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Genotypic Responses, Yield Stability, and Association between Characters among some of Sudanese Faba bean (*Vicia faba* L.) Genotypes under Heat stress

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Abstract

Heat stress is one of the abiotic stresses that affect and reduce yield productivity of faba bean. This study aimed to evaluate the performance and stability of twenty two faba bean (*Vicia faba* L.) genotypes under terminal heat stress. The genotypes were field tested for two consecutive years (2001/02-2002/03) during winter in Sudan, at Shambat (the Experimental Farm of Faculty of Agriculture, University of Khartoum). To induce heat stress, three sowing dates were used, namely: S_1 (optimum), S_2 (14 days later than optimum), and S_3 (28 days later than optimum). The genetic variability, yield stability and correlation between yield, yield components and other vegetative traits were determined. The results showed that the induced terminal heat stress was severe enough to cause significant reduction in yield and most of the studied characters. Significant differences between genotypes for most of the studied characters were found. Some genotypes tolerate slight heat stress (S_2), but become susceptible under severe heat stress (S_3) and vice versa. Under slight heat stress, genotype C.52/1/1/1 was highly stable, gave the highest yield and was moderately tolerant to heat stress, whereas under severe heat stress, genotypes C.52/1/1/1 and C.42 showed the highest yield, were highly stable and moderately tolerant to terminal heat stress. Significant positive phenotypic correlations for seed yield/plant with its components; number of podded nodes/main stem, and number of pods/plant were obtained. These two components were positively and significantly correlated with each other, but negatively and highly significant associated with 100-seed weight. Seed yield/plant was positively correlated with dry matter/plant, harvest index and plant height in both years. Positive and significant correlation of seed yield/plant with 100-seed weight and seed yield (kg/ha) was observed. It could be concluded that the high yielding genotypes under terminal heat could be used to improve heat tolerance in faba beans and making possibilities of extending production of faba bean in the non-traditional areas. Moreover, the traits that exhibited strong and positive association with yield could be used as selection criteria for improving faba bean under heat stress conditions.

Introduction

Faba bean is one of the most important field crops in Sudan, it is used in many forms. Most of the sudanese people especially those from low and middle scale are depending on faba bean for breakfast and dinner as a main staple food. It is considered as the main source for protein, which can replace meat. The production of this crop is restricted to the northern and River Nile states of Sudan. The average yield was 2.567 ton/ha and 0.960 ton/ha in the Northern and River Nile states, respectively (FAO, 2000). Due to the low and fluctuation in yield, there is a tendency to extend cultivation and production of faba bean to the south of the non-traditional areas of production (Khartoum and Elgezira area), which are characterized by shorter winter and high temperatures. Therefore the aim is to develop more adapted varieties to the conditions of these non-traditional areas.

Like other some crops, faba bean is subjected to many biotic and abiotic stresses which reduce yield and affect stability. The abiotic stresses such as drought and heat are the major constraints of faba bean production. High temperature has an adverse effect on faba bean productivity. Therefore delay of sowing date, which subjects the crop to high temperature increased the number of flowers but decreased the number of pods and seeds (Sekara et al., 2001). Delayed sowing date affects adversely and significantly yield and yield components (Saghin, 1998; and Hatam et al, 1999), where the crop is exposed to terminal heat stress. In Sudan, as we go from the north region to southwards, the temperature increases, so the selection of the high-yielding and heat-tolerant genotypes capable of surviving under heat stress is very important to the breeders. The main objectives of this study were to: 1) evaluate the performance and determine the genetic variability of 22 genotypes for terminal heat stress. 2) determine yield stability of faba bean genotypes under terminal heat stress conditions. 3) estimate the correlation between yield and yield components under heat stress.

