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Evaluation of fifteen faba bean (*Vicia faba* L.) genotypes for Orobanche crenata tolerance and foliar diseases resistance

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ABSTRACT

The present study was carried out at Sakha Agricultural Research Station, Kafr El-Sheikh governorate, Egypt during 2020/21 and 2021/22 seasons to study the behavior of eleven faba bean promising breeding lines i.e., (L1 (Giza 2 x Misr1), L2(Sakha 3 x Giza 2), L3(Giza843 x Misr 3), L4 (Nubaria1 x Misr 3) , L5 (Misr 1 x Giza843) , L6 (Nubaria 3 x Misr 1) , L7 (Sakha 1 x Misr 1), L8 (Triple white x Giza429), L9 (Giza40 x Giza429), L10 (Ohishima-Zaira x Giza 429) and L11(Giza 429 x Sakha 4) compared with four commercial cultivars Sakha 4 and Nubaria1 (susceptible to *Orobanche crenata*), Misr1 and Giza843 (tolerant to *Orobanche crenata*). The obtained results showed that under the non-infested soil with Orobanche, L7 genotype (Sakha 1 x Misr 1) was better in producing the highest number of branches/plant, number of pods, number of seeds per plant and seed yield per feddan without significant difference from L6 (Nubaria 3 x Misr 1) faba bean genotype and surpassed the commercial varieties in the studied traits during both seasons. Under Orobanche crenata infestation, L6 and L7 genotypes exceeded the other tested faba bean genotypes in most studied traits and recorded the highest values for number of branches, pods and seeds per plant and yielded 7.42 and 7.15 ardab/fed of seeds respectively as an average of the two seasons. The lowest number of Orobanche spike, during this study. Based on the obtained results, it could be concluded that L6 and L7 breeding lines surpassed all tested genotypes under both free and infested soils with *Orobanche crenata* and produced the highest seed yield in addition to the resistance against chocolate spot and rust diseases. So, both breeding lines deserve further evaluation in advanced yield trials to release the best as a new faba bean cultivar tolerant to Orobanche and resistant to foliar diseases along with the high yield potentiality, results of seed quality traits revealed significant differences among genotypes under the two soils, in both seasons. The genotypes L7, L6 and Giza843 gave the highest values of crude protein, total carbohydrates and total tannins contents, respectively while Nubaria1 gave the lowest values.

Keywords: Faba bean, Orobanche, tolerance, diseases, resistance, chocolate spot, rust.

INTRODUCTION

Faba bean (*Vicia faba*L) is grown in Egypt and other countries as a strategic legume crop with high nutritional value (rich in protein, fibers, folic acid, vitamins, phosphorus, and minerals). It is an important and cheap source for protein and energy suitable for human nutrition. Some countries use faba bean to feed their animals (Larralde, 1982). Faba bean can be cultivated in Nile delta as well as new reclaimed areas. Farmers grow faba bean for its high nutritive value and to improve the soil fertility across nitrogen fixation by rhizobium bacteria associated with root system of *Vicia faba*. Unfortunately, the cultivated area in Egypt has gradually decreased from 385,000 feddan in 1997/98 to about 62,790 feddan in 2019/2020 due to the increased Orobanche infested fields (FAOSTAT, 2021), and the competition with others crops.

Faba bean is facing different biotic stresses such as diseases, insects, and weeds. The parasitic weed broomrape (*Orobanche crenata* L.) is the most limiting factor for faba bean cultivation not only in Egypt but also worldwide. Orobanche causes yield losses in faba bean ranging from 5 to 95% according to the degree of infestation (number of Orobanche spikes per m^2 and the sowing date of faba bean (Mesa_Garcia and Garcia_Torres, 1986). Most of life cycle of broomrape remains underground associated with the host root, so it is not proper to control *orobanche* after appearing above soil surface, because it got most of food from the host.

Breeding for Orobanche tolerance became the most important objective for most of the national faba breeding programs in many countries in the Mediterranean region, such as (Spain, Egypt, ICARDA, Morocco, Tunisia…etc.) in order to develop resistance or tolerant cultivars to Orobanche. This procedure will be more

effective in reducing seed bank of orobanche in the soil (Joel *et al.,* 2007). Many Orobanche tolerant genotypes along with acceptable seed yield have been released such as Giza 402(Nassib *et al.*, 1978), Baraca (Nadal *et al.*, 2004) Giza 429,Giza 674, Giza843, Misr1and Misr2 (El-Shiribini and Mamdouh, 2004) and Najeh (XBJ90.03-16-1-1-1) (Kharrat*et al.*, 2010 and Abbes *et al.*, 2011).The present study aimed to evaluate the behavior of fifteen faba bean genotypes for Orobanche tolerance under natural heavy infested and non-infested fields with Orobanche.

