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Directional Selection in Faba Bean (*Vicia faba* L.) Under Infestation of *Orobanche crenata*

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Abstract: This study was conducted in the experimental farm of Mallawi Agricultural Research Station, Agricultural Research Center, Egypt, during the two successive winter seasons of 2008/2009 and 2009/2010 to study the effect of two successive cycles of phenotypic directional selection on the offspring of 10 crosses among local cultivars with variable levels of resistance. The selection was performed for relative seed yield per host plant to that of the most resistant cultivar Giza-843 under heavy natural infestation with broomrape. Five faba bean parents Giza-843, Giza-429, (57/721/94) Line-3, Line-4 (664/689/94) and Giza 2 were randomly hybridized to give ten crosses. The first cycle of selection was applied to 10 F2 populations that exceeded Giza-843 in seed yield per plant under infestation using single plant selection where the top yielding five plants among the 60 segregates of each population were selected and the analysis also indicated that there were significant variations among the F_3 selected families in 8 out of the 10 populations which permit for further response to another cycle of selection. The most outstanding yielding ability under heavy infestation was shown by the F_3 selection of two crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line-3) with a mean seed yield per plant of 55 grams and population 1 (Giza-843 x Giza-429) with a mean of 45 grams. The highest yielding ability under heavy infestation was shown by the F4 selection of three crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line-3), with a mean seed yield per plant of 60 grams, population 1 (Giza-843 x Giza-429), with a mean seed yield per plant of 49.9 grams and population 3 (Giza-843 x Line-4), with a mean of 48.6 grams. Similar results were obtained for both F_3 and F4 generation in both cycles of selection for both number and weight of *Orobanche* spikes indicating that the cultivar Giza-843 effectively shared in transmitting its properties of high yield and its immense ability of resisting broomrape.

Key words: Faba bean · Yield and its component · Orobanche crenata · Phenotypic selection · Heritability

INTRODUCTION

Orobanche crenata Forsk. is a root parasite that produces devastating effects on many crop legumes and has become a limiting factor for faba bean production in the Mediterranean region. The efficacy of available control methods is minimal and breeding for broomrape resistance remains the most promising method of control. Resistance seems to be scarce and complex in nature, being a quantitative characteristic difficult to manage in breeding programs. Prior to application of modern genetic techniques, it is required to obtain preliminary information concerning the genetic makeup of a given organism. Such information has traditionally been obtained by conventional methods. Yield tests have to be performed under open field conditions in a highly and homogeneously infested plot. Because of the statistical distribution of the parasite, selection between lines and/or segregating generations is preferable to the simple average value of any kind of index. Statistical designs should include many repetitions. It is essential to try to modify the statistical distribution rather than use averages. The expected progress in selection will always be slow, as the main characteristics involved resistance to *Orobanche* and yield per plant which is quantitative characters from a genetic point of view. In spite of this difficulty, recent results show that it is feasible to combine resistance and yield in the same genotype. The

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Table 1: The name and pedigree of the five faba bean genotypes used as parents in this study

No.	Genotypes	Pedigree
1	Giza-843	Single cross (Giza-461x 561/2076/65), tolerant to *Orobanche* infestation
2	Giza-429	Single plant selection from Giza-402, tolerant to *Orobanche* infestation
3	Line 957/721/94 PROMISING 3	New breeding line selection (Giza-402 x BPL582), promising for *Orobanche* resistance or tolerance
4	Line 664/689/94 PROMISING 4	New breeding line selection (Giza-402 x 249/802/80), promising for *Orobanche* tolerance
5	Giza-2	Selected from landraces (commercial cultivars), susceptible to *Orobanche* infestation

conclusion of Radwan *et al*. [1] that single plant selection is the most effective method for improving tolerance to *Orobanche crenata* gave support to such kind of work.

Improving faba bean through selection is considered to be most important way to maximize the productivity. Despite the pressing need for greater annual production of faba bean in order to meet an increasing demand, productivity of the existing cultivars has been dwindling lately due to the infestation with broomrape (*Orobanche crenata*). Being a noxious root parasite, broomrape represents a major constraint in the main production areas of Middle and Upper Egypt where it causes great loss in seed yield and sometimes a complete failure of the crop in endemic land. Relative resistance of faba bean plant to *Orobanche* as measured by the percentage of seed yield per plant under infestation of the most resistant cultivar Giza-843 was found to be under control of genes with mainly additive effects with partial dominance for greater yield being operating, in accordance with the conclusions of Suso [2], Cubero and Fernandez [3] and Cubero [4]. The highest narrow-sense heritability estimate for the relative yielding ability under infestation reached 0.75 suggested using this character as the prime selection criterion in this study for enhancing resistance to *Orobanche*. The objectives of this study are to develop, through selection, faba bean genotypes with increased levels of resistance to broomrape.

