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Breeding for Orobanche Tolerance in *Vicia faba*

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Abstract

This study aimed to provide materials for selecting good combinations from segregating generations and exploring new hybrids tolerant to *Orobanche* to use it in breeding programs. Six faba bean genotypes were crossed in a diallel system excluding reciprocals. Obtained results recorded variability among genotypes (parents and their crosses) in most studied characters especially tolerance characters of *Orobanche*. Moreover, there was significance in tolerance characters of *Orobanche*. It was noticed that tolerance to *Orobanche* to be a complex character. There were an inbreeding gain in yield components and this may comes back to remaining heterotic effects and epistasis (transgressive segregation). Based on previous results, it was concluded that the commercial cost of producing hybrid seed can be reduced by and growing F_1 or directly.

1. Introduction

Faba bean is the commercial name of (*Vicia faba* L.) which considers the most important source of proteins that used in human nutrition. The parasitic weed broomrape (*Orobanche crenata*) is a yield-limiting factor in some fields, which could completely wipe out the crop [1]. Broomrape is an obligate parasite, completely lacking chlorophyll and causing significant reductions in yield and quality. Broomrape attaches to the root system of the host plant, establish a connection with the vascular system of the host via haustorium. Sources of resistance to broomrape are scarce and of complex nature. However, several resistant cultivars were released to farmers in Egypt under the commercial name 'Giza'. An acceptable level of resistance was found in Vf1071, an inbred line selected from cv. Giza 402 in Southern Spain**.** This line has been used in breeding programs to develop the well-adapted, high yielding cv. Baraca [2, 3]. The study aimed to explore new hybrids tolerant to *Orobanche* and used it in breeding programs.

2. Methods

The field experiments of the present study were carried out at Gemmiza Research Station, Agriculture Research Center (ARC), Egypt, during three successive seasons 2015/16, 2016/17 and 2017/18.

Six widely diverse faba bean (*Vicia faba* L.) genotypes were used as parents in this study. A brief description of these genotypes is presented in Table 1.

The six parents were hybridized to secure F_1 hybrid seeds in 2015/16 season. In 2016/17season, the six parents re hybridized again and their 15 F_1 hybrids were grown in a randomized complete block design with three replications under insect free cage.

In 2017/18 season**,** parents, F_1 hybrids, and F_2 hybrids were grown in naturally *Orobanche*-infested field and evaluated for tolerance to *Orbanche*. The experimental trial was conducted in an open field that included six parents, 15 F_1's and 15 F_2's. The studied characters were (DF), (PH), (BP), (PP), (SP), (SY), (100-SW), (DFS), (SN) and (SDW).

Statistical analysis

A randomized complete blocks design (RCBD) with three replications was used and recorded data were analyzed using Griffing [4] analysis**,** method 2, model 1.

Significant differences among genotypes were tested by regular analysis of variance of the RCBD according to Gomez and Gomez, [5]. Data were analyzed according to [4]. Moreover, **ASSISTAT** program [6, 7]. was used to calculate differences between means that tested using LSD, significance of mean square, correlation coefficient and inbreeding effects.

Table (1): A brief description of the six parental genotypes in the present study.

Name	*Type*	*Pedigree*	*Characteristics*
Nubaria 1 (P_1)	*Major*	Selected individually from Spanish variety	Resistant to foliar diseases, large seeds
Giza 843 (P_2)	*Equina*	Selected individually from Rebaya 40 (FCRI)	Tolerant to *Orobanche*
Sakha 4 (P_3)	*Equina*	81/35/2001 (Shkha 4) derived from Sakha 1 x Giza 3**	Susceptible to *Orobanche*.
Camilina (P_4)	*Minor*	Introducion from Ethiopea..	Small seeds, Susceptible to *Orobanche*.
Misr 1 (P_5)	*Equina*	Derived from Giza3 × 123A/45/76 (FCRI, ARC, Egypt).	Tolerant to *Orobanche*
Cairo 33 (P_6)	*Equina*	Selected individually from breeding program (FACU)	Tolerant to *Orobanche*.

