	39	37	38	94	93	94	82.6	97.1	89.8
H.93 (check)	38	34	36	94	93	94	80.6	92.0	86.3
S.E+(SXG)	0.4*			0.8**			3.9 n.s		
Mean	38	36	37	95	95	95	80.7	95.9	88.3
S.E+	1.5 **		0.3***	0.3 *		0.5*	1.4*		2.7n.s
C.V (%)	2.1			1.5			7.1		

***, ** Significant at 0.05 and 0.01 probability levels, respectively.**

Table 2: Average number of pods /plant, seed/pod, 100-seed weight (g) and seed yield (kgha^{-1}) of 12 faba bean genotypes, over two seasons.

Genotype	pods/plant		Mean	seed/pod		Mean	100 – SW (g.)		Mean	Seed yield (kg ha^{-1})		Mean
	2010/11	2011/12		2010/11	2011/12		2010/11	2011/12		2010/11	2011/12	
C.98/02	9.1	21.9	15.5	2.5	1.9	2.2	50.6	50.3	50.5	3256	4357	3806
C.98/8	12.8	41.4	27.1	2.1	1.9	2.0	48.0	49.0	48.5	3331	3986	3658
C.1/02	13.7	32.9	23.3	2.1	2.2	2.1	48.2	48.0	48.1	2805	3894	3349
C.4/02	17.0	22.6	19.8	2.2	2.2	2.2	42.4	47.0	44.7	2856	4206	3531
C.8/02	11.9	27.3	19.6	2.2	1.8	2.0	42.6	43.0	42.8	2843	4068	3455
C.9/02	12.7	25.4	19.0	2.5	2.4	2.4	49.6	49.3	49.5	3241	4504	3872
C.14/02	15.1	34.1	24.6	2.1	1.8	1.9	46.6	46.7	46.6	3006	3955	3480
C.15/02	12.1	28.3	20.2	2.3	2.3	2.3	44.4	46.7	45.5	3482	3992	3737
C.19/02	12.1	24.8	18.4	2.7	2.4	2.6	43.9	49.0	46.5	3387	4402	3894
C.28/02	15.6	22.1	18.9	2.1	2.5	2.3	50.3	49.3	49.8	3616	4770	4193
BB-7 (check)	16.7	30.2	23.4	2.1	2.5	2.3	43.5	44.7	44.1	3180	3816	3498
H.93 (check)	14.9	27.7	21.3	2.3	2.5	2.4	46.6	49.3	48.0	3115	4185	3650
S.E+(SXG)												
Mean	13.6	28.2	20.9	2.3	2.2	2.2	46.4	47.7	47.0	3176	4178	3677
S.E+	9.2*			0.5*			4.8**			542**		
C.V(%)	25.2			13.7			6.3			8.9		

***, ** Significant at 0.05 and 0.01 probability level, respectively.**

Table 3: Correlation coefficient analysis among characteristics in investigated 12 faba bean genotypes, combined over two seasons.

Characters	Flowering	Maturity	Plant height	Pods/plant	Seeds/pod	100-seed wt
Maturity	0.539 **					
Plant height	-0.064	-0.117				
Pods/plant	-0.181	-0.018	0.060			
Seeds/pod	-0.092	-0.291	0.302*	-0.523**		
100-seed weight	-0.547**	-0.236	0.294	-0.182	0.163	
Seed yield	-0.071	0.218	0.469*	-0.522**	0.572**	0.573**

***, ** Significant at 0.05 and 0.01 probability levels, respectively.**

Table 4: Path coefficient analysis among characteristics in investigated 12 faba bean genotypes, combined over two seasons.

Characters	Direct Effect	Indirect effect						Correlation value with yield
		DF	DM	PH	NPP	NSP	HSW	
DF	-0.090		0.286	-0.017	0.042	-0.040	-0.247	-0.071
DM	0.531	-0.051		-0.032	0.004	-0.128	-0.107	0.218
PH	0.273	0.006	-0.062		-0.014	0.133	0.133	0.469*
NPP	-0.233	0.017	-0.010	0.016		-0.230	-0.082	-0.522
NSP	0.440	0.009	-0.155	0.082	0.122		0.074	0.572**
HSW	0.452	0.051	-0.125	0.080	0.042	0.072		0.573**

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm), NPP: Number of pods per plant, NSP: Number of seeds per pod, HSW: hundred seed weight (g).
***, ** Significant at 0.05 and 0.01 probability levels respectively.**
Residual effect = 0.11

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