MATERIALS AND METHODS

The experiments of this study were carried out at Mallawy Agricultural Research Station, Agricultural Research Center, Egypt in two successive winter seasons of 2008/2009 and 2009/2010. Five genotypes of faba bean (*Vicia faba* L.); represent a wide range of agronomic traits as well as different levels of resistance to broomrape, besides 10 crosses were used. The name and pedigree of the five genotypes used in the study are given in Table 1. In 2008/2009 season, a field experiment was conducted in order to measure the response to selection for resistance to *Orobanche crenata* and other related traits. Seeds of five selected F_3 families of each of the 10 crosses were sown on 1st November in a field heavily infested with seeds of *Orobanche crenata* against the F_3 bulk of each cross and the susceptible cultivar Giza-2 as a control. A randomized complete block design with three replications was used. In each block, a plot of seven ridges was assigned to each of the 10 entries; five ridges for the five F_3 selected families; one ridge for the F_3 bulk; and one ridge for the control Giza-2. The five parents were also represented by a plot of one ridge for each parent in each block. Each ridge was two-meter long, 60-cm wide and contained 10 plants spaced 20 cm from each other. Seed yield per plant, degree of infestation and other attributes were measured. A second cycle of selection was applied in which the best family for yield among the five F_3 selected families of each of the 10 crosses was chosen to be advanced. In 2009/2010 season, the five parents and the 10 F4 selected families were sown on 1st November in a heavily infested field with *Orobanche crenata* in a randomized complete blocks design with three replications. Each parental entry was represented in each block with a plot of one ridge. As to the F4 selected families, a ridge was assigned to the selection of F4 of a cross, a second ridge for the F4 bulk of that cross and a third ridge to the control Giza-2. Each ridge was two-meter long, 60-cm wide and contained 10 plants 20 cm apart. The characters of seed yield per plant (g), number and dry weight of *Orobanche crenata* spikes per plant were measured on individual plant basis throughout the different experiments. The differential selection was measured for each population as a deviation of the mean of selected F2 plants from the F2 population mean. Response to selection was expressed as percentage of change in the mean of the selected families from that of bulked plants of each population.

RESULTS AND DISCUSSION

The results revealed response to selection over two successive cycles for seed yield per plant under heavy natural infestation of *Orobanche crenata* in both F_3 and F_4 generations followed by correlated responses in other traits. The mean of seed yield per plant under heavy infestation for the five parents and their 10 F_2 of the diallel crossing (Table 2).

The average seed yield per plant for Giza-843 was 36 g that out yielded all other parents and crosses. The mean of 50 plants of each of the 10 crosses constituting the base population for selection ranged from 5 to 30 grams comparing to the mean of Giza-843 of 36 grams (Table 3). The means of the best five plants selected out of the 120 F_2 plants of each cross (an intensity of 4.16%) ranged from 40 to 70 grams with an average of 49.7 grams. The differential selection ranged from 26 to 40 grams with an average of 33.7 grams. The results obtained are in agreement with those obtained by Parker and Riches [5], Kharrat [6], Abbes *et al.* [7] and Kharrat and Halila [8].