FCRI = Field Crops Research Institute. **FACU** = Faculty of Agriculture, Cairo University (**see Abdalla,** [8]. **for details**). (* see Muratova, [9].

3. Results and Discussion

1. There was highly significant variation between genotypes (parents, F_1's, F_2's) for most studied characters, indicating genetic variability of parents for most traits. (Table 2)
2. Mean performance of parents along with F_1's and F_2's are illustrated in Table 3. There was wide variance between parents in all studied characters. Whereas, Giza 843 recorded the highest values in most morphological characters and Misr 1 was the most tolerant to *Orobanche* where it recorded (103.33; 3.67 and 22.90) for days of first spike, spikes number and spikes dry weight, respectively.

Table (2): Significance of mean squares of some traits of six faba bean genotypes and their crosses in F_1 and F_2 generations.

S. O. V.	df	DF		PH		BP		PP		SP		SY	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Genotypes	20	11.88**	11.48**	231.02**	585.66**	0.68**	0.49**	17.76**	9.11**	52.17**	50.59**	25.54**	20.38**
Parents(P)	5	12.99**		398.09**		0.37**		8.29**		47.71**		27.28**	
Crosses (C)	14	12.28**	11.71**	180.99**	690.90**	0.83**	0.57**	22.41**	10.05**	56.81**	54.56**	26.46**	19.31**
P *vs.* C	1	0.70	0.70	96.06**	50.29**	0.00	0.03	0.00	0.06	9.46**	9.36**	4.04*	1.01**
GCA	5	6.45**	2.45**	63.90**	147.91**	0.13	0.05	5.15**	2.42**	17.51**	20.04**	11.21**	4.12**
SCA	15	3.13**	4.28**	81.38**	210.99**	0.26*	0.20**	6.17**	3.24**	17.35**	15.80**	7.62**	7.69**
GCA/SCA		2.06	0.57	0.79	0.70	0.50	0.22	0.83	0.75	1.01	1.27	1.47	0.54
Error	40	0.26	0.31	3.23	3.16	0.01	0.003	0.14	0.10	0.01	0.01	1.55	0.001

S. O. V.	df	100-SW		DFS		SN		SDW(g)	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Genotypes	20	872.05**	677.66**	264.33**	289.05**	2188.45**	1971.65**	1620.06**	1300.37**
Parents(P)	5	1292.22**		493.16**		4587.57**		3094.97**	
Crosses (C)	14	748.93**	502.71**	198.94**	234.04**	379.31**	144.85**	453.80**	307.80**
P *vs.* C	1	494.90**	54.25**	35.71**	38.63**	15520.84**	14467.24**	10573.09**	6223.49**
GCA	5	617.13**	366.19**	233.57**	240.63**	1321.35**	927.64**	1088.24**	722.91**
SCA	15	181.87**	179.12**	39.63**	48.26**	532.19**	567.08**	357.28**	336.97**
GCA/SCA		3.39	2.04	5.89	4.99	2.48	1.64	3.05	2.15
Error	40	0.001	6.87	1.48	2.81	4.36	7.17	24.00	30.44

* and ** refer to significance and highly significance, respectively.

