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# GENETIC NATURE AND HERITABILITY OF *Orobanche crenata* RESISTANCE IN FABA BEAN (*Vicia faba* L.)

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## ABSTRACT

The present study aimed to understand the genetic nature and heritability of *orobanche crenata* resistance in faba bean, using a diallel analysis of $F_1$ generation. Five genotypes were used; Misr 1, x-1714, x-1722 (tolerant), Nubaria 1 and Giza 40 (susceptible). Seed yield and its attributes (days to 90% maturity, plant height (cm.), no. of branches/plant, no. of pods/plant, no. of seeds/plant, seed yield/plant (g) and 100-seed weight (g) were recorded under both free and infested field. The orobanche resistance related criteria (Date of *Orobanche* emergence, no. of *Orobanche* spikes/ $m^2$ and *Orobanche* dry weight ($g/m^2$) were recorded under infested field. The results indicated that additive effect is very important for genetic control of 90% maturity, while dominance effect plays an important role in genetic control of 100-seed weight under infested condition. Both additive and dominance effects play an important role in the genetic control of three *Orobanche* criteria, which related to *Orobanche* resistance. Mean degree of dominance $(H_1/D)^{1/2}$ indicated the presence of over dominance for no. of pods/plant, 100-seed weight(g) and *Orobanche* dry weight ($g/m^2$)under infested field. Regarding, no. of *Orobanche* spikes/ $m^2$ possessed complete dominance. While, other characters had partial dominance under both free and infested conditions. Unequal frequencies of positive and negative genes were found among parents under study as well as unequal distribution occurred between dominant and recessive genes with more dominant than recessive genes in the parents for three *Orobanche* related resistant criteria and plant height (cm.) under infested condition. The direction of dominance was towards of late of maturity , increasing no. of branches/plant and no. of seeds/plant under free field while, under infested field the direction of dominance was towards of long of plant height (cm.) and increasing 100-seed weight (g). Important and remarkable findings were noticed whereas, three *Orobanche* related resistance criteria possessed a positive correlation coefficient (r), the direction of dominance towards low values of three criteria were dominant over high values. Therefore, the *Orobanche* resistant gene was dominant over susceptible recessive genes. High heritability estimates in the broad-sense ($h^2_b s$) were recorded for all the studied characters. High heritability estimates in narrow-sense were obtained for almost criteria except 100-seed weight and *Orobanche* dry weight under infested field. The $F_1$ graphic analysis confirmed the above results on the mean degree of dominance. In addition, additive gene effects play an important role in the genetic control of 90% maturity under free condition. Misr 1 variety possessed most resistance genes for *Orobanche*. The correlation coefficient confirmed the highly negative correlation between seed yield and its attributes i,e date of *Orobanche* emergence and no. of *Orobanche* spikes/ $m^2$.

**Keywords:** Genetic studies, Heritability, *Orobanche crenata*, Resistance, Faba bean.

## INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the main pulse crops grown for seed in Egypt. It is widely considered as a good source of protein, starch, cellulose and minerals for humans in developing countries and for animals in industrialized countries (Haciseferogullari *et al.*, 2003). In

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addition, faba bean is one of the most efficient fixers of the atmospheric nitrogen and, hence, can contribute to sustain or enhance total soil nitrogen fertility through biotical $N_2$-fixation (Lindemann and Glover, 2003).

The average cultivated area in Egypt over the last five years (2006-2011) was about 147.000 feddans with an average yield of 8.8 ardabs/feddan.

Broomrape (*Orobanche sp.* Orobanchaceae) is a parasitic plant that attacks and causes yield loss of many important dicotyledonous crops throughout the world (Parker, 1986), by removing carbohydrates and water (Schaffer *et al.*, 1991).

Despite of the pressing need for greater annual production in order to meet an increasing demand of faba bean seeds, the existing cultivars has been dwindling lately mainly due to pest attacks of the most devastating pest of 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 losses in seed yield and sometimes a complete failure of the crop in endemic land. Moreover, seeds of this parasitic weed remain viable for years in the infested soil thus posing a constant threat to the annual acreage since more land is being rendered uncultivable with faba bean every year. Various measures for *Orobanche* control have been tried including improved cultural practices, use of chemicals (Nassib *et al.*, 1992) and use of high levels of nitrogen fertilization (Nassib and Hussein, 1985). However, cultivar resistance remains the most effective and economic control means. Resistant genotypes can grow satisfactorily and yield well in infested fields thus alleviating the hazards of *Orobanche* attacks. Breeding efforts have been employed for combining genes for adaptability and high yield from elite faba bean genotypes with those for tolerance to Orobanche (Cubero, 1973; Nassib *et al.*, 1979; El-Deeb *et al.*, 1999). However, information on the genetics of resistance to *Orobanche* is scant and the nature of the genetic system involved is far from clear which might account for the rather limited number of resistant cultivars released through breeding. The limited success of the breeding efforts for selecting faba bean cultivars with enhanced resistance to the devastating parasitic weed *Orobanche crenata* could be attributed to the ambiguity in defining resistance / tolerance, hence the inappropriate choice of the selection criterion. Number of broomrape spikes per host plant was adopted as the most stable index for resistance (Cubero and Moreno, 1979; Abdalla *et al.*, 1981; Gil *et al.*, 1987; Cubero *et al.*, 1993). However, responses to selection for the population of plants without *Orobanche* shoots (zero-broomrape plants) was found to be slow with very little advance being achieved (Cubero and Moreno, 1979). Soliman *et al.*, 2011, recorded that there was negatively correlated between weight of broomrape spikes per host plant and both of seed yield per host plant and number of seeds per host plant but no such associations were found with number broomrape spikes per host plant.

Resistance against most parasitic weeds is difficult to access, scarce, of complex nature and of low heritability, making breeding for resistance a difficult task. In spite of these difficulties, significant success has been achieved in some crops especially at legumes. In a few instances, resistance of simple inheritance has been identified and widely exploited in breeding (Fernández *et al.*, 2007).