First Cycle of Selection - F_3 Generation: The means of seed yield per plant for the bulk and selected F_3 families of each of the 10 populations grown under heavy natural infestation of the parasite *Orobanche crenata* are presented in Table 4. The responses to selection were also calculated for the 10 populations as a difference between bulk and selected F_3 families. Positive responses were obtained in all of the populations which were significant in 8 populations as shown in Table 4. The responses ranged from 5.0 to 66.6% with an average of 30.7% of the population mean. Yielding ability of the selected F_3 families varied considerably among the 10 populations with mean of the seed yield per plant which ranged from 12 to 41 grams. Mean seed yield per host plant under infestation of 6 out of the selected 10 F_3 exceeded that of the most resistant parent Giza-843 by 3 to 71.9%. The most outstanding yielding ability under heavy infestation was shown by the F_3 selections of two crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line 3), with mean seed yield per plant of 55 grams and population 1 (Giza-843 x Giza-429), with mean of 45 grams. Meanwhile, the analysis also indicated that there were variations among the F_3 selected families in 8 out of the 10 populations which permit for further response to another cycle of selection. These results are in agreement with those obtained by Abbes *et al.* [9], Kharrat and Halila [10], Wegmann *et al.* [11] and Wegmann [12]. The main problem in breeding for resistance to *Orobanche* is to avoid the 'dilution' of favorable genes once the crosses between the resistant and the adapted (susceptible) lines have been performed. Because of the quantitative genetic system underlying the resistance to broomrape in faba bean, Cubero [4] suggested a recurrent selection method to accumulate genes for resistance in the host at the quickest possible rate.

Second Cycle of Selection - F4 Generation: Means of seed yield per plant for the selected F4 families of each of the 10 populations grown under heavy natural infestation of *Orobanche crenata* are presented in Table 5. The responses to selection were also calculated for the 10 populations according to the difference between bulk and selected F4 families. The responses ranged from 11.1 to 55.8% with an average of 25.9% of the population mean. Yielding ability of the selected F4 families varied considerably among the 10 populations with mean of the seed yield per plant ranged from 10.3 to 53 grams. The mean seed yield per host plant of eight F4 selected under infestation exceeded that of the most resistant parent Giza-843 by 8.5 to 82.3%. The results obtained are in agreement with those obtained by Abbes *et al.* [9], Harloff and Wegmann [13] and Abbes *et al.* [14].

The most outstanding yielding ability under heavy infestation was shown after the F4 selections of three crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line-3), with mean seed yield per plant of 60 grams, population 1 (Giza-843 x Giza-429), with mean of 49.9 grams and population 3 (Giza-843 x Line-4), with mean of 48.6 grams. Meanwhile, the analysis also indicated that there were significant variations among the F4 selected families in all the 10 populations which permit for further response to another cycle of selection. The remarkable positive responses to selection obtained in the 10 F2 populations which averaged 22.7% and 22.8% than the population mean after the first and second cycles of selection, respectively, supported the suggestion of Cubero [15] of applying a recurrent selection method in order to accumulate genes for resistance in the host at the quickest possible rate. The limited success of the breeding effects for selecting faba bean cultivars with enhanced resistance to the devastating parasitic weed *Orobanche crenata* may be attributed to the ambiguity in defining resistance/tolerance, hence the inappropriate choice of the selection criterion.

Correlated Responses to Selection for Seed Yield per Plant in Weight of *Orobanche crenata* Spikes per Host Plant

First Cycle of Selection - F_3 Generation: The means of dry weight of *Orobanche crenata* spikes per host plant (g) of Giza-843, the F_3 bulk and F_3 selected families of the 10 populations with the correlated responses to selection are presented in Table 6. The responses to selection were also calculated for the 10 populations according to the difference between bulk and selected F_3 families.

Table 2: The mean of seed yield per plant (g) under heavy infestation with *Orobanche crenata* for the 5 parents and 10 F_2 crosses.

Parents	1	2	3	4	5
1. Giza-843	36	25	30	20	16
2. Giza-429	--	28	28	22	12
3. Line (3) 957/721/94	--	--	35	27	15
4. Line (4) 664/689/94	--	--	--	16	5
5. Giza-2	--	--	--		0.5

Table 3: Means of seed yield per host plant of the 10 populations and the selected F_2 plants of each population grown under heavy infestation with *Orobanche crenata* with the differential selection.

Populations	Giza 843	F2 population mean	Means of selected plants	Differential selection
1. G.843 x G-429	36 g	25	55	30
2. G-843 x Line 3	36 g	30	70	40
3. Giza-843 x Line 4	36 g	20	54	34
4. Giza-843 x Giza-2	36 g	16	50	34
5. G-429 x Line 3	36 g	28	65	37
6. G-429 x Line 4	36 g	22	48	26
7. G-429 x Giza-2	36 g	12	45	33
8. Line 3 x Line 4	36 g	27	63	36
9. Line 3 x Giza-2	36 g	15	48	33
10. Line 4 x Giza-2	36 g	5	40	35
Mean	36	20	49.7	33.7