3. The cross P_5xP_1 was the best one in most studied traits, such as, it was the earliest in flowering (40.67 days), the best one in all *Orobanche* tolerance criteria (101.67, 3.00 and 27.43) for days of first spike, spikes number and spikes dry weight, respectively. Meanwhile, the cross P_5xP_4 was the best pod setter (11.33) followed by cross P_5xP_1 (9.93). Moreover, cross P_5xP_4 recorded the highest number of seeds / plant (19.53) followed by (16.50) with cross P_5xP_1. Highest seed yield per plant (11.53 g) was shown also by this cross P_5xP_4 (65.36 g). (Table 3)
4. With regard to tolerance parameters of *Orobanche crenata* in this study, it was clear that the cross P_5xP_1 was the latest one in the emergence of the parasite *Orobanche* on its host, while the first spike appeared after 103.33 days, followed by 89.67 days for cross P_5xP_4. Moreover, according to the second parameter of tolerance (number of spikes) that appeared on the same host plant, it was found that cross P_5xP_1 ranked the first one in this parameter, while it scored the lowest number of spikes (3.00) that appeared on its host, followed by P_5xP_2 and P_5xP_4 (3.00 and 7.00), respectively. (Table 3)
5. Heterosis relative to both mid parents and better parent (Heterobeltiosis) was significant in different hybrids for all traits. (Table 4)
6. Studied parents scored significant GCA effects, where, positive significance was desirable in some traits (plant height, yield traits and days of first spike (that want to delay the appearance of the first spike) and negative significance was desirable in other traits (date to 50% flowering, spikes number and spikes dry weight where we want the smallest numbers). (Table 5).
7. The genotype Misr 1 showed desirable GCA effects in characters of DF, PH, PP, 100-SW, DFS, SN and SDW, while genotype Giza 843 had significant GCA effects in 100-SW. On the other hand, Genotype Sakha 4 recorded significant GCA effects for 100 -SW and significant GCA

effects for all *Orobanche* tolerance parameters (DFS, SN and SDW), but these were not desirable significance.

Table (3): **Mean performance of faba bean generations (parents, F_1 and F_2) for various studied traits.**

Genotype		DF		PH		BP		PP		SP		SY(g)		100-SW (g)	
(P_1)		47.67		63.33		1.50		3.23		5.20		3.79		73.17	
(P_2)		47.33		93.67		2.10		7.00		13.47		10.44		78.06	
(P_3)		46.00		65.00		1.57		4.00		9.63		4.93		51.26	
(P_4)		42.33		74.00		1.00		2.50		5.57		1.50		26.65	
(P_5)		43.67		83.00		1.50		5.67		14.50		6.84		47.44	
(P_6)		45.33		80.33		1.43		3.83		7.23		5.47		77.71	
Crosses		**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
P_2	**P_1**	48.67	47.0	76.33	89.33	1.37	1.67	3.00	4.23	8.23	9.57	6.14	5.55	75.19	58.29
P_3		47.67	46.33	64.67	59.67	1.17	1.00	2.67	2.70	6.43	5.53	4.03	3.38	63.19	38.78
P_4		46.33	45.67	70.00	87.33	1.70	1.33	5.20	5.77	11.50	12.30	3.56	4.95	31.42	40.58
P_5		40.67	41.67	82.67	83.33	2.57	2.47	9.93	5.90	16.50	13.23	10.79	10.08	66.03	76.72
P_6		47.33	44.00	79.67	75.33	1.33	0.95	2.70	1.87	6.17	5.53	3.38	3.58	56.62	64.24
P_3	**P_2**	45.00	46.33	78.33	69.67	1.53	1.30	3.23	2.67	5.83	4.90	4.17	3.56	72.12	71.52
P_4		44.33	43.67	58.33	62.33	1.43	0.97	3.50	4.30	6.67	11.87	1.90	6.12	28.88	52.10
P_5		47.00	43.33	75.67	67.67	1.07	1.02	2.63	3.57	5.47	8.50	3.00	3.71	53.64	44.17
P_6		46.00	47.33	61.33	92.33	1.67	1.50	4.77	2.63	8.83	6.47	4.00	5.36	44.61	81.47
P_4	**P_3**	45.00	44.67	76.67	89.33	1.00	1.43	1.67	5.67	4.13	11.17	0.93	6.18	22.33	56.73
P_5		46.00	47.00	77.33	67.00	1.33	1.43	4.53	4.23	7.37	9.67	4.97	6.00	67.95	63.17
P_6		44.67	41.33	81.33	75.67	1.43	1.47	3.87	4.27	7.43	9.30	3.92	4.77	52.73	51.12
P_5	**P_4**	43.33	46.33	83.67	114.67	2.83	1.90	11.33	7.87	19.53	18.73	11.53	11.44	58.90	61.79
P_6		47.67	45.33	68.00	85.33	1.05	2.10	3.93	7.77	7.90	18.17	4.12	8.93	51.66	49.49
P_6	**P_5**	44.67	47.33	73.33	59.00	1.23	1.57	2.40	3.17	4.13	6.87	7.59	3.04	47.37	44.72
Mean		**45.62**	**45.16**	**73.82**	**78.53**	**1.51**	**1.48**	**4.36**	**4.44**	**8.41**	**10.12**	**4.93**	**5.78**	**52.84**	**56.99**
LSD $_{0.05}$		**1.45**	**1.60**	**5.14**	**5.08**	**0.23**	**0.16**	**1.06**	**0.89**	**0.25**	**0.30**	**3.56**	**0.08**	**0.10**	**7.49**

8.