MATERIALS AND METHODS

The present investigation was carried out at Sakha Agricultural Research Station, Kafr El-Sheikh governorate, ARC, Egypt during 2020/21 and 2021/22 growing seasons, to evaluate fifteen genotypes of faba bean contained eleven promising breeding lines derived from 11 cross-populations for Orobanche tolerance comparing with four commercial cultivars as checks. The check cultivars were Sakha4 and Nubaria1 (susceptible to *O. crenata*), Misr1 and Giza843 (tolerant to *Orobanche crenata*). The pedigrees of the tested fifteen faba bean genotypes were as follow:

Table 1. Names, pedigrees, origin and botanical group of faba bean genotypes used in this investigation.

Genotypes	Pedigrees	Origin	Botanical group
Line 1	(Giza 2 x Misr1)	Egypt	Equina
Line 2	(Sakha 3 x Giza2)	Egypt	Equina
Line 3	(Giza843 x Misr3)	Egypt	Equina
Line 4	(Nubaria1 x Misr 3)	Egypt	Equina
Line 5	(Misr 1 x Giza843)	Egypt	Equina
Line 6	(Nubaria3x Misr1)	Egypt	Equina
Line 7	(Sakha 1 x Misr 1)	Egypt	Equina
Line 8	(Triple white x Giza429)	Egypt	Equina
Line 9	(Giza40 x Giza429)	Egypt	Equina
Line 10	(Ohishima-Zaira x Giza429)	Egypt	Equina
Line 11	(Giza429 x Sakha 4)	Egypt	Equina
Nubaria 1	Individual plant selected from Spanish variety	Egypt	Major
Sakha 4	(Giza 3 x Sakha 1)	Egypt	Equina
Misr 1	(Giza 3 / 123A /45 / 76)	Egypt	Equina
Giza 843	(461 / 845 / 83 x 561 / 2076 / 85)	Egypt	Equina

The tested faba bean genotypes were evaluated in a Randomized Complete Blocks Design (RCBD) with three replications in both infested and Orobanche-free soils. The experimental plot consisted of four ridges, 3 m length and 0.6 m width. Faba bean seeds were planted in single seeded hills, 20 cm apart on both sides of each ridge. Sowing was done during the last week of October in the two growing seasons. The other cultural practices were applied as recommended.

Days to 50% flowering were recorded for each genotype under infested and non-infested soils. Also, the reaction to foliar diseases was recorded on mid-March for chocolate spot (*Botrytis fabae*) and rust (*Uromyces fabae*), according to the diseases scales reported by (Bernier *et al.,* 1993).

At harvest maturity, ten guarded plants were taken at random from each plot to determine the agronomic traits: plant height (cm), number of branches/plant, number of pods/plant, number of seeds/plant, seed yield /plant (g) and 100-seed weight (g).The two middle ridges of each plot were harvested to determine the seed yield in ardab/feddan (one ardab=155 Kg and one feddan =4200 m^2). The *Orobanche* spikes in one square meter in each plot were pulled and counted to estimate the number of *Orobanche* spikes/m^2, spikes fresh weight (g/m^2) and spikes dry weight (g/m^2).

Seed properties were carried out at Seed Technology Dept. Sakha, Agric. Research Station as follows:

Viability: Electrical conductivity (EC) of leaches from four replicates of 50 seeds weighted and soaked in 250 ml of distilled water for 24 h and was measured in µ-mhos using conductivity meter, under optimum conditions according to the international rules (I.S.T.A, 1999).

1-The conductivity (E.C) per gram of seed weight for each sub sample is calculated:

$$E.C = \frac{Conductivity\ for\ each\ flask}{Weight(g)\ seed\ sample}$$

2- Seed protein and carbohydrate contents: were determined according to procedures outlined in A. O. A. C. (1990).

3- **Total Tannins content (TTC):**

The analyses of tannin content in seeds were performed according to the International Pharmacopoeia and AOAC methods (Horwitz, 2010)with some modifications. Three grams of seeds powder was infused with 250 mL of deionized double distilled water, then filtered through a 0.45 µm sample filter. 25 mL of the distillation was added into 1 L conical flask and then 25 mL of indigo solution [0.6%] and 750 mL deionized distilled water was added. The solution was titrated with 0.1 N aqueous solution of $KMNO_4$ until the blue-colored solution changed to the golden yellow one. The standard solution of indigo carmine was prepared as follows: 6 g indigo carmine was dissolved in 500 mL of deionized distilled water by heating, and after cooling, 50 mL of 98% H_2SO_4 was added. The solution was diluted to 1 L with deionized distilled water and filtered through a 0.2 µm membrane filter. The blank test was carried out by titration of 25 mL indigo carmine and 775 mL double distilled water. All samples were analyzed in duplicates. The tannin percent [%] in the samples was calculated as Eq1 follows:

TTC = [V – V0] 0.004157 × 250 × 100/g × 25

where V is the volume of 0.1 N aqueous solution of $KMNO_4$ used in the titration of the sample and V_0 is the volume of 0.1 N aqueous solution of $KMNO_4$ used in the titration of the blank sample as mL; 0.004157 is the tannins equivalent in 1 mL of 0.1 N aqueous solution of $KMNO_4$; g is the mass of the sample taken for the analysis as gram and 250 is the volume of the volumetric flask

Statistical Analysis:

Obtained data were subjected to proper statistical analysis of variance according to Snedecor and Cochran, (1971). MSTATC program was used to analyze data. Duncan´s Multiple Range Test (Duncan, 1955) was used to compare means of studied traits.