Table 4: Means of seed yield per plant (g) of the parent Giza-843, the F3 bulk and F3 selected families of the 10 crosses grown in heavily infested field with Orobanche with the response to selection as a percentage of the population mean

	Means of seed yield per plant (g)			
Populations	Giza-843	F3 bulk	F3 selected	Response %
1. G.843 x G-429	32 g	35	45	28.5**
2. G-843 x Line 3	32 g	41	55	34.1**
3. Giza-843 x Line 4	32 g	28	33	17.8**
4. Giza-843 x Giza-2	32 g	27	37	37.1*
5. G-429 x Line 3	32 g	36	50	28.8**
6. G-429 x Line 4	32 g	19	20	5.0**
7. G-429 x Giza-2	32 g	16	17	5.0**
8. Line 3 x Line 4	32 g	37	49	59.4
9. Line 3 x Giza-2	32 g	20	23	15**
10. Line 4 x Giza-2	32 g	12	20	66.6
Mean	32	27.1	34.9	30.7

**, * significant at 0.01 and 0.05 probability levels.

Table 5: Means of seed yield per plant (g) of the parent Giza-843, the F4 bulk and selected families for the 10 populations grown in heavily infested field with *Orobanche* in response to selection as a percentage of the population mean.

		Means of seed yield per host plant (g)		
			F4 selected	
		F4 bulk		
Populations	Giza-843	Mean	Mean	Response
1. G.843 x G-429	34 g	43.0	49.9	16.0**
2. G-843 x Line 3	34 g	53.0	60.0	13.2**
3. Giza-843 x Line 4	34 g	35.2	48.6	38.0**
4. Giza-843 x Giza-2	34 g	34.0	42.3	24.4**
5. G-429 x Line 3	34 g	49.8	58.0	16.5**
6. G-429 x Line 4	34 g	34.0	37.8	11.1**
7. G-429 x Giza-2	34 g	10.3	12.9	25.2**
8. Line 3 x Line 4	34 g	42.3	57.0	34.7**
9. Line 3 x Giza-2	34 g	28.2	34.9	23.7**
10. Line 4 x Giza-2	34 g	17.0	26.5	55.8**
Mean	34	35.7	38.8	25.9

** Significant at 0.01 probability level.

Table 6: Means of dry weight of *Orobanche crenata* spikes per host plant (g) represented as one family for each of the parent Giza-843, F_3 bulk and selected F_3 families of the 10 populations.

	Means of dry weight of *Orobanche crenata* spikes (g)			
Populations	Giza-843	F_3 bulk	F_3 selected	Response %
1. G.843 x G-429	5.4 g	7.8	4.9	- 37.2**
2. G-843 x Line 3	5.4 g	3.2	2.8	- 12.5**
3. Giza-843 x Line 4	5.4 g	8.9	6.1	- 31.5**
4. Giza-843 x Giza-2	5.4 g	9.9	5.2	- 47.4**
5. G-429 x Line 3	5.4 g	6.6	3.5	- 46.9**
6. G-429 x Line 4	5.4 g	10.8	6.4	- 40.7**
7. G-429 x Giza-2	5.4 g	13.2	9.2	- 30.3**
8. Line 3 x Line 4	5.4 g	5.6	4.4	- 21.4**
9. Line 3 x Giza-2	5.4 g	12.9	6.8	- 47.3**
10. Line 4 x Giza-2	5.4 g	18.2	7.4	- 59.3**
Mean	5.4	9.7	5.7	- 34.1**

**Significant at 0.01 probability level.

Table 7: Means of dry weight of *Orobanche crenata* spikes per host plant (g) of the parent Giza-843, the F4 bulk and F4 selected families for the 10 populations.

	Means of seed yield (g) for one family			
Populations	Giza-843	F_3 bulk	F_3 selected	Response %
1. G.843 × G-429	6.2 g	7.0	5.2	- 25.7**
2. G-843 × Line 3	6.2 g	5.3	3.5	- 33.9**
3. Giza-843 × Line 4	6.2 g	9.5	5.6	- 41.1**
4. Giza-843 × Giza-2	6.2 g	10.0	6.0	- 40.0**
5. G-429 × Line 3	6.2 g	6.0	4.6	- 23.3**
6. G-429 × Line 4	6.2 g	8.5	6.4	- 24.7**
7. G-429 × Giza-2	6.2 g	17.0	13.0	- 23.5**
8. Line 3 × Line 4	6.2 g	7.7	4.9	- 36.4**
9. Line 3 × Giza-2	6.2 g	11.5	8.0	- 30.4**
10. Line 4 × Giza-2	6.2 g	14.0	12.0	- 14.3**
Mean	6.2	9.7	6.9	- 29.3

**Significant at 0.01 probability level.

Table 8: Means of number of *Orobanche crenata* spikes per host plant represented as one family for each of the parent Giza-843, bulk and F_3 selected families of the populations.