Genotype		DFS		SN		SDW(g)	
(P_1)		75.33		69.33		90.03	
(P_2)		83.00		24.00		54.63	
(P_3)		70.33		102.33		114.17	
(P_4)		68.00		72.67		59.23	
(P_5)		103.33		3.67		22.90	
(P_6)		76.67		15.00		50.80	
Crosses		**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
P_2	**P_1**	84.33	78.33	12.67	10.67	29.17	33.73
P_3		68.33	69.67	41.33	14.33	73.67	40.87
P_4		80.33	83.00	12.67	14.33	37.37	44.63
P_5		101.67	107.67	3.00	4.00	27.43	25.47
P_6		71.33	85.33	7.67	5.33	33.47	30.83
P_3	**P_2**	78.67	77.67	36.00	17.00	52.73	55.17
P_4		74.67	79.67	18.67	27.00	33.30	49.93
P_5		82.67	82.00	3.00	10.00	21.33	35.03
P_6		83.67	81.00	11.00	14.00	33.17	48.03
P_4	**P_3**	79.33	75.33	14.00	17.67	40.37	54.73
P_5		86.67	74.00	8.00	4.67	30.47	30.33
P_6		82.00	78.00	6.33	21.00	33.97	54.00
P_5	**P_4**	89.67	87.67	7.00	16.67	32.90	45.60
P_6		72.67	73.33	9.33	25.67	34.57	56.23
P_6	**P_5**	80.67	85.00	5.67	12.00	35.37	44.80
Mean		**81.11**	**81.18**	**13.09**	**14.29**	**36.62**	**43.29**
LSD $_{0.05}$		**3.48**	**4.79**	**5.97**	**7.66**	**14.01**	**15.78**

Table (4): **Heterosis (H) and heterobeltiosis (Hb) in F_1 generation for studied traits.**

Cross	DF		PH		BP		PP		SP		SY	
	H	Hb	H	Hb	H	Hb	H	Hb	H	Hb	H	Hb
P_2 x P_1	2.46**	2.10**	-2.76	-18.51**	-24.07**	-34.92**	-41.37**	-57.14**	-11.79**	-38.86**	-13.72**	-41.19**
P_3 x P_1	1.78**	0.00	0.78	-0.51	-23.91**	-25.53**	-26.27**	-33.33**	-13.26**	-33.22**	-7.56**	-18.24**
P_4 x P_1	2.96**	-2.80**	1.94	-5.41*	36.00**	13.33**	81.40**	60.82**	113.62**	106.59**	34.72**	-6.06**
P_5 x P_1	-10.95**	-14.69**	12.98**	-0.40	71.11**	71.11**	123.22**	75.29**	67.51**	13.79**	102.88**	57.70**
P_1 x P_1	1.79**	-0.70	10.90**	-0.83	-9.09**	-11.11**	-23.58**	-29.57**	-0.80**	-14.75**	-26.95**	-38.15**
P_3x P_2	-3.57**	-4.93**	-1.26	-16.37**	-16.36**	-26.98**	-41.21**	-53.81**	-49.49**	-56.68**	-45.75**	-60.06**
P_4 x P_2	-1.12*	-6.34**	-30.42**	-37.72**	-7.53**	-31.75**	-26.32**	-50.00**	-29.95**	-50.50**	-68.22**	-81.83**
P_5 x P_2	3.30**	-0.70	-14.34**	-19.22**	-40.74**	-49.21**	-58.42**	-62.38**	-60.91**	-62.30**	-65.32**	-71.30**
P_6x P_2	-0.72	-2.82**	-29.50**	-34.52**	-5.66**	-20.63**	-12.00**	-31.90**	-14.65	-34.41**	-49.66**	-61.64**
P_4 x P_3	1.89**	-2.17**	10.31**	3.60	-22.08**	-36.17**	-48.72**	-58.33**	-45.61**	-57.09**	-71.18**	-81.22**
P_5x P_3	2.60**	0.00	4.50*	-6.83**	-13.04**	-14.89**	-6.21**	-20.00**	-38.95**	-49.20**	-15.63**	-27.39**
P_6 x P_3	-2.19**	-2.90**	11.93**	1.24	-4.44**	-8.51**	-1.28**	-3.33**	-11.86**	-22.48**	-24.58**	-28.28**
P_5 x P_4	0.78	-0.76	6.58**	0.80	126.67**	88.89**	177.55**	100.00**	94.68**	34.71**	176.53**	68.52**
P_6 x P_4	8.75**	5.15**	-11.88**	-15.35**	-13.70**	-26.74**	24.21**	2.61**	23.44**	9.22**	18.18**	-24.74**
P_6x P_5	0.37	-1.47*	-10.20**	-11.65**	-15.91**	-17.78**	-49.47**	-57.65**	-61.96**	-71.49**	23.26**	10.92**