RESULTS

Faba bean genotypes were evaluated under both free and infested field with broomrape parasitic weed, the obtained data showed significant differences in all agronomic studied characteristics and *orobanche* studied traits among tested genotypes under both conditions. Data will be discussed as follow:

A- Performance of Vicia faba genotypes under free-Orobanche soil.

Data of faba bean genotypes at field free of broomrape parasitic weed infestation are presented in Tables 2, 3 and 4. For diseases resistance, all tested genotypes were resistant or moderately resistant against chocolate spot and rust, moreover all tested lines as well as Sakha 4 variety exceeded other commercial varieties and lines under evaluation.

L7 and L10 were the earlier genotypes and recorded the lowest days to flowering during both seasons. On the other hand, L7 and L6 faba bean genotypes recorded the highest values for most studied traits (plant height, number of branches per plant, pods/plant, and number of seeds/plant in addition to seed yield) in the was free field of broomrape infestation. While, the highest 100-seed weight was recorded by commercial variety Nubaria1 during both seasons. For seed yield, L7 faba bean genotype followed by L6 genotype and produced the highest seed yield (16.62 and 16.25 ardab fed^{-1}), respectively as an average of both seasons.

Table 2. Reaction of studied faba bean genotypes to chocolate spot and rust diseases infection and flowering date under *Orobanche*free-soil during 2020/2021 and 2021/2022 seasons.

Genotype	Chocolate spot		Rust disease		Flowering date (days)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	3.7 bcd	4.0 a-d	3.0	3.3 bc	56.7 b	56.7 b
L2	3.7 bcd	3.7 bcd	2.7	3.0 bc	56.7 b	56.7 b
L3	3.7 bcd	3.7 bcd	2.7	3.0 bc	53.3 bcd	53.3 bcd
L4	3.7 bcd	4.0 a-d	3.7	3.3 bc	51.7 cde	53.3 bcd
L5	3.7 bcd	3.7 bcd	3.7	3.0 bc	53.3 bcd	55.0 bc
L6	3.7 bcd	3.7 bcd	3.3	3.0 bc	51.7 cde	53.3 bcd
L7	3.3 cd	3.7 bcd	3.3	3.7 bc	46.7 fg	46.7 ef
L8	3.3 cd	3.7 bcd	3.7	3.7 bc	51.7 cde	51.7 bcd
L9	3.3 cd	3.7 bcd	3.7	3.7 bc	53.3 bcd	53.3 bcd
L10	3.3 cd	3.3 cd	3.3	3.0 bc	45.0 g	45.0 f
L11	3.7 bcd	3.7 bcd	3.0	2.7 c	48.3 efg	48.3 def
Nubaria 1	4.3 ab	4.3 abc	3.3	3.3 bc	63.3 a	71.7 a
Sakha 4	3.0 d	3.0 d	3.0	2.7 c	55.0 bc	55.0 bc
Misr 1	5.0 a	5.0 a	4.0	5.0 a	50.0 def	50.0 cde
Giza 843	4.0 bc	4.7 ab	3.7	4.0 b	55.0 bc	55.0 bc
F. test	*	*	N S	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

Table 3. Plant height, number of branches/plant and number of pods/plant of studied faba bean genotypes under *Orobanche* free-soil during 2020/2021 and 2021/2022 seasons.

Genotype	Plant height (cm)		Number of branches/plant		Number of pods/plant	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	124.7 bcd	145.0 b	1.8 g	3.5 bcd	15.8 de	30.1 cde
L2	112.3 fg	141.7 bc	2.2 fg	3.0 efg	17.3 d	32.3 bcd
L3	112.7 fg	135.0 de	3.1 e	3.4 h	16.8 d	33.4 bcd
L4	121.7 cde	143.0 bc	3.5 cde	3.3 c-f	18.1 cd	34.2 bc
L5	119.7 def	145.0 b	3.6 b-e	3.7 bc	20.1 bc	30.2 cde
L6	131.3 a	157.0 a	4.1 b	3.9 b	21.0 b	35.4 b
L7	128.7 bc	137.3 cd	4.9 a	4.3 a	23.4 a	41.3 a
L8	113.3 fg	131.7 ef	3.7 bcd	3.9 b	13.2 f	28.9 de
L9	116.3 efg	128.0 fg	1.7 g	2.8 fg	10.9 g	26.8 e
L10	121.7 cde	138.7 cd	2.4 f	2.6 gh	14.2 ef	28.8 de
L11	136.7 a	156.3 a	2.5 f	3.1 def	19.6 bc	32.4 bcd
Nubaria 1	110.3 g	123.0 g	4.0 bc	4.0 ab	16.1 de	19.8 f
Sakha 4	121.0de	126.0 fg	3.4 de	3.3 cde	21.9 ab	30.3 cde
Misr 1	124.7 bcd	128.3 fg	4.1 b	3.6 bc	20.2 bc	29.8 cde
Giza 843	119.0 def	129.7 ef	3.8 bcd	3.5 bcd	20.9 b	30.3 cde
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

Table 4. Number of seeds per plant, 100-seed weight and seed yield per feddan of studied faba bean genotypes under *Orobanche* free-soil during 2020/2021 and 2021/2022 seasons.