In a systematic breeding program, the components of genetic variance analysis in terms of type of gene action, heritability and breeding potentials of genetic entries involved in the program are obviously essential. Heritability estimates provide a measure of relative importance of the genotypic to the phenotypic variation and the latter being the sum of genotypic and environmental variations. Narrow-sense heritability estimates in faba bean were studied using different materials and methods reported that narrow-sense heritability values were high for 100-seed weight and low to moderate for seed yield and number of pods and seed/plant (El-Hady *et al.*, 1991; El-Lithy,1996; El-Hady *et al.*, 1997; Helal, 1997; El-Hady *et al.*, 1998; Abdalla *et al.*, 2001; Attia *et al.*, 2001; Attia *et al.*, 2002; Attia and Salem 2006; El-Hady *et al.*, 2006 ; El-Hady *et al.*, 2007).

The genetic nature of broomrape resistance does not clear at now and requires more studies on Egyptian faba bean genotypes. Therefore, the present study aimed to estimate the nature of gene action and heritability in broad and narrow sense for related criteria of broomrape resistance, seed yield and some its attributes under heavy infested broomrape and free soils.

## MATERIALS AND METHODS

The present study was carried out under insect free cages at Gemmeza Agricultural Research Station, ARC, Egypt during three successive winter seasons 2008/2009, 2009/2010 and 2010/2011. Five faba bean (*Vicia faba* L.) genotypes were used that comprised three local varieties and two advanced breeding lines. The five genotypes were chosen to represent a wide range of agronomic traits as well as different levels of tolerance to *Orobanche*. The pedigree and the important characteristics of these genotypes are given in Table 1. In 2008/2009 season all possible cross combinations excluding reciprocals were made among the five genotypes using hand emasculation and pollination in order to produce the seeds of the 10 F1 hybrids of the half-diallel cross. In the following season (2009 /2010), re-hybridization were made in order to obtain more hybrid seeds. The parents and their 10 F1's were sown in a randomized complete block design (RCBD) with three replications. In 2010/2011 season under both *Orobanche*-infestion and *Orobanche*-free conditions at Dakahlia governorate. Each block included 10 F1's as well as five parents. Seeds were planted in single seeded hills, 20 cm apart. Each genotype was represented by one row, 3 meters long, and 60 cm in between. Cultural practices were adopted as recommended for faba bean production in the area. Flowering and maturity date were counted. At harvest, all plants were handled individually from each entry and the following characters were recorded; plant height, first pod height, numbers of branches, pods and seeds/plant, seed yield/plant (g) and 100-seed weight (g).The degree of infestation [Date of *Orobanche* emergence, No. of *Orobanche* spikes /$m^2$and *Orobanche* dry weight (g /$m^2$)] were determined. Diallel analysis and heritability in broad and narrow sense were estimated as recording of Hayman, 1954 (a & b) and Mather and Jinks, 1971. Correlation coefficient between seed yield and its attributes with *Orobanche* related criteria were estimated according to Gomez and Gomez, 1984.

**Table 1. The pedigree and some important characteristics of five faba bean parental genotypes**

| Genotype | Pedigree | Characteristics |
|---|---|---|
| **Misr 1 ($P_1$)** | Giza 3 X 123 A / 45 / 76 | Medium seeded type |
| | FCRI | Tolerant to *Orobanche* |
| | | Planting zone : All over the country |
| **x-1714 ($P_2$)** | L.667 X (G. 429 X G.843) | Medium seeded type |
| | FCRI | Tolerant to *Orobanche* |
| **x-1722 ($P_3$)** | L.667 X (C. 241 X G.461) | Medium seeded type |
| | FCRI | Tolerant to *Orobanche* |
| **Giza 40 ($P_4$)** | Individual selected plant from Rebaya 40 | Small seeded type |
| | FCRI | Susceptible to *Orobanche* |
| | | early maturity |
| | | Planting zone : Upper Egypt and New vally |
| **Nubaria 1 ($P_5$)** | Individual selected plant from | large seeded type |
| | Spanish variety Reina blanca | Susceptible to *Orobanche* |
| | Spain | Resistant to foliar diseases |
| | | late maturing |
| | | Planting zone : New lands at Nubaria region |

# RESULTS AND DISCUSSION

Analysis of variance, $t^2$ values and regression coefficient as testing of validity of hypothesis of genotypes under both free and infested conditions for the studied traits Tables 2 and 3. Highly significant differences were recorded for almost traits except number of branches/plant under infested condition. These results indicated the large variation between genotypes under study, especially broomrape criteria and subsequently the genetic improvement and selection of broomrape resistant genotypes.

The major assumptions postulated for diallel analysis (Hayman, 1954a) were found to be valid as the $t^2$ value was insignificant for all characters. Another way for testing the hypothesis is through regression coefficient (b). The regression of Wr/Vr was non-significant different from unity for all characters, except for 100-seed weight (g) under infested field, that confirm the validity of diallel assumptions. The deviation of (b) value from zero was highly significant or significant for plant height, number of pods/plant, 100-seed weight, date of *Orobanche* emergence, no. of *Orobanche* spikes /$m^2$ and *Orobanche* dry weight (g /$m^2$ )under infested field.

The same trend was observed under free field for days to 90% maturity, number of branches/plant, number of pods / plant, number of seeds/plant and 100-seed weight (g) Table 3, suggesting the absence of non-allelic interaction-while it was insignificant for days to 90% maturity, number of branches / plant, number of seeds/plant and seed yield /plant (g) under infested field and for plant height and seed yield/plant (g) (under free field), Tables 2 and 3 suggesting the presence of non-allelic interaction.