Cross	100-SW		DFS		SN		SDW	
	H	Hb	H	Hb	H	Hb	H	Hb
P_2 x P_1	-0.56**	-3.68**	6.53**	1.61	-72.86**	-81.73**	-59.68**	-67.60**
P_3 x P_1	1.58**	-13.63**	-6.18**	-9.29**	-51.84**	-59.61**	-27.85**	-35.47**
P_4 x P_1	-37.05**	-57.06**	12.09**	6.64**	-82.16**	-82.57**	-49.93**	-58.50**
P_5 x P_1	9.50**	-9.75**	13.81**	-1.61	-91.78**	-95.67**	-51.42**	-69.53**
P_1 x P_1	-24.94**	-27.13**	-6.14**	-6.96**	-81.82**	-88.94**	-52.47**	-62.83**
P_3x P_2	11.55**	-7.60**	2.61*	-5.22**	-43.01**	-64.82**	-37.52**	-53.81**
P_4 x P_2	-44.83**	-63.00**	-1.10	-10.04**	-61.38**	-74.31**	-41.51**	-43.78**
P_5 x P_2	-14.51**	-31.28**	-11.27**	-20.00**	-78.31**	-87.50**	-44.97**	-60.95**
P_6x P_2	-42.73**	-42.60**	4.80**	0.80	-43.59**	-54.17**	-37.09**	-39.29**
P_4 x P_3	-42.67**	-56.43**	14.70**	12.80**	-84.00**	-86.32**	-53.44**	-64.64**
P_5x P_3	37.69**	32.55**	-0.19	-16.13**	-84.91**	-92.18**	-55.54**	-73.31**
P_6 x P_3	-18.23**	-32.15**	11.56**	6.96**	-89.20**	-93.81**	-58.82**	-70.25**
P_5 x P_4	59.00**	24.17**	4.67**	-13.23**	-81.66**	-90.37**	-19.89**	-44.46**
P_6 x P_4	-1.00**	-33.52**	0.46	-5.22**	-78.71**	-87.16**	-37.17**	-41.64**
P_6x P_5	-24.30**	-39.04**	-10.37**	-21.94**	-39.29**	-62.22**	-4.03	-30.38**

* and ** refer to significance and highly significance, respectively.