	Means of number of *Orobanche* spikes per host plant			
Populations	Giza-843	F_3 bulk	F_3 selected	Response %
1. G.843 x G-429	6.4 spikes	4.33	3.9	- 9.9*
2. G-843 x Line 3	6.4 spikes	3.66	2.53	- 30.87*
3. Giza-843 x Line 4	6.4 spikes	5.0	4.46	- 10.8
4. Giza-843 x Giza-2	6.4 spikes	6.0	4.13	- 31.2*
5. G-429 x Line 3	6.4 spikes	4.05	3.1	- 23.5**
6. G-429 x Line 4	6.4 spikes	6.8	4.9	- 27.9
7. G-429 x Giza-2	6.4 spikes	7.66	6.7	- 12.5
8. Line 3 x Line 4	6.4 spikes	3.9	3.5	- 10.3*
9. Line 3 x Giza-2	6.4 spikes	7.0	5.9	- 15.7**
10. Line 4 x Giza-2	6.4 spikes	8.0	6.2	-22.5
Mean	6.4	5.6	4.5	- 19.5

**, * Significant at 0.01 and 0.05 probability levels

Table 9: Means of number of *Orobanche crenata* spikes per host plant of the parent Giza-843, F4 bulk and F4 selected families for the 10 populations.

	Means of number of *Orobanche* spikes per host plant			
Populations	Giza-843	F4 bulk	F4 selected	Response%
1. G.843 x G-429	6.2 grains	3.9	3.5	- 10.3**
2. G-843 x Line 3	6.2 grains	3.4	2.6	- 23.5**
3. Giza-843 x Line 4	6.2 grains	7.1	4.8	- 32.4**
4. Giza-843 x Giza-2	6.2 grains	7.4	5.5	- 25.7**
5. G-429 x Line 3	6.2 grains	3.5	2.7	- 22.9**
6. G-429 x Line 4	6.2 grains	6.3	5.5	- 12.7**
7. G-429 x Giza-2	6.2 grains	12.2	9.5	- 22.1
8. Line 3 x Line 4	6.2 grains	5.5	3.0	- 45.4
9. Line 3 x Giza-2	6.2 grains	8.5	6.5	- 23.5**
10. Line 4 x Giza-2	6.2 grains	9.7	9.0	- 7.2**
Mean	6.2	6.8	5.3	- 22.6

**Significant at 0.01 probability level.

Significant negative correlated responses to conventional selection were observed for the trait of dry weight of *Orobanche crenata* spikes per host plant in all of the 10 populations The negative correlated responses ranged from - 59.3 to - 12.5% of the population mean with an average of -34.1%. *Orobanche* tolerance ability of the selected F3 families varied considerably among the 10 populations with mean of the dry weight of *Orobanche crenata* spikes per host plant ranged from 3.2 to 18.2 grams. The mean dry weight of *Orobanche crenata* spikes per host plant (g) under infestation showed that 6 out of the 10 F_3 selections which surpassed that of the most resistant parent Giza-843 by 3.8 to 0.3 grams. The most outstanding *Orobanche* resistance ability under heavy infestation was shown after the F_3 selections of three crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line-3), with a mean dry weight of *Orobanche crenata* spikes per host plant of 2.8 grams, population 1 (Giza-843 x Giza-429), with mean of 4.9 grams and population 4 (Giza-843 x Giza-2), with mean of 5.2 grams. The results are in agreement with those obtained by Suso [2], Wegmann *et al.* [11], Sabah [16] and Darwish [17].