Materials and Methods

The data of this study was collected from a research work conducted for two consecutive years (2001/02 & 2002/03) during the winter at the Experimental Farm of Faculty of Agriculture, University of Khartoum, in Shambat (Khartoum) which is located at 15 40 N. latitude and 32 32 E. longitude and altitude of 380 m above sea level. The genetic material used in this study comprised a total of 22 genotypes of faba beans which were advanced breeding lines and two released varieties. The heat stress was simulated by sowing at three dates: S_1, S_2 and S_3 with interval of 14 days. The first sowing date was considered as non-stressed environment (NS_1E) and the last two dates were considered as heat stress environments (HS_2E and HS_3E). the experiment was laid out in a split plot design with three replications. Sowing dates were assigned as main plots and genotypes were sub-plots. The seed bed preparation and other cultural practices were given as recommended. During the two years, observations were taken on ten plants randomly selected per each genotype. These included yield and yield components, plant height, dry matter and harvest index. The relative yield (yield under stress/yield under non-stress condtion) was used as index to measure heat tolerance. combined analysis of variance was carried out according to Gomez and Gomez (1984). The stability analysis was carried out according to Eberhart and Russel (1966) and Wricke (1962).

Results

Significant differences were exhibited between different sowing dates for most of the traits (Table 1) e. g., Seed yield/ha, seed yield/plant and other yield components, except number of seeds/pod. Terminal heat stress (S_3) resulted in significant reduction of most of the traits, except number of seeds/pod. (Table 1). Delayed sowing dates (S_2 and S_3) significantly reduced number of pods/plant. Seed yield7plant and seed yield/unit area (Table 1). Number of podded nodes/main stem was reduced significantly under S_3. Number of seeds/pod was not affected significantly with delayed sowing. Plant height, dry matter/plant and harvest index were reduced significantly only under S_3 (Table 1).

Table 1: Means of performance of 22 faba bean genotypes for different traits under three different sowing dates (S_1 , S_2 & S_3) averaged over two years (2001/02 & 2002/03) , at Shambat (Sudan)

Traits	Sowing dates			mean
	S_1	S_2	S_3	
Seed yield/ha (kg)	3400 a	2570 b	1250 c	2407
Seed yield/plant (g)	15.0 a	12.4 b	6.8 c	11.4
Number of podded nodes/ main stem	5.20 a	5.00 a	3.85 b	4.69
Number of pods/plant	12.33 a	10.40 b	7.10 c	9.94
Number of seeds/pod	2.50 a	2.58 a	2.40 a	2.49
100-seed weight (g)	51.6 a	48.4 a	42.0 b	47.3
Plant height (cm)	90.6 a	91.6 a	80.6 b	87.6
Dry matter/plant (g)	29.5 a	26.0 a	17.3 b	24.3
Harvest index (%)	50 a	48 a	40 b	46

Means followed by the same letters are not significantly different at 5% probability level according to DMR-test.

The highest yield under non-stress condition (S_1) was given by genotypes Bulk 1/2 and C.22 (Table 2). Under S_2, the highest seed yield/plant was exhibited by genotype C.52/1/1/1, which also gave the highest seed yield/plant under terminal heat stress (S_3). The lowest seed yield/plant under S_1, S_2 and S_3 was recorded for genotypes C.28, C.34 and C.80/1, respectively. Some genotypes tolerate slight heat stress (S_2), but become susceptible under severe heat stress (S_3) and vice versa. High heat tolerance (YS_3/ YS_1) under both stress conditions (S_2 and S_3) was exhibited by genotype C.52/1/1/1, and the most heat-stress sensitive genotypes under S_2 and S_3 were C.22 and Berber 1, respectively (Table 2).

Table 2: Means of the performance of the 22 faba bean genotypes for yield/plant (g) under the three different sowing dates (S_1 , S_2 & S_3), and estimates of heat tolerance (based on seed yield/plant), averaged over the two years (2001/02 & 2002/03)