The values of Vr + Wr and Yr of parental genotypes for days to 90% maturity, number of branches/plant and no. of seeds / plant, also plant height (cm.), date of *Orobanche* emergence, no. of *Orobanche* spikes /$m^2$ and *Orobanche* dry weight (g /$m^2$) under infested field, also no. of pods/ plant and 100-seed weight (g) under both conditions were presented in Tables 4 and 5.

Estimation of the genetic and environmental components of variance are presented in Tables 5, 6 and 7. Highly significant differences of D and $H_1$ estimates were recorded for *Orobanche* criteria i.e., date of *Orobanche* emergence, no. of *Orobanche* spikes /$m^2$ and *Orobanche* dry weight (g /$m^2$), indicating the importance of additive and dominance gene effects in the genetic control of *Orobanche* criteria, which related to *Orobanche* resistance of faba bean. These results confirmed the selection for improvement of these criteria should occur at early and late segregating generation by using biparametal mating at each generation. In the same trend, additive and dominance components of variation (D, $H_1$) were highly significant for plant height (cm.) under infested field, no. of pods/plant under both conditions, no. of seeds/plant and 100-seed weight (g) under free condition as well as seed yield and its attributes. No. of branches / plant under free condition alone possessed highly significant and significant at D and $H_1$, respectively.

**Table 2. Analysis of variance, $t^2$ values, regression coefficient and their test of significance for Days to 90% maturity, Plant height (cm.), No. of branches / plant, No. of pods / plant and No. of seeds / plant for $F_1$ plants under both free and infested conditions**

| Source of variation | d.f | Days to 90% maturity | | Plant height (cm.) | | No. of branches / plant | | No. of pods / plant | | No. of seeds / plant | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free | Infes. | Free | Infes. | Free | Infes. | Free | Infes. | Free | Infes. |
| **Replication** | **2** | 1.76 | 3.48* | 0.97 | 5.91 | 0.11 | 0.20 | 2.45 | 0.32 | 10.95* | 0.03 |
| **Treatment** | **14** | 24.33* | 26.27** | 59.94** | 82.04** | 2.17** | 0.23 | 43.77** | 98.39** | 134.38** | 739.46** |
| **Error** | **28** | 1.48 | 3.54 | 5.95 | 4.97 | 0.23 | 0.31 | 2.43 | 1.11 | 3.54 | 0.88 |
| $t^2$ | | 0.08 | 0.99 | 5.59 | 0.02 | -1.0 $E^{-05}$ | - | 0.05 | 0.27 | 0.05 | 0.22 |
| **b** | | 0.95 | 0.55 | 0.314 | 0.91 | 0.95 | - | 1.05 | 1.16 | 0.89 | 1.03 |
| **± S.E(b)** | | 0.04 | 0.22 | 1.40 | 0.16 | 0.20 | - | 0.19 | 0.28 | 0.10 | 0.38 |
| $H_0$:b=0 | | 23.28** | 2.51 | 0.22 | 5.85** | 4.82* | - | 5.55* | 4.18* | 8.63** | 2.73 |
| $H_1$:b=1 | | 1.14 | 2.09 | 0.49 | 0.61 | 0.28 | - | -0.27 | -0.56 | 1.08 | -0.09 |

*,** indicate significance at 0.05 and 0.01 levels of probability, respectively.
b=0 and b=1 indicate difference of regression coefficient value from 0 and 1 (unit), respectively.

**Table 3. Analysis of variance, $t^2$ values, regression coefficient and their test of significance for Seed yield / plant (g), 100-seed weight (g), Date of *Orobanche* emergence, No. of *Orobanche* spikes /$m^2$ and *Orobanche* dry weight (g /m2 )for $F_1$ plants under both free and infested conditions**

| Source of variation | d.f | Seed yield / plant (g) | | 100-seed weight (g) | | Date of *Orobanche* emergence | No. of *Orobanche* spikes /$m^2$ | *Orobanche* dry weight (g /$m^2$) |
|---|---|---|---|---|---|---|---|---|
| | | Free | Infes. | Free | Infes. | Infes. | Infes. | Infes. |
| Replication | 2 | 1.48 | 0.01 | 36.80 | 2.93 | 0.311 | 0.474 | 1.703 |
| Treatment | 14 | 47.99** | 397.49 ** | 407.49** | 1177.62** | 111.042 ** | 421.348 ** | 2655.098 ** |
| Error | 28 | 0.98 | 1.12 | 8.25 | 18.68 | 2.799 | 0.942 | 2.617 |
| $t^2$ | | 0.54 | 9.4 $E^{-07}$ | 0.08 | 7.96 | 1.062 | 0.049 | 0.379 |
| b | | -0.34 | 0.84 | 1.11 | 0.32 | 1.505 | 0.884 | 0.750 |
| ±S.E(b) | | 0.77 | 0.32 | 0.13 | 0.10 | 0.177 | 0.122 | 0.097 |
| $H_0$:b=0 | | -0.44 | 2.65 | 8.74** | 3.30 * | 8.503 * | 7.235 ** | 7.763 ** |
| $H_1$:b=1 | | 1.75 | 0.52 | -0.87 | 7.14 ** | -2.853 | 0.950 | 2.589 |

*,** indicate significance at 0.05 and 0.01 levels of probability, respectively.

b=0 and b=1 indicate difference of regression coefficient value from 0 and 1 (unit), respectively.