Genotype	Number of seeds /plant		100-seed weight		Seed yield (Ardab/fed)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	42.1 f	94.8 efg	71.8 h	67.9 efg	13.87 h	13.54 f
L2	45.9 ef	92.3 fgh	71.6 h	66.5 efg	13.87 h	15.64 bc
L3	47.7 ef	86.6 h	76.9 fg	70.5 def	15.50 d-e	15.35 cd
L4	47.1 ef	101.8 cde	73.0 h	64.5 g	14.12 gh	14.69 de
L5	61.8 bc	98.8 def	83.2 c	68.7 efg	16.15 abc	15.86 bc
L6	74.0 a	114.0 b	78.0 efg	66.1 fg	16.45 ab	16.11 ab
L7	79.2 a	121.9 a	66.6 i	64.2 g	16.53 a	16.71 a
L8	49.2 e	100.0 de	80.7 cde	70.9 de	15.96 a-d	15.79 bc
L9	31.6 g	76.7 i	87.8 b	86.8 b	10.97 j	13.52 f
L10	32.4 g	88.7 gh	83.3 c	71.0 de	11.25 j	12.63 g
L11	45.9 ef	103.1 cd	79.9 def	67.3 efg	14.64 e-h	13.52 f
Nubaria 1	35.4 g	73.3 i	114.5 a	112.7 a	12.61 i	11.43 h
Sakha 4	65.0 b	99.0 def	81.7 cd	73.8 cd	15.21 c-f	14.40 e
Misr 1	55.8 d	89.9 gh	76.1 g	75.5 c	14.28 fgh	11.56 h
Giza 843	58.6 cd	107.2 c	78.7 d-g	68.8 efg	15.02 d-g	11.74 h
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

B- Behavior of faba bean genotypes for *Orobanche* sp under weed infestation:

Data of fifteen faba bean genotypes under heavy natural infestation by *Orobanche* (this field is used to evaluate faba bean genotypes for many years before) are shown in Tables 5, 6 and 7. All genotypes showed different response for biotic stress by the parasitic weed in all studied traits during 2020/2021 and 2021/2022 growing seasons. All tested genotypes appeared resistance to moderately resistance against both of chocolate spot and rust diseases through this study. Genotypes L1, L3, L7, L8, L9 and Sakha4 cultivar exceeded the rest genotypes and were resistant to both diseases in the two seasons.

Flowering date for tested genotypes ranged from 43.3 to 60 days, while L7 and L8 were the earlier than the others and recorded the significant lowest days to flowering. L6 genotype surpassed rest faba bean genotypes under *Orobanche* infestation and produced the highest values of number of branches, pods per plant, plant height, number of seeds/plant and seed yield per feddan significantly followed by L7 genotype in both growing seasons. While the heaviest 100-seeds were scored by Nubaria 1 cultivar in both seasons. These findings agree with those recorded by (Abdalla and Darwish, 1999, Abd El-Wahab, 2007 and Abbes *et al.,* 2008).

Table 5. Reaction of studied faba bean genotypes against chocolate spot and rust diseases infection and flowering date affected by genotypes under *Orobanche* infested-soil during 2020/2021 and 2021/2022 seasons.

Genotype	Chocolate spot		Rust disease		Flowering date (days)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	3.0 c	3.0 d	2.0 d	2.3 f	56.7 ab	51.7 b
L2	4.0 b	4.0 b	3.7 b	3.7 bc	56.7 ab	51.7 b
L3	3.0 c	3.0 d	2.0 d	2.3 f	56.7 ab	51.7 b
L4	4.0 b	4.0 b	4.0 a	4.0 b	51.7 bc	48.3 bcd
L5	4.0 b	4.0 b	3.0 c	3.0 de	48.3 cd	46.7 bcd
L6	4.0 b	4.0 b	4.0 a	4.0 b	50.0 cd	46.7 bcd
L7	3.0 c	3.0 d	3.0 c	3.0 de	45.0 d	41.7 d
L8	3.0 c	3.0 d	3.0 c	3.0 de	43.3 d	43.3 cd
L9	3.0 c	3.0 d	3.0 c	3.0 de	46.7 cd	46.7 bcd
L10	5.0 a	5.0 a	4.0 a	4.0 b	43.3 d	45.0 bcd
L11	3.0 c	3.3 cd	3.0 c	3.0 de	43.3 d	45.0 bcd
Nubaria 1	3.0 c	3.7 bc	3.0 c	3.3 cd	60.0 a	60.0 a
Sakha 4	3.0 c	3.0 d	2.0 d	2.7 ef	48.3 cd	50.0 bc
Misr 1	5.0 a	5.3 a	4.0 a	4.7 a	45.0 d	45.0 bcd
Giza 843	4.0 b	4.0 b	4.0 a	4.0 b	43.3 d	45.0 bcd
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

Table 6. Plant height, number of branches/plant and number of pods / plant of studied faba bean genotypes under *Orobanche* infested-soil during 2020/2021 and 2021/2022 seasons.