		Performance (yield/plant)			**Heat tolerance**	
No	**Genotypes**	**YS_1**	**YS_2**	**YS_3**	**YS_2/ YS_1**	**YS_3/ YS_1**
1	P.M/1	15.7	12.3	7.28	0.78	0.47
2	C.86	15.5	11.8	7.26	0.76	0.47
3	C.34	14.2	**10.4**	5.58	0.74	0.39
4	C.52/1/1/1	14.5	**14.4**	**7.93**	**0.99**	**0.55**
5	C.28	**12.6**	12.5	6.42	**0.99**	0.51
6	Dabba 1/1	15.6	12.1	6.38	0.78	0.41
7	F 402/7	14.1	12.3	6.21	0.87	0.44
8	C.80/1	13.2	11.7	**4.90**	0.89	0.37
9	C.36	15.4	12.0	6.98	0.78	0.45
10	Super L.85	13. 9	13.2	6.93	0.95	0.50
11	D.E.2	14.3	11.0	5.74	0.77	0.40
12	Bulk 1/2	**17.0**	13.7	7.46	0.81	0.44
13	C.22	**17.0**	11.6	7.39	**0.68**.	0.43
14	C.42/1/1/1	13.3	13.1	7.16	0.99	0.54
15	BB 25	16.7	12.8	6.26	0.77	0.38
16	Golid 1	13.3	11.1	5.85	0.84	0.44
17	ZBF 1/1	15.1	12.4	7.12	0.82	0.47
18	Berber 1	16.5	11.2	5.49	0.68	**0.33**
19	Mass 55	14.2	11.3	6.79	0.79	0.48
20	C.42	14.7	13.0	**7.93**	0.88	0.54
21	BB7	16.9	13.6	7.30	0.77	0.43
22	H 93	16.6	12.3	6.51	0.82	0.39
	mean	**14.9**	**12.3**	**6.68**	**0.83**	**0.45**

The stability analysis showed that the parameters *bi* and σ^2 differentiated the genotypes C.52/1/1/1 and Berber 1 for the highest and lowest values, respectively (Table 3). Whereas, the stability parameters S^2d and *Wi* differentiated the genotypes C.86 and Golid 1 for the lowest and highest values, respectively. Accordingly, the genotype C.52/1/1/1 and C.86 were considered to be highly stable, heat tolerant and adapted to unfavorable conditions. Whereas, genotype Berber 1 is considered to be more adapted to favorable conditions and non-stable under stress conditions.

Table 3: Estimates of stability, regression coefficient (*bi*), mean square deviation (S^2d), variance (σ^2) and ecovalence (*Wi*) for yield/plant of 22 genotypes of faba bean across six macro-environments(2 years x 3 sowing dates)

		Stability parameters				
No	**Genotypes**	**mean**	***bi***	S^2d	σ^2	***Wi***
1	P.M/1	11.7	0.91	7.33	18,2	6.00
2	C.86	11.5	0.96	**7.94**	20.3	**6.37**
3	C.34	10.1	1.00	0.49	15.3	0.38
4	C.52/1/1/1	11.9	**0.74**	3.10	**10.7**	3.48
5	C.28	10.5	0.84	1.78	12.0	1.80
6	Dabba 1/1	11.4	1.15	1.32	20.9	1.40
7	F 402/7	10.9	1.01	1.25	16.2	1.00
8	C.80/1	10.0	1.04	1.33	17.2	1.08
9	C.36	11.4	0.99	2.37	16.9	2.05
10	Super L.85	11.3	0.85	2.74	13.1	2.53
11	D.E.2	10.3	1.05	3.62	19.4	2.93
12	Bulk 1/2	12.7	1.12	0.58	19.3	0.68
13	C.22	12.0	1.10	2.83	20.5	2.41
14	C.42/1/1/1	11.2	0.80	2.57	11.6	2.67
15	BB 25	11.9	1.26	0.36	24.0	1.27
16	Golid 1	10.1	0.92	**0.19**	13.0	**0.24**
17	ZBF 1/1	11.5	0.95	1.75	14.9	1.44
18	Berber 1	11.1	**1.29**	2.01	**26.5**	2.85
19	Mass 55	10.8	0.85	0.70	11.4	0.91
20	C.42	11.9	0.86	0.45	11.4	0.66
21	BB7	12.4	1.15	0.43	20.1	0.67
22	H 93	12.2	1.18	2.33	22.6	2.33

The association between seed yield/ha was significantly positive with seed yield/plant, number of podded nodes/main stem, number of pods/plant and harvest index. Strong positive and significant correlation was observed for seed yield/plant with number of pods/plant and dry matter/plant and 100-seed weight (Table 4). The 100-seed weight significantly and negatively associated with number of pods/plant and number of seeds/pod. Plant height was positively and significantly correlated with seed yield/plant and its components.