**Table 4. Value of Vr + Wr and Yr of five faba bean parental genotypes for Days to 90% maturity, Plant height (cm.), No. of branches/plant, No. of pods/plant and No. of seeds/plant**

| Genotypes | Days to 90% maturity | | Plant height (cm.) | | No. of branches/plant | | No. of pods / plant | | | | No. of seeds / plant | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Free | | Infested | | Free | | Free | | Infested | | Free | |
| | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr |
| Misr-1 ($P_1$) | 14.14 | 153.08 | 23.75 | 80.40 | 1.66 | 5.42 | 26.07 | 21.50 | 52.53 | 18.77 | 116.46 | 51.92 |
| X-1714 ($P_2$) | 10.14 | 152.17 | 17.76 | 84.42 | 1.33 | 5.93 | 21.22 | 28.03 | 44.32 | 13.72 | 53.74 | 65.26 |
| x-1722 ($P_3$) | 14.57 | 151.75 | 14.16 | 73.78 | 1.22 | 5.63 | 28.10 | 18.95 | 95.44 | 16.60 | 65.22 | 57.21 |
| Nubaria-1 ($P_4$) | 10.27 | 160.50 | 17.43 | 77.67 | 0.46 | 7.94 | 9.98 | 17.13 | 14.21 | 10.00 | 64.86 | 50.68 |
| Giza-40 ($P_5$) | 11.16 | 151.33 | 107.42 | 65.33 | 0.49 | 6.26 | 19.88 | 28.29 | 24.44 | 2.500 | 19.80 | 68.88 |

**Table 5. Value of Vr + Wr and Yr of five faba bean parental genotypes for 100-seed weight (g), Date of Orobanche emergence, No. of Orobanche spikes /$m^2$ and *Orobanche* dry weight (g /$m^2$)**

| Genotypes | 100-seed weight (g) | | | | Date of *Orobanche* emergence | | No. of *Orobanche* spikes /$m^2$ | | *Orobanche* dry weight (g /$m^2$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Free | | Infested | | Infested | | Infested | | Infested | |
| | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr | Vr+Wr | Yr |
| Misr-1 ($P_1$) | 313.88 | 80.50 | 2.67 | 75.53 | 61.65 | 110.42 | 5.32 | 4.82 | 58.11 | 32.33 |
| X-1714 ($P_2$) | 250.94 | 81.16 | 738.73 | 72.79 | 59.79 | 103.27 | 161.34 | 8.38 | 1117.41 | 60.06 |
| x-1722 ($P_3$) | 111.95 | 72.21 | -15.96 | 66.81 | 64.68 | 99.59 | 200.50 | 19.34 | 1883.65 | 89.08 |
| Nubaria-1 ($P_4$) | 215.55 | 98.28 | 1280.72 | 63.22 | 27.28 | 93.75 | 346.16 | 35.19 | 857.41 | 85.23 |
| Giza-40 ($P_5$) | 83.28 | 61.90 | 622.20 | 41.98 | 58.94 | 89.33 | 205.98 | 35.05 | 1454.94 | 111.36 |

**Table 6. Estimates of genetic and environmental components of variation, derived ratios and heritability (%) in $F_1$ diallel cross analysis for Days to 90% maturity, Plant height (cm.), No. of branches / plant, No. of pods / plant and No. of seeds / plant under both free and infested conditions in 2010/2011 season**

| Components of variation | Days to 90% maturity | Plant height (cm.) | No. of branches / plant | No. of pods / plant | | No. of seeds / plant |
|---|---|---|---|---|---|---|
| | Free | Infested | Free | Free | Infested | Free |
| D±S.E(D) | 14.09±0.07** | 51.13±4.58 ** | 0.93±0.07** | 25.75±0.87** | 40.55±5.56** | 63.47±2.98** |
| F±S.E(F) | -2.50±0.18 | 29.99±11.44** | -0.33±0.18 | 0.97±2.18 | 2.28±13.90 | -18.05±7.44 |
| $H_1$± S.E ($H_1$) | -0.64±0.20 | 45.62±12.36 ** | 0.43±0.19* | 6.31±2.36** | 66.54±15.02** | 25.24±8.04** |
| $H_2$±S.E ($H_2$) | -0.45±0.18 | 31.41±11.21 ** | 0.34±0.18 | 4.41±2.14* | 61.59±13.63** | 19.70±7.30** |
| $h^2$±S.E ($h^2$) | -0.32±0.12 | 18.46±7.57 * | -0.01±0.12 | 1.594±1.44 | 9.01±9.20 | 5.84±4.93 |
| E±S.E(E) | 0.50±0.03** | 1.68±1.87 | 0.08±0.03** | 0.81±0.36* | 0.35±2.27 | 1.34±1.22 |

*,** indicate significance at 0.05 and 0.01 levels of probability, respectively.

**Table 7. Estimates of genetic and environmental components of variation, derived ratios and heritability (%) in $F_1$ diallel cross analysis for 100-seed weight (g), Date of *Orobanche* emergence, No. of *Orobanche* spikes /m² and *Orobanche* dry weight (g /m2 )under both free and infested conditions in 2010/2011 season**

| Components of variation | 100-seed weight (g) | | Date of *Orobanche* emergence | No. of *Orobanche* spikes /m² | *Orobanche* dry weight (g /m²) |
|---|---|---|---|---|---|
| | Free | Infested | Infested | Infested | Infested |
| D±S.E(D) | 175.83±8.65** | 169.98±225.59 | 66.51±2.78** | 205.07±12.03** | 915.98±90.94** |
| F±S.E(F) | -56.97±21.61 | 28.38±563.52 | 10.51±6.95 | 52.03±30.04 | 157.89±227.17 |
| $H_1$± S.E ($H_1$) | 128.22±23.36** | 1641.31±609.23** | 36.56± 7.52** | 223.34±32.48** | 1862.32±245.59** |
| $H_2$±S.E ($H_2$) | 114.25±21.19** | 1588.03±552.58** | 34.42± 6.82** | 180.21±29.46** | 1623.47±222.76** |
| $h^2$±S.E ($h^2$) | -2.13±14.30 | 300.14±373.07 | 0.45±4.60 | 234.247±19.890** | 2893.72±150.39** |
| E±S.E(E) | 3.38±3.53 | 5.88±92.10 | 0.88±1.136 | 0.303±4.910 | 0.85±37.13 |

*,** indicate significance at 0.05 and 0.01 levels of probability, respectively.