Second Cycle of Selection F4 Generation: The means of dry weight of *Orobanche crenata* spikes per host plant (g) of the selected F4 families for the 10 populations with the correlated responses to selection as the percentages of the population mean are presented in Table 7 and the responses to selection were also calculated for the 10 populations according to the difference between bulk and selected F4 families. Significant negative correlated responses to conventional selection were found for the trait of dry weight of *Orobanche crenata* spikes per host plant in the 10 populations. The negative correlated responses ranged from - 41.1 to - 14.3% of the population means with an average of -29.3%. *Orobanche* tolerance ability of the selected F4 families varied considerably among the 10 populations with mean of the dry weight of *Orobanche crenata* spikes per host plant ranged from 5.3 to 17 grams. The mean dry weight of *Orobanche crenata* spikes per host plant (g) under infestation showed that 6 out of the 10 F4 selections surpassed that of the most resistant parent Giza-843 by - 2.7 to - 0.2 grams. The most outstanding *Orobanche* resistance ability under heavy infestation was shown after the F4 selections of four crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line 3), with a mean dry weight of *Orobanche crenata* spikes per host plant of 3.5 grams, population 1 (Giza-843 x Giza-429), with a mean of 5.2 grams, population 3 (Giza-843 x Line-4) with a mean of 5.6 grams and population 4 (Giza-843 x Giza-2), with a mean of 6.0 grams. These results are in concordance with those obtained by Cubero and Fernandez [3], Cubero [4, 15] and Darwish [17].

Correlated Response to Selection for Seed Yield per Plant in Number of *Orobanche* Spikes per Host Plant

First Cycle of Selection - F_3 Generation: The means of number of *Orobanche crenata* spikes per host plant Giza-843, the F_3 bulk and F_3 selected families of the 10 populations with the correlated responses to selection are presented in Table 8 and the responses to selection were also calculated for the 10 populations according to the difference between bulk and selected F_3 families. Negative correlated responses to conventional selection were

found for number of *Orobanche crenata* spikes per host plant in the 10 populations. The negative correlated responses ranged from -31.2 to -9.9% of the population mean with an average of -19.5%. *Orobanche* tolerance ability of the selected F_3 families varied considerably among the 10 populations with the mean number of *Orobanche crenata* spikes per host plant ranged from 3.66 to 8 spikes. The mean number of *Orobanche crenata* spikes per host plant (g) under infestation showed that 8 out of the 10 F_3 selections surpassed that of the most resistant parent Giza-843 by -3.7 to -0.3 spikes. The most outstanding *Orobanche* resistance ability under heavy infestation was shown by the F_3 selections of three crosses involving the most resistant parental cultivar Giza-843, namely population 2 (Giza-843 x Line-3), with mean number of *Orobanche crenata* spikes per host plant of 2.53 spikes, population 1 (Giza-843 x Giza-429), with mean of 3.9 spikes and population 4 (Giza-843 x Giza-2), with a mean of 4.13 spikes. The results obtained are similar to those of Harloff and Wegmann [13], El-Sayed *et al.* [18], Karamanas and Avgoulas [19] and Khalil *et al.* [20].

Second Cycle of Selection - F4 Generation: The means of number of *Orobanche crenata* spikes per host plant of the selected F4 families for the 10 populations with the correlated responses to selection as the percentages of the population mean are presented in Table 9 and the responses to selection were calculated for the 10 populations according to the difference between bulk and selected F4 families. Negative correlated responses to conventional selection for the trait of number of *Orobanche crenata* spikes per host plant in the 10 populations which were significant in 8 out of the 10 populations. The negative correlated responses ranged from -45.4 to -7.2% of the population mean with an average of -22.6%. The *Orobanche* tolerance ability of the selected F4 families varied considerably among the 10 populations with mean of number of *Orobanche crenata* spikes per host plant ranged from 3.4 to 12.2 spikes. The mean number of *Orobanche crenata* spikes per host plant under infestation showed 7 out of the 10 F_3 selections which surpassed that of the most resistant parent Giza-843 by - 3.6 to - 0.7 spikes. The most outstanding *Orobanche* resistance ability under heavy infestation was shown by the F4 selections of four crosses involving the most resistant parental cultivar Giza-843 namely population 2 (Giza-843 x Line 3) with a mean number of *Orobanche crenata* spikes per host plant of 2.6 spikes, population 1 (Giza-843 x Giza-429) with a mean of 3.5 spikes, population 3 (Giza-843 x Line-4) with a mean of 4.8 spikes and population 4 (Giza-843 x Giza-2) with a mean of 5.5 spikes. These results are in concordance with those obtained by Radwan *et al.* [1], Parker and Riches [5], Kharrat [6] and Perrino *et al.* [21].

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