Table (5): **Estimates of the general combining ability effects (gi) of parental lines in the F_1 crosses for studied traits.**

Parents	DF	PH	BP	PP	SY	100-SW	DFS	SN	SDW (g)
	F_1	F_1	F_1	F_1	F_1	F_1	F_1	F_1	F_1
Nubaria 1 (P_1)	0.89	-2.78	0.07	-0.07	-0.02	7.06**	-0.97	6.86*	8.44
Giza 843 (P_2)	0.85	1.89	0.08	0.08	0.55	6.03**	0.69	-3.97	-4.34
Sakha 4 (P_3)	0.18	-1.74	-0.13	-0.82	-0.97	-0.18**	-3.60*	18.65**	18.23**
Camilina (P_4)	-0.94	-2.19	-0.07	0.01	-1.33	-16.98**	-3.97*	5.74*	-2.09
Misr 1 (P_5)	-1.24*	4.56*	0.18	1.45**	1.99	0.81**	10.44**	-15.89**	-15.05*
Cairo 33 (P_6)	0.26	0.26	-0.13	-0.65	-0.21	3.26**	-2.60	-11.39**	-5.19
S.E. gi	0.18	0.64	0.03	0.13	0.44	0.01	0.43	0.74	1.73
S.E. (gi - gj)	0.25	0.90	0.04	0.19	0.62	0.02	0.61	1.04	2.45

* and ** refer to significance and highly significance, respectively.

9. SCA effects varied in different cross combinations for the studied characters (Table 6). However, there were two crosses out of 15 (P_5 x P_1 and P_6 x P_3) recorded negative significant SCA effects in

F_1 generation, and cross (P_3 x P_2) also, showed negative significant SCA that was desirable effects in F_1 only.

10. Crosses (P_4 x P_1, P_5 x P_1, P_4 x P_3 and P_6 x P_3) possessed desirable SCA effects in *Orobanche* tolerance parameters (DFS and SN) in F_1 generation. Table (6)

Table (6): Estimates of the specific combining ability effects (S_{ij}) of diallel crosses for studied traits of F_1 generation.

Hybrids	DF	PH	BP	PP	SP	SY	100-SW	DFS	SN	SDW (g)
	F_1	F_1	F_1	F_1	F_1	F_1	F_1	F_1	F_1	F_1
P_2 x P_1	1.38*	2.62	-0.30**	-1.37**	-0.43**	0.51	7.48**	3.98*	-13.24**	-19.74**
P_{31} x P_1	1.04	-5.42*	-0.29**	-0.80	-0.79**	-0.07	1.70**	-7.73**	-7.20**	2.19
P_4 x P_1	0.83	0.37	0.19	0.90*	2.98**	-0.18	-13.28**	4.64**	-22.95**	-13.79*
P_5 x P_1	-4.54**	6.29**	0.81**	4.19**	5.34**	3.73*	3.55**	11.56**	-10.99**	-10.77
P_6 x P_1	0.63	7.58**	-0.12	-0.94*	-0.86**	-1.48	-8.31**	-5.73**	-10.82**	-14.59*
P_3 x P_2	-1.58*	3.58	0.06	-0.38	-1.73**	-0.51	11.66**	0.94	-1.70	-5.97
P_4x P_2	-1.13	-15.96**	-0.09	-0.95*	-2.20**	-2.42	-14.79**	-2.69	-6.11*	-5.08
P_5x P_2	1.83**	-5.38*	-0.71**	-3.26**	-6.04**	-4.64**	-7.81**	-9.11**	-0.15	-4.09
P_6 x P_2	-0.67	-15.42**	0.20*	0.98*	1.46**	-1.43	-19.30**	4.94**	3.35	-2.11
P_4 x P_3	0.21	5.99*	-0.32**	-1.89**	-3.29**	-1.87	-15.12**	6.27**	-33.40**	-20.59**
P_5x P_3	1.50*	-0.09	-0.24*	-0.46	-2.70**	-1.14	12.71**	-0.82	-17.78**	-17.53**
P_6x P_3	-1.33*	8.20**	0.17	0.98*	1.50**	0.01	-4.97**	7.56**	-23.95**	-23.88**
P_5 x P_4	-0.04	6.70**	1.21**	5.51**	8.17**	5.78**	20.46**	2.56	-5.86*	5.23
P_6 x P_4	2.79**	-4.67*	-0.26*	0.21	0.67**	0.57	10.76**	-1.40	-8.03**	-2.96
P_6x P_5	0.08	-6.09*	-0.33**	-2.77**	-5.74**	0.72	-11.32**	-7.82**	9.93**	10.80
S_{ij}	0.45	1.59	0.07	0.33	0.08	1.10	0.03	1.08	1.85	4.34
S_{iJ} - S_{ik}	0.51	1.80	0.08	0.37	0.09	1.25	0.03	1.22	2.09	4.90

* and ** refer to significance and highly significance, respectively.