As regard with days to 90% maturity under free condition and 100-seed weight (g) under infested condition showed highly significant of D and highly significant of $H_1$, indicating the important role of additive effect in the genetic control of 90% maturity. In contrast, dominance effect plays an important role in genetic control of 100-seed weight under infested condition. The estimates of (F) were negative or positive in studied criteria under study. Negative and positive indicate excess of recessive or dominance alleles which were found in parents, respectively. The value of $H_1$ comparing with $H_2$ showed the apart between them, indicating, non equal distribution of positive and negative alleles between parents under study. The $h^2$estimates, which measured of heterozygous loci averaged overall loci, were significant or highly significant and positive for plant height (cm.), no. of *Orobanche* spikes /m² and *Orobanche* dry weight (g/m²) under infested field, indicating the heterozygous in most loci were recorded of these three criteria. The proportion of genetic components, most dominant and recessive genotypes and heritability in broad and narrow sense for studied characters Tables 8 and 9. Mean degree of dominance $(H_1/D)^{1/2}$ indicated the presence of over dominance for no. of pods/plant, 100-seed weight (g) and *Orobanche* dry weight (g/m$^2$) under infested field. Regarding, no. of *Orobanche* spikes/m$^2$ under infested field possessed complete dominance, while other characters had partial dominance under both free and infested conditions. Proportions of $(H_2/4H_1)$ were smaller than 0.25, indicating, unequal distribution of positive and negative genes between the parents. This agrees with finding of (Kaul and Vaid, 1996 ; Attia *et al.*, 2006).

Unequal proportions occurred between dominant and recessive genes with more dominant than recessive genes in the parents for three *Orobanche* related resistant criteria and plant height under infested condition. Equal distribution of dominant and recessive genes between the parents were recorded at no. of pods/plant under both conditions and 100-seed weight under infested condition. Other studies characters possessed unequal distribution of dominant and recessive genes between the parents with more recessive genes than dominant genes. By comparing Wr +Vr values for each array with the mean of the common parent, i.e. comparing (Wri +Vri) with Yri we can see the direction of dominance Tables 4 and 5. If the correlation coefficient (r) between them is negative it means that parents containing most increasing genes have the lowest values of Wri +Vri and thus contain most dominant genes, and correlation will be positive if the case is reversed. Thus, one can conclude whether or not the increasing or decreasing genes are the dominant ones (Singh and Chaudhary, 1977). Therefore, the results revealed that the direction of dominance was towards the late of maturity, and increasing of no. of branches/plant and no. of seeds/plant under free field, while under infested field the direction of dominance was towards long of plant height and increasing 100-seed weight as a dominant than the lowest of these characters as a recessive.

Very important remarkable, that three *Orobanche* related resistance criteria possessed the correlation coefficient (r) were positive, then the direction of dominance towards low value of three criteria dominant over high values. Therefore, the *Orobanche* resistant gene dominant over susceptible recessive genes, i.e. $P_1$ (Misr-1) possess most dominant resistant genes, in contrast (Giza 40) possess most recessive susceptible genes. These results are in accordance with the results obtained by Cubero and Hernandez (1991) and El-Rodeny (2002).

High heritability estimates in broad-sense ($h^2_b$) [0.91 to 0.999] were found for all studied characters, indicating the little effects of environmental conditions and subsequently, these characters were considered highly inherited ones. Moreover, high heritability estimate in narrow-sense was obtained for almost criteria (0.65 to 0.94) except no. of pods /plant,100-seed weight and *Orobanche* dry weight (g/m$^2$) under infested condition, indicating that additive genes play an important role in genetic control of these characters, i.e., days to 90% maturity, no. of branches /plant, 100-seed weight (g) under free condition, plant height (cm.), date of *Orobanche* emergence, no. of *Orobanche* spikes /m$^2$ under infested field and no. of pods/plant under both conditions, while dominance gene effects play an important role in the genetic control of 100-seed weight (g) and *Orobanche* dry weight (g/m$^2$) under infested field. Therefore, genetic improvement of characters controlled with additive gene effects carry out at early segregating generations, in contrast the 100-seed weight (g) and *Orobanche* dry weight (g/m$^2$) under infested field, which controlling by dominant gene effects carry out at late segregating generations.

The $F_1$- graphic analysis for the studied characters are shown in Figures 1 and 2. The regression line passed throw the point of origin for no. of *Orobanche* spikes /m$^2$ under infested field suggesting the importance of complete dominance for this character. The regression line passed under the point of origin for no. of pods/plant, 100-seed weight (g) and *Orobanche* dry weight (g/m$^2$) under infested field, suggesting the importance of over dominance

**Table 8. The proportion of genetic components, most dominant and recessive genotypes and heritability in broad and narrow sense for Days to 90% maturity, Plant height (cm.), No. of branches / plant, No. of pods / plant and No. of seeds / plant for $F_1$ plants under both free and infested conditions**

| Parameters | Days to 90% maturity | Plant height (cm.) | No. of branches / plant | No. of pods/plant | | No. of seeds/plant |
|---|---|---|---|---|---|---|
| | Free | Infested | Free | Free | Infested | Free |
| $(H_1/D)^{1/2}$ | 0.21 | 0.95 | 0.67 | 0.50 | 1.28 | 0.63 |
| $H_2/4H_1$ | 0.18 | 0.17 | 0.20 | 0.18 | 0.23 | 0.20 |
| Dom/Res proportion | 0.41 | 1.90 | 0.59 | 1.08 | 1.05 | 0.63 |
| r | -0.41 | -0.82 | -0.80 | 0.16 | 0.67 | -0.79 |
| $r^2$ | 0.17 | 0.67 | 0.64 | 0.03 | 0.44 | 0.62 |
| $h^2$ (bs) | 0.96 | 0.94 | 0.91 | 0.95 | 0.99 | 0.97 |
| $h^2$ (ns) | 0.94 | 0.65 | 0.81 | 0.88 | 0.58 | 0.87 |