Genotype	Plant height (cm)		Number of branches/plant		Number of pods/plant	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	124.0 ab	128.3 cd	2.0 c	2.2 c-f	5.6 e	14.7 bc
L2	123.7 ab	139.0 ab	2.2 c	1.9 f	6.3 e	16.1 b
L3	119.3 bc	133.7 bcd	3.1 b	2.1 def	12.6 d	16.9 b
L4	124.3 ab	136.7 abc	3.3 ab	2.5 b-e	14.4 c	19.5 a
L5	119.0 bc	139.7 ab	3.1 b	2.8 b	13.4 cd	13.3 cd
L6	131.3 a	145.7 a	3.7 a	3.7 a	18.4 a	21.2 a
L7	131.7 a	139.3 ab	3.3 ab	3.3 a	16.7 b	20.9 a
L8	116.7 bc	100.0 f	2.2 c	2.1 def	5.0 ef	11.9 de
L9	117.3 bc	95.3 f	2.1 c	2.3 c-f	5.1 ef	10.1 e
L10	117.7 bc	108.7 e	2.3 c	2.5 b-e	3.7 fg	9.8 e
L11	112.7 c	127.0 d	2.3 c	2.1 def	3.8 fg	7.0 f
Nubaria 1	93.7 d	60.0 g	1.1 d	1.9 f	0.7 h	1.5 g
Sakha 4	90.7 d	91.7 f	1.3 d	2.0 ef	3.1 g	4.5 f
Misr 1	120.3 bc	134.7 bcd	3.0 b	2.6 bcd	12.1 d	14.8 bc
Giza 843	116.7 bc	115.0 e	3.2 b	2.8 bc	14.4 c	21.3 a
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

C- Number fresh and dry weights of *Orobanch* spikes as affected by faba bean genotypes: Data presented in Table (8) showed significant differences among evaluated genotypes in behavior against parasitic weed broomrape, L6 was the best in reducing number of *Orobanche* spikes, fresh and dry weights in both growing seasons with no significant difference between L7, L4 and L5in this respect. Misr 1 and Giza 843 as resistant cultivars against broomrape showed the same significance in abovementioned traits for parasitic weed during this study. On the other hand, Nubaria 1 as a sensitive variety to *Orobanche crenata* recorded the highest spikes number, fresh and dry weights of broomrape followed by Sakha.

Table 7. Number of seeds per plant, 100-seed weight and seed yield per feddan of faba bean genotypes under *Orobanche* infestation in 2020/2021 and 2021/2022 seasons.

Genotype	Number of seeds /plant		100-seed weight(gm)		Seed yield (Ardab/fed)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	14.6 f	39.2 de	63.0 ef	50.0 e	3.17 d	6.64 e
L2	26.4 d	54.6 ab	62.6 ef	57.1 cd	4.15 c	7.73 cd
L3	20.4 e	49.5 bc	67.3 de	63.6 bc	1.66 e	7.79 cd
L4	47.2 b	46.9 c	70.3 cd	62.2 bc	5.95 a	8.18 bc
L5	39.7 c	46.6 c	75.5 bc	64.1 b	5.25 b	8.16 bc
L6	57.6 a	61.1 a	71.3 bcd	62.5 bc	6.02 a	8.82 a
L7	45.5 b	58.4 a	63.2 ef	63.5 bc	5.84 ab	8.45 ab
L8	15.5 f	24.2 f	75.7 bc	61.3 bcd	1.12 e	5.17 f
L9	10.9 fg	26.3 f	60.8 f	61.9 bc	0.49 f	4.74 f
L10	11.2 fg	25.5 f	74.1 bc	60.9 bcd	0.46 f	4.23 g
L11	39.4 c	60.8 a	73.1 bcd	55.3 de	4.64 c	4.94 f
Nubaria 1	2.4 h	1.2 h	87.1 a	74.3 a	0.16 f	0.14 i
Sakha 4	8.3 g	12.0 g	67.0 de	63.1 bc	0.22 f	1.13 h
Misr 1	36.8 c	44.9 cd	75.1 bc	74.3 a	5.31 b	7.44 d
Giza 843	37.8 c	36.0 e	77.4 b	67.1 b	5.64 ab	8.02 bc
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

Table 8. Number of *Orobanche* spikes m^{-2}, fresh and dry weights infested field as affected by faba bean genotypes in 2020/2021 and 2021/2022 seasons.