11. Inbreeding effects in F_2 (depression or gain) was significant in 6 cases for days to 50 % flowering, 15 for plant height, 10 for branches per plant, 15 for pods per plant, 7 for seeds per plant, 6 for seed yield per plant and 5 for seed index. Moreover, the significance of tolerance characters of *Orobanche* were 4, 15 and 13 for days of first spike, spikes number and spikes dry weight, respectively. (Table 7)

Table (7): Inbreeding effects (%) in F_2 for studied traits.

Cross	DF	PH	BP	PP	SP	SY	100-SW	DFS	SN	SDW (g)
P_2 x P_1	3.43	-17.03**	-21.90*	-41.00**	-16.28	9.61	22.48	7.12*	15.79**	-15.63**
P_{31} x P_1	2.80	7.73**	14.53*	-1.12**	13.99	16.13	38.63*	-1.95	65.33**	44.52**
P_4 x P_1	1.44	-24.76**	21.77*	-10.96**	-6.96	-39.05*	-29.15*	-3.32	-13.10*	-19.43**
P_5 x P_1	-2.46	-0.80**	3.89	40.58**	19.82	6.58	-16.19	-5.90	-33.33**	7.15*
P_6 x P_1	7.04*	5.45**	28.57*	30.74**	10.37	-5.92	-13.46	-19.63**	30.51**	7.89*
P_3 x P_2	-2.96	11.06**	15.03*	17.34**	15.95	14.63	0.83	1.27	52.78**	-4.63
P_4x P_2	1.50	-6.86**	32.17*	-22.86**	-77.96*	-222.11**	-80.40*	-6.70*	-44.62**	-49.94**
P_5x P_2	7.80**	10.57**	4.67	-35.74**	-55.39*	-23.67	17.66	0.81	-233.33**	-64.23**
P_6 x P_2	-2.90	-50.55**	10.18	44.86**	26.73*	-34.00*	-82.63*	3.19	-27.27**	-44.80**
P_4 x P_3	0.74	-16.51**	-43.00*	-239.52**	-170.46**	-564.52**	-154.05**	5.04	-26.21**	-35.57**
P_5x P_3	-2.17	13.36**	-7.52	6.62**	-31.21*	-20.72	7.04	14.62**	41.63**	0.46
P_6x P_3	7.46*	6.96**	-2.80	-10.34**	-25.17	-21.68	3.05	4.88	-231.75**	-58.96**
P_5 x P_4	-6.92*	-37.05**	32.86*	30.54**	4.10	0.78	-4.91	2.23	-138.14**	-38.60**
P_6 x P_4	4.90*	-25.49**	-100.00**	-97.71**	-130.00**	-116.7**	4.20	-0.92	-175.13**	-62.66**
P_6x P_5	-5.97*	19.54**	-27.64*	-32.08**	-66.34*	59.95*	5.59	-5.37	-111.64**	-26.66**

* and ** refer to significance and highly significance, respectively.

12. The results of Correlation coefficients showed that there were a clear correlation (positive or negative) between all studied traits, moreover, between many characters the correlation coefficients didn't reach to the level of significance and other characters reached to not only significant but highly significant (Table 8).
13. There was positive correlation between DFS as a parameter of *Orobanche* tolerance and both plant growth and yield characters except DF (negative correlation). Whereas, scored results were (r= 0.362*, 0.549**, 0.492**, 0.485** and 0.554**) with PH, BP, PP, SP and SY, respectively, and it was (r= -0.440**) with DF.
14. Moreover, the character DFS was correlated negatively with other parameter of *Orobanche* tolerance (SN and SDW), and recorded (r= -0.486** and -0.520**), respectively. (Table 8).