**Table 9. The proportion of genetic components, most dominant and recessive genotypes and heritability in broad and narrow sense for 100-seed weight (g), Date of *Orobanche* emergence, No. of *Orobanche* spikes /$m^2$ and *Orobanche* dry weight (g /m2 )for $F_1$ plants under both free and infested conditions**

| Parameters | 100-seed weight (g) | | Date of *Orobanche* emergence | No. of *Orobanche* spikes /$m^2$ | *Orobanche* dry weight (g /$m^2$) |
|---|---|---|---|---|---|
| | Free | Infested | Infested | Infested | Infested |
| $(H_1/D)^{1/2}$ | 0.85 | 3.11 | 0.74 | 1.04 | 1.43 |
| $H_2/4H_1$ | 0.22 | 0.24 | 0.24 | 0.20 | 0.22 |
| Dom/Res proportion | 0.68 | 1.06 | 1.24 | 1.28 | 1.13 |
| r | 0.62 | -0.29 | 0.42 | 0.82 | 0.79 |
| $r^2$ | 0.38 | 0.08 | 0.17 | 0.68 | 0.63 |
| $h^2$ (bs) | 0.98 | 0.99 | 0.98 | 0.99 | 0.99 |
| $h^2$ (ns) | 0.79 | 0.20 | 0.75 | 0.68 | 0.55 |

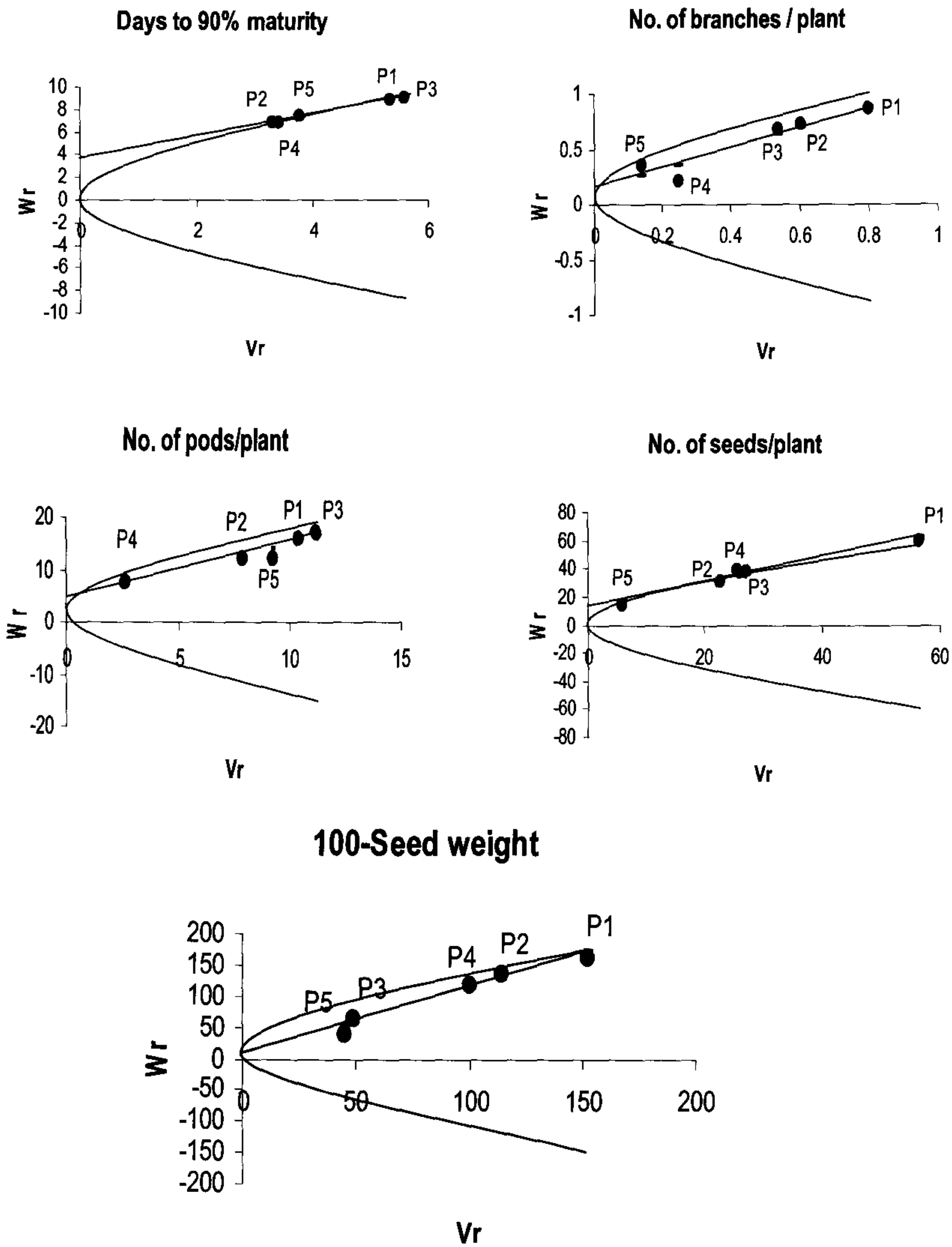


**Fig. 1.** $F_1$ graphic analysis of Days to 90% maturity, No. of branches/plant No. of pods/plant, No. of seeds/plant and 100-seed weight (g) under free field