Genotype	No of O .spikes (m^{-2})		Fresh weight (g m^{-2})		Dry weight (g m^{-2})	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	56.7 de	61.3 cd	475.6 d	706.7 b	201.9 cd	279.5 e
L2	71.0 b	74.7 b	426.0 e	535.7 c	209.7 cd	354.7 c
L3	67.3 bc	65.0 c	352.7 f	377.1 d	182.1 de	272.0 ef
L4	51.7 de	50.3 e-h	356.2 g	322.7 de	164.6 de	234.7 fg
L5	52.3 de	47.3 fgh	376.0 fg	316.7 de	172.8 de	232.7 fg
L6	50.3 e	44.7 h	296.3 h	292.0 e	141.4 e	159.4 i
L7	53.7 de	46.3 gh	326.0 h	308.0 de	166.5 de	190.0 hi
L8	56.3 de	53.0 d-h	450.7 d	550.7 c	242.2 bc	328.7 cd
L9	58.3 de	55.0 d-g	532.3 c	557.0 c	264.0 b	350.3 c
L10	55.3 de	56.3 def	452.7 d	496.3 c	252.7 b	363.3 c
L11	60.0 cd	58.3 cde	536.0 c	526.7 c	257.7 b	293.0 de
Nubaria 1	96.0 a	99.0 a	853.3 a	833.3 a	452.6 a	485.3 a
Sakha 4	100.3 a	75.3 b	760.0 b	727.3 b	416.0 a	441.7 b
Misr 1	56.7 de	51.7 e-h	374.7 fg	332.0 de	173.1 de	218.7 gh
Giza 843	60.0 cd	56.3 def	408.0 ef	330.3 de	174.1 de	212.0 gh
F. test	**	**	**	**	**	**

*, **, N.S indicates P< 0.05, P< 0.01 and not significant, respectively. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

D- Comparison among faba bean genotypes in infested and free fields by broomrape. Under this investigation, eleven faba bean genotypes in addition to four commercial varieties (two resistant to broomrape and two sensitive) were evaluated in infested and free fields of broomrape parasitic weed.

L6 and L7 genotypes surpassed other tested genotypes under the two environments. In free fields of *Orobanche*, L7 ranked first and produced 16.62 ardab/fed, while L6 recorded 16.28 ardab/fed as average of both seasons. While under high natural infestation by *Orobanche*, the seed yield decreased by 57 and 54% for both genotypes respectively. Giza 843 commercial variety tolerant to *Orobanche* produced 13.38 and 6.83 ardab/fed as an average under free and infested fields respectively by reduction percent of 52.3% in seed yield. For sensitive cultivars, Sakha 4 produced 14.8 and 0.68 ardab/fed, while Nubaria 1 recorded 12.02 and 0.15 ardab/fed seed yield under free and infested fields respectively by reduction percent of 95.4 and 98.7% for both cultivars, respectively under heavy infestation of *Orobanche* parasitic weed.

E- Seed quality traits:

The mean performance of studied faba bean genotypes under *Orobanche* -infested and Orobanche-free soil conditions in two seasons is presented in Tables 9 and 10. The results showed significant differences among evaluated genotypes in all seed quality traits in both seasons.

For EC, data illustrated in Tables 9 and 10 showed that all studied genotypes significantly showed less values of electrical conductivity in the *orobanche*-free field than those in the *orobanche*-infested field in both seasons, electrical conductivity for tested genotypes ranged from 22.3 to 38.0 µ-mhos .respectively, L3 gave the higher EC value under the two soils, while lower EC values were scored by Nubaria-1 cultivar in both seasons. In general, the best viability (by decline electrical conductivity) was recorded in the *orobanche* -free soil. The percentages of crude protein and total carbohydrates contents were higher in *orobanche* -free soil than those in the orobanche -infested field in both seasons. The results of Tannin content showed noticeable increase in tannin upon infection of faba bean plants with Orobanche. Regarding tannin contents of tested genotypes L7, L6 and Giza843 recorded the highest tannin contents. Respectively, the lowest values of tannin were exhibited for Nubaria-1 under two field conditions in both seasons.

Table 9. **Seed quality as affected by faba bean genotypes in free-soil of *Orobanche* during 2020/2021 and 2021/2022.**