Table (8): Correlation coefficients among studied traits of faba bean genotypes (combined data).

	DF	PH	BP	PP	SP	SY	100-SW	DFS	SN	SDW
DF	1.000									
PH	-0.074	1.000								
BP	-0.271	0.429**	1.000							
PP	-0.346*	0.484**	0.854**	1.000						
SP	-0.305	0.539**	0.759**	0.938**	1.000					
SY	-0.233	0.616**	0.790**	0.828**	0.828**	1.000				
100-SW	0.210	0.356*	0.333*	0.151	0.106	0.476**	1.000			
DFS	-0.440**	0.362*	0.549**	0.492**	0.485**	0.554**	0.260	1.000		
SN	0.067	-0.232	-0.114	-0.168	-0.144	-0.206	-0.067	-0.486**	1.000	
SDW	0.177	-0.161	-0.069	-0.123	-0.104	-0.115	0.085	-0.520**	0.906**	1.000

* and ** refer to significance and highly significance, respectively.

However, from previous results in this study it was clearly noticed that there were a positive relationship between yield characters (seed yield per plant) and tolerance criteria, where traits were in the same time in cross P_5xP_1 followed by P_5xP_4 and P_5xP_2, respectively, especially days of first spike, spikes number and spikes dry weight. Moreover, the tolerance of these crosses may be inherited from its mother (P_5 Misr 1) which is tolerant to *Orobanche*. The F_1 generation will express hetrosis rebulting in improving host characters and host reaction to *Orobanche*. On the other hand F_2 generation will express "some" heterosis and possibly some useful transgressive segregants. Moreover, F_2 with 50% theoretical homozygosity per locus will contribute to higher tolerance to *Orobanche* because of homozygosity.

The superior faba bean parents in their GCA effects (significant and positive) indicated that these parents are favorable for inclusion in the production of synthetic cultivars. These results are in accordance with those obtained by Darwish *et al*.- Ashrei *et al*. [10-14].

The fact that several F_2 hybrids indicated inbreeding gain in almost all characters may drew the attention of the remaining heterosis in F_2 coupled with the presence of transgressive segregants. Selection may be practiced in such transgressive segregants to obtain genotypes with improved characters than parents. However, it had to be emphasized here that for better and safer improvement, selection may be carried out in F_2 crosses derived from *eu faba* ssp. types (*minor*, *equina* and *major*).

Abdalla *et al.* [15]. studied the heterotic and inbreeding effects, in addition to general, specific combining ability (GCA and SCA) and correlations among morphological characters in faba bean. Their results showed that there were significant differences between parents, F_1's and F_2's for all studied traits indicating genetic diversity of parents. Moreover, the heterosis relative to mid parents was significant in different hybrids in all traits.

Abdalla *et al.* [16]. conducted a diallel-cross including reciprocals among six parents of faba bean to study the heterotic and inbreeding effects, as well as general and specific combining ability. Results showed significant differences between parents, F_1's and F_2's for all studied traits and these differences may be mainly due to the genetic diversity of the parents. The parents and their crosses would be interesting and prospective for improving seed yield and its components in faba bean.

Conclusion

- Parents in this study and their crosses can used to improve seed yield and *Orobanche* tolerance programs in faba bean.
- The inheritance of tolerance to *Orobanche* is not simple. It is a complex character.
- Inbreeding may uncover useful genotypes.
- Correlation coefficients indicated that selection for pods, seeds per plant and seed weight would result in high yielding ability.
- The materials used in this study are good potential for combining ability and heterotic effects and may as well as useful segregants with good performance and tolerance to *Orobanche*.

Abbreviations

DF= Days to 50 % flowering, **PH** = Plant height, **BP** = Branches / plant, **PP** = Pods / plant, **SP** = Seeds / plant, **SY** = Seed yield / plant, **100 SW** = 100 seed weight (seed index), **DF**S= Days of first spike, **SN** = Spikes number, **SDW** = Spikes dry weight.

(H)= heterosis**, (Hb)=** heterobeltiosis, **(GCA)=** General combining ability and **(SCA)=** Specific combining ability.

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