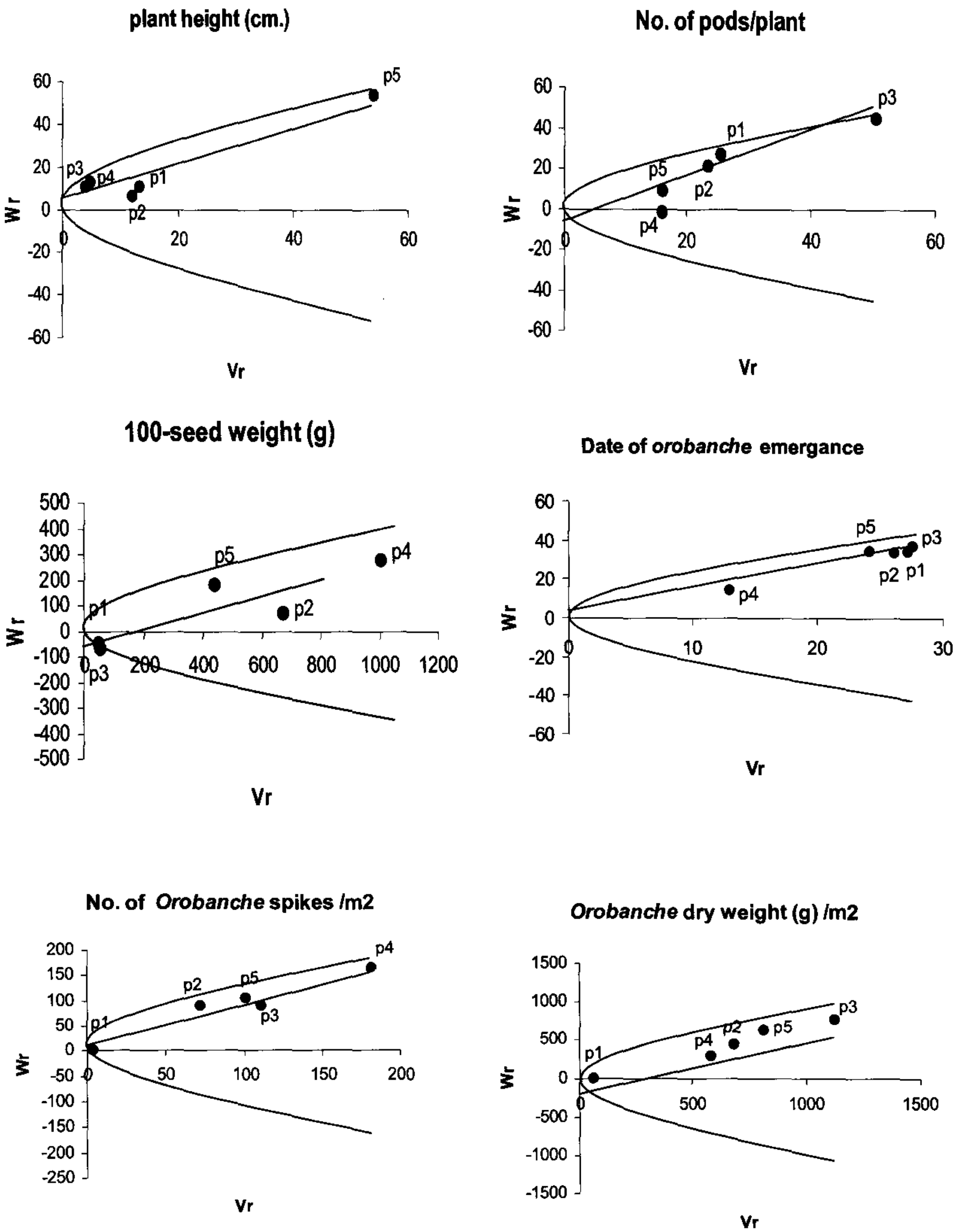


**Fig. 2.** **$F_1$ graphic analysis of plant height, No. of pods/plant, 100-seed weight (g), First *Orobanche* shoot date emergence, No. of *Orobanche* shoots /m$^2$ and *Orobanche* shoots dry weight (g /m$^2$) under infested field**

for these characters. Regarding no. of pods/plant and *Orobanche* dry weight (g /m$^2$) under infested field passed slightly below the point of origin, indicating complete dominance to negligible over dominance. While, plant height (cm.) under infested field and 100-seed weight under free condition passed slightly above the point of origin, indicating complete dominance to negligible partial dominance. The regression lines passed over the point of origin for no. of branches/plant, no. of pods/plant, no. of seeds/plant under free condition and date of *Orobanche* emergence under infested condition suggesting the importance of partial dominance for these characters. These findings confirmed the pervious results from $(H_1/D)^{1/2}$ proportions.

If the regression line touches parabola limit it indicate no-dominance; therefore, the area between parabola limit and regression line determine dominance volume and subsequently additive effects. Regarding 90% maturity under free condition, the regression line almost touched the parabola limit and the array points of the parents also was near regression line, suggesting that additive gene effects play an important role in the genetic control of this trait.

The order of the array points along the regression line showed that variety Misr-1 ($P_1$) had most dominant genes for 100-seed weight, no. of *Orobanche* spikes /m$^2$ and *Orobanche* dry weight (g /m$^2$ )under infested field but it had most recessive genes for No. of branches/plant, 100-seed weight (g) and No. of seeds/plant under free field. Therefore, Misr-1 variety possessed most resistance genes for *Orobanche* resistance. Inbred line x-1722 ($P_3$) had most recessive genes for 90% maturity under free field, it had most recessive genes for date of *Orobanche* emergence, *Orobanche* dry weight (g /m$^2$ )under infested field and No. of pods/plant under both conditions, while it had most dominant genes for plant height (cm.) under infested field. These differences between the two conditions of free and infested field may be conflicted by the potential yield under free conditions which may be conditioned by different alleles that controlling seed yield and its components under *Orobanche* infestation (El-Marsafawy, 2006). The relation between seed yield and its attributes with *Orobanche* related criteria is shown in Table 10.

These results confirmed that the selection of *Orobanche* resistance may be depend on seed yield and its attributes, while *Orobanche* dry weight (g /m$^2$ )possessed positive relationship with seed yield and its attributes, therefore, *Orobanche* dry weight (g /m$^2$ )consider as no benefit criteria for selection of *Orobanche* resistance. These results are in accordance with those obtained by El-Rodeny (2002), Abd El-Makasoud *et al.* (2007) and El-Galaly *et al.* (2008).