Genotype	E.C µ m g^{-1}		Crude protein content (%)		Carbohydrates content (%)		Tannin content mg/g	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	26.3 g	25.5 h	30.9 d	31.0d	43.3 f	44.6 ef	6.0 c	6.50 a
L2	28.5 de	28.4 de	25.9 f	26.3f	47.3 de	47.3 cd	5.5 d	5.01 b
L3	38.0 a	37.7 a	32.7 c	32.0c	40.9 g	42.8 fg	2.5 f	2.32 d
L4	32.8 b	32.3 b	24.7 f	24.7f	47.8 cd	48.3 bcd	4.0 e	6.72 a
L5	28.7 cde	28.3 e	32.6 c	32.4c	40.3 g	41.3 gh	4.3 e	4.20 b
L6	25.0 h	25.1 i	34.1 b	35.0b	50.2 b	50.4a	7.0ab	6.72 a
L7	24.7 h	24.1 j	36.2a	37a	52.8 a	51.2 a	7.2 a	6.82 a
L8	23.2 i	22.8 l	27.3e	28.0e	32.4 j	40.0gh	5.7 cd	5.04 b
L9	26.0 g	25.8 h	33.4 bc	33.7bc	38.6 hi	39.4 h	6.9 ab	6.73 a
L10	27.3 f	26.8 g	20.9 g	21.0g	46.6 de	40.0 h	5.3 d	4.23 b
L11	29.0 cd	29.5 c	25.6 f	26.1f	47.1 de	48.2 cd	5.3 d	5.05 b
Nubaria 1	22.3 j	22.1 m	22.6 g	21.2g	37.4 i	36.1 i	3.8 g	1.60 d
Sakha 4	23.1 i	23.4 k	20.9 g	22.3g	46.1 e	40.3	4.0 e	5.96 a
Misr 1	27.9 f	27.7 f	24.8 f	25.0f	40.0 gh	49.9 abc	6.7 b	4.95 b
Giza 843	29.3 c	28.8 d	33.8bc	34.0ba	49.2 bc	50.9 ab	7.0 ab	6.72 a
F. test	**	**	**	**	**	**	**	**

** indicates P< 0.01. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

Table 10. **Seed quality as affected by faba bean genotypes under *Orobanche* infestation during 2020/2021 and 2021/2022.**

Genotype	E.C µ m g^{-1}		Crude protein content (%)		Carbohydrates content (%)		Tannin content mg/g	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
L1	28.3 e	29.0 f	29.4 d	29.2 cd	44.6 d	43.0d	6.7 d	7.7 c
L2	31.6 c	31.3 de	27.7 e	27.4 de	46.9 c	46.7c	5.9 e	6.0ef
L3	36.3 a	37.0 a	31.0 c	30.7 bc	43.0 e	41.5e	9.3 b	9.4 b
L4	30.0 d	31.0 e	24.8 g	24.6 f	48.2 bc	48.5bc	7.5 c	11.4 a
L5	30.3 d	32.0 cd	31.3 c	32.0 b	40.7 fg	40.7fg	5.9 e	6.3 e
L6	27.0 f	27.0 h	32.3 bc	34.32b	49.1 b	45.27b	9.2a	11.4 a
L7	26.7 fg	27.7 gh	35.0a	34.5a	52.3 a	48.2a	11.7a	9.0 b
L8	24.6 h	25.0 i	27.0ef	26.9 e	35.3 h	38h	5.1 f	6.0ef
L9	27.0 f	28.3 fg	32.3 b	32.0 b	39.7 fg	36.0fg	6.7 d	7.0 d
L10	28.7 e	29.0 f	21.0 h	22.3 g	46.9 c	38.0h	5.1 f	4.3 g
L11	31.4 c	32.7 bc	26.0 fg	22.5 ef	47.0 c	47.9bc	5.9 e	6.3 e
Nubaria 1	24.9 h	24.9 i	22.0 h	20.7 g	39.4 g	31.0i	3.8 h	1.8 h
Sakha 4	24.6 n	24.2 i	20.8 h	20.7g	51.4 a	36.4h	4.2 g	7.0 d
Misr 1	26.3 g	27.0 h	22.0 h	20.9 g	41.0 f	46.0bc	7.6 c	5.7 f
Giza 843	32.1 b	33.0 b	33.0b	32.0 b	49.5 b	49.4b	9.2 b	9.4 b
F. test	**	**	**	**	**	**	**	**

** indicates P< 0.01. In a column, values *fb* the same letters are not significantly differed at 5% level, using DMRT

DISCUSSION

All genotypes showed different responses for biotic stress by the parasitic weed for all studied traits. High genetic diversity was found which; it could be helpful to identify superior genotypes with high disease resistance in addition to reduce the damage caused by broomrape infestation.

L7 and L6 were superior genotypes, under broomrape infestation, in addition to the highest values of plant height, number of branches per plant, pods/plant, number of seeds/plant and seed yield. The superiority of both genotypes may be related to high ability in producing more branches, pods and number of seeds per plant which reflex on improving seed yield of both genotypes. These results are similar to those obtained by (Abdalla and Darwish, 1999; Abd El-Wahab, 2007; Abbes et al., 2008; Ashrie *et al.,* 2010). Also, L6 followed by L7 were the best in reducing number of *Orobanche* spikes, fresh and dry weight, these results are in harmony with those confirmed by (Abbes *et al*., 2007; Abbes *et al*., 2011)**.**

The seed yield was decreased in L7 and L6 by 57 and 54%, respectively under *Orobanche* infestation. While the sensitive cultivars, Sakha 4 and Nubaria 1 were reduced by 95.4 and 98.7% for both cultivars, respectively under heavy infestation of *Orobanche* parasitic weed. These data reflex the important role of breeding resistant faba bean genotypes against broomrape as a main component of integrated weed management (IWM) especially in infested fields by such parasite. These results agree with those obtained by Rubiales *et al*., 2003, Abbes *et al*., 2010 and Trabelsi *et al.,*(2015).