Table 4: Coefficients of correlation between yield and yield components for 22 genotypes of faba beans, averaged over three dates of sowing (S_1 , $S_{2\ \&}$ S_3)at Shambat (Sudan) during the year 2002/03

Traits	SY/Pl	NPN/MS	NP/PL	NS/P	HSW	PH	DM/PL	HI
SY/ha	.51 **	.58 **	.62 **	.01	-.31	.17	.31	.47 *
SY/Pl		.69 **	.83 **	.35	.48 *	.46 *	.86 **	.53 *
NPN/MS			.90 **	.34	-.58 **	.55 **	.46 *	.60 **
NP/PL				.44 *	-.63 **	.45 *	.60 **	.59 **
NS/P					-.70 **	.39	.31	.20
HSW						-.25	.28	-.44 *
PH							.59 **	-.13
DM/PL								.07

SY/ha = Seed yield/ha (kg); **SY/Pl** = Seed yield/plant (g); **NPN/MS =** Number of podded nodes/mainstesm; **NP/PL** = Number of pods/plant; **NS/P** = Number of seeds/pod; **HSW** = 100-seed weight (g); **PH** = Plant height (cm); **DM/PL** = Dry matter/plant (g); **HI** = Harvest index (%).

Discussion

The artificially induced terminal heat stress in the present study was severe enough to cause a tremendous reduction in yield and yield components of faba bean genotypes. Similar results were also reported by Ahmed (1989) in faba beans. This adverse effect could be attributed mainly to the high temperature during the vegetation period, that checked growth and led to the development of small, short- stemmed crop with few branches and pods. The significant effect of sowing dates was also shown by other workers (Badlwin, 1980; and Sekara et al., 2001). Number of seeds/pod was not affected by delaying sowing date, this might be referred to the fact that number of seeds/pod is more influenced by genetic than environmental factors. Similar results were reported by Salih and Khalafalla (1982). The genotypes in this study exhibited variable yield performances and responses under slight and high heat stress conditions. This indicates that heat tolerance in faba bean varies with the incidence of heat, and also its severity. Lin et al., (1984) reported that heat tolerance varied with species, genotypes and plant tissues.

In this study, the highly stable genotypes produced moderate seed yield and were moderately tolerant under terminal heat stress. Genotype C.52/1/1/1 exhibited the highest seed yield/plant, and was more adapted to unfavorable environments. These results indicate close association between high stability, adaptation to unfavorable environments, and moderate heat tolerance that connected with high seed yield. This is in accordance with the conclusion of Chopra and Viswanathan (1999). Therefore such genotypes with high yield under heat stress and high yield stability are better adapted to heat stress and could be used to improve faba bean under terminal heat stress. The close phenotypic association between the characters could be attributed to the effects of genes as well as the effects of environments as suggested by Falconer (1980). The different associations of seed yield /plant with its components observed in the present study, with some exceptions, were in agreement with findings observed by other workers (e. g., Bakhait and Mahdy, 1988; and Abdelmula, 1992). The negative association of number of podded nodes/main stem, number of pods/plant and number of seeds/pod with 100-seed weight may be due to the compensatory phenomenon in faba bean between yield components during plant development. Similar results and conclusion were also reported by many researchers (Yassin, 1973; and Abdelmula et al., 1993). It could be concluded that the high yielding genotypes, such as C.52/1/1/1, under terminal heat could be used to improve heat tolerance in faba beans and making possibilities of extending production of faba bean in the non-traditional areas of Sudan. Moreover, the traits that exhibited strong and positive association with yield could be used as selection criteria for improving faba bean under heat stress conditions.

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