**Table 10. Relation between seed yield and its attributes with *Orobanche* related criteria**

| | Plant heig. | No. of bran. | No. of pods | No. of seeds | seed yield | 100-seed weight | Date of *Orobanch.* emergence | No. of *Orobanch.* spikes /m$^2$ | *Orobanch.* dry weight (g /m$^2$) |
|---|---|---|---|---|---|---|---|---|---|
| **90% maturity** | 0.51 | -0.55 | 0.30 | 0.35 | 0.35 | 0.48* | -0.05 | -0.51 | 0.289 |
| **Plant height** | - | 0.20 | 0.67 | 0.73 | 0.76 | 0.89 | -0.72 | -0.79 | 0.72 |
| **No. of branches** | - | - | 0.31 | 0.27 | 0.34 | 0.23 | -0.74 | -0.41 | 0.55 |
| **No. of pods** | - | - | - | 0.99** | 0.99** | 0.93* | -0.82 | -0.80 | 0.90* |
| **No. of seeds** | - | - | - | - | 0.99** | 0.96** | -0.81 | -0.80 | 0.89* |
| **seed yield** | - | - | - | - | - | 0.97** | -0.87 | -0.86 | 0.94* |
| **100-seed weight** | - | - | - | - | - | - | -0.82 | -0.87 | 0.89* |
| **Date of *Orobanche* emergence** | - | - | - | - | - | - | - | 0.87 | -0.96* |
| **No. of *Orobanche* spikes /m$^2$** | - | - | - | - | - | - | - | - | -0.95* |

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# الطبيعة الوراثية والمكافئ الوراثى لمقاومة الهالوك فى الفول البلدى

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تهدف هذه الدراسة إلى التعرف على طبيعة التوارث والمكافئ الوراثى لمقاومة الهالوك فى الفول البلدى. تم فى هذه الدراسة استخدام تحليل diallel للجيل الأول. استخدمت خمس تراكيب وراثية وهى مصر ١، x-1714، x-1722 (متحمل)، نوبارية ١، جيزة ٤٠(حساس). تم تسجيل صفات المحصول وكذلك الصفات المرتبطة بها(عدد الأيام من الزراعة وحتى نضج ٩٠% من النباتات، طول النبات (سم)، عدد الفروع/ النبات، عدد القرون/ النبات، عدد البذور/النبات، محصول البذور/النبات(جرام)، وزن ١٠٠- بذرة (جرام) فى كلا من التربة الموبؤة والخالية من الاصابة. تم تقدير صفات لها علاقة بالمقاومة للهالوك فى التربة الموبؤة (ميعاد ظهور أول شمراخ زهرى ، عدد سيقان الهالوك / م٢ ، الوزن الجاف للهالوك جرام/ م٢).أوضحت النتائج أن التأثير المضيف هام جدا للتحكم فى صفة عدد الأيام من الزراعة حتى نضج ٩٠% من النباتات، على النقيض من ذلك يلعب التأثير السيادى دور هام فى التحكم الوراثى لصفة وزن ١٠٠- بذرة تحت ظروف الاصابة. يلعب كلا من التأثير المضيف والسيادى دور هام فى التحكم الوراثى لصفات الهالوك الثلاثة والتى ترتبط بالمقاومة للهالوك. يشير متوسط درجة السيادة $(H_1/D)^{1/2}$ الى وجود سيادة فائقة لصفات عدد القرون/النبات، وزن ١٠٠- بذرة(جرام)، الوزن الجاف للهالوك (جرام)/م٢ فى التربة الموبؤة. فيما يتعلق بعدد شماريخ الهالوك/م٢ حققت سيادة كاملة بينما كانت باقى الصفات سيادة جزئية تحت ظروف الاصابة وخلوها من الاصابة. عدم وجود تكرار متساوى لكلا من الجينات الموجبة والسالبة بين الآباء تحت الدراسة وكذلك أظهرت توزيع غير متساوى بين الجينات السائدة والمتنحية فزادت الجينات السائدة عن المتنحية فى الآباء فى الصفات الثلاثة المرتبطة بالمقاومة للهالوك و طول النبات (سم) تحت ظروف الاصابة. كان اتجاه السيادة نحو التأخير فى النضج، زيادة عدد الفروع/ النبات، عدد البذور/النبات فى التربة الخالية بينما فى التربة المصابة كان اتجاه السيادة نحو زيادة طول النبات (سم)، زيادة وزن ١٠٠- بذرة (جرام). كانت قيمة r للصفات الثلاثة المرتبطة بالهالوك عالية و موجبة لذلك كان اتجاه السيادة نحو القيمة المنخفضةفكانت سائدة على القيمة العالية لذلك فان جينات المقاومة سائدة على جينات الحساسية (المتنحية). وجد أن المكافئ الوراثى على المستوى الواسع مرتفع فى جميع الصفات المدروسة، كان المكافئ الوراثى على المستوى الضيق فى معظم الصفات مرتفع ماعدا وزن ١٠٠-بذرة، الوزن الجاف للهالوك (جرام) /م٢ فى التربة المصابة. يؤكد الرسم البيانى للجيل الانعزالى الأول النتائج السابقة المتعلقة بمتوسط درجة السيادة بالاضافة لأن تأثير الجين المضيف يلعب دور هام فى التحكم الوراثى فى عدد الأيام من الزراعة وحتى نضج ٩٠% من النباتات تحت ظروف التربة الخالية. احتوى صنف مصر ١ على معظم جينات المقاومة للهالوك. أثبت معامل الارتباط أن محصول البذور والصفات المرتبطة بها ترتبط بصفتى ميعاد ظهور أول شمراخ زهرى و عدد شماريخ الهالوك /م٢ ارتباط سالب عالى.