An increase in seed protein content was observed and cloud be related to the reduced seed yield in infected plant/ and, in parallel, to the enhanced N content in leaves (Alonge *et al*., 2005). These findings are clearly supported by those obtained by Morsy and Attia, 2002 and Zakaria *et al*., 2015 the susceptible cultivar Nubaria 1 gave the lowest values for crude protein and total carbohydrates, while L7, L6 and Giza843 gave the highest values for protein and total carbohydrates. It could be concluded that seeds from *Orobanche*-free field were better than those of *Orobanche*-infested field. In general, the recent finding match true with those presented by Ashrie *et al.* (2010).

Tannin content as well as antioxidant and activity play an important role in the plant defense mechanisms. L7 and L6, Giza843 recorded the highest tannin content, where the lowest values of tannin were exhibited for the sensitive variety Nubaria-1 under two field conditions in both seasons. These results agree with (Ashrie *et al.,* 2010; Skorie *et al.,* 2012; Zakaria *et al.,* 2015).

CONCLUSION

Based on the obtained results of current study, it could be concluded that L6 (Nubaria 3 x Misr 1) and L7 (Sakha1 x Misr 1) genotypes surpassed all tested genotypes under infected and free fields of *Orobanche crenata* parasitic weed and produced 16.28 and 16.62 ardab/fed seed yield, respectively as average of the two seasons under free-field of broomrape, while under high natural infestation by the weed recorded 7.42 and 7.15 ardab/fed, respectively, Along with the resistance against chocolate spot and rust diseases in both seasons. L7, L6 and Giza843 genotypes gave the highest values of crude protein, total carbohydrates, and total Tannin contents, respectively, while Nubaria1 gave the lowest values.

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التقييم الحقلي لخمسة عشر تركيباً وراثياً من الفول البلدي لتحمل الهالوك و مقاومة أمراض المجموع الخضري

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أجريت هذه الدراسة فى موسمي الزراعة 2020/ 21و 2021/ 22 في محطة البحوث الزراعية بسخا محافظة كفر الشيخ مصر لدراسة سلوك خمسة عشر تركيب وراثي منهم أحد عشر سلاله مبشره ناتجه من برنامج لتربية وهم : L1 (جيزة x2 مصر1) ,L2 (سخا3 x جيزة2) , L3 (جيزة843 x مصر3) , L4(نوبارية1 xمصر3) ,L5 (مصر1 xجيزة843), L6 (نوبارية3x مصر1),L7 (سخا1 x مصر1) , L8(Triplewhite x جيزة 429) , L9 (جيزة40x جيزة 429) , L10 (x Ohishima-Zaira جيزة 429) وL11 (سخا 4 x جيزة 429) مقارنة بأربعة أصناف تجارية هي سخا 4 ونوبارية 1 (صنفين حساسين للإصابة بالهالوك) , مصر1 وجيزة 843 (صنفين متحملين للإصابة بالهالوك). أوضحت النتائج المتحصل عليها في الحقل الخالي من الإصابة بالهالوك أن التركيب الوراثي L7 (سخا1 x مصر1) كان الأفضل وسجل أعلي عدد فروع /النبات, عدد قرون وعدد البذور للنبات ومحصول البذور للفدان بدون فروق معنوية مع التركيب الوراثي L6 (نوبارية3 x مصر1) متجاوزاً الأصناف التجارية تحت الدراسة في الموسمين. بينما في الحقل المصاب بالهالوك أظهرت التراكيب الوراثية L7 وL6 تفوقاً علي التراكيب الوراثية الأخري في معظم الصفات المدروسة حيث سجلا أعلي القيم في عدد الفروع وعدد القرون وعدد البذور للنبات وكان المحصول بمتوسط 7,42 و7,15 أردب للفدان كمتوسط للموسمين علي التوالي وأقل عدد شماريخ ، وزن رطب و وزن جاف للهالوك. ونستنتج أن التراكيب الوراثية L6وL7 قد تفوقت علي كل التراكيب الوراثية في الحقلين المصاب وغيرالمصاب بالهالوك مع أعلي إنتاج من محصول البذور بالإضافة الي مقاومة مرضي الصدأ والتبقع البني لذلك تستحق هذه التراكيب الوراثية التقييم في تجارب المحصول المتقدمه فربما يستنبط منها وتصبح أصناف تجارية متحملة للهالوك و مقاومة للأمراض بالإضافة الي انتاجية عالية للمحصول. وأظهرت النتائج وجود إختلافات معنوية لكل صفات الجودة بين التراكيب الوراثية تحت الدراسة في كل من الحقلين (الخالي والموبوء بالهالوك) وسجلت التراكيب الوراثية L7 وL6 والصنف جيزة 843 أعلي قيم لنسب البروتين والكربوهيدرات والتنينات في حين سجل الصنف نوبارية 1 أقل القيم لتلك الصفات المدروسة.

الكلمات المفتاحية: الفول البلدي، تحمل الهالوك، مقاومة الامراض ، التبقع الشوكلاتى ، الصدأ.