RESULTS AND DISCUSSION

1- Performance of the F_3 base population

The base population in the present study was the F_3-bulk populations of five crosses. The mean values of all studied characters for the five crosses with the check varieties Giza 9 and Sinai 1 are presented in Table (3). Plant height ranged from 24.25 cm for cross 1 to 32.32 cm for cross 3. In comparison Giza 9 and Sinai 1 showed plant heights of 36.20 and 25.39 cm, respectively. Cross 3 had higher mean values for all characters than other crosses, but it was late in flowering and maturity.

The average of seed yield/plant was very low for all crosses, except cross 3, and ranged from 0.16g for cross 2 to 0.97g for cross 5. Cross 3 gave a reasonable average seed yield of 1.47 g/plant. Low seed yield was mainly due to broomrape's (*Orobanche*) infection, which spread over the field. However, many plants were not infected and gave reasonable seed yield. Thus useful pedigree selection was practiced in all the five crosses. Many selected plants gave seed yield above 1.4 g/plant with average seed yields of the five crosses ranged from 1.0 to 1.8 g/plant (Appendix 1).

2. Mean values, variability and selection response

2.1. F_4 generation

2.1.1. Performance of F_4 families

The analyses of variance were made for each cross separately. Results presented in Table (4) reveal significant differences among F_4

families for several characters in each cross. For example, the F_4 families varied significantly in plant height in cross 2 and cross 4, seed yield/plant in cross 1 and 4 and days to flowering in cross 1, 2, 4

and 5. Interestingly, no significant differences between F_4–families of cross 3 have been observed for all studied characters (Table, 4).

Table 4. Mean square values of studied characters of the F4-families of the five lentil crosses (Giza 9 and Sinai 1 excluded).

Character	Cross number				
	1	**2**	**3**	**4**	**5**
Plant height	31.39	24.88**	3.83	45.23**	20.74
Branch./plant	78.20*	502.2**	433.6	645.83*	178.8
No. of pods/plant	5690	12091	3567.9	1989.2**	7998.8
No. of seeds/plant	14179*	12751	2038.1	26368.2**	20384.9
No. of seeds/pod	0.01	0.012	0.084	0.074	0.085**
Biological y/plant	43.87*	1191*	11.95	115.72**	111.42
Seed yield/plant	4.31**	7.33	0.482	38.31*	7.80
Growth vigor	0.40	0.333	0.10	0.25	0.174
Days to flowering	472*	70.08*	23.75	33.11**	385.481**
Days to maturity	4.87	4.28	4.21	20.68**	17.77
Harvest index	70.68	39.11**	10.90	1913.90	106.57

**,* Significant at 0.01 and 0.05 levels of probability, respectively.

The performances of F_4–families of cross 1 (6 families) for plant height, number of branches/plant, growth vigor (the morphological characters) and days to flowering and days to maturity (the phenological characters) are given in Tables (5 and 6).

The results in Table (5) show that plant height ranged from 32.43 cm for family no. 3 to 41.6 cm for family no. 6 with an average of 38.31 cm. In comparison, the plant height of the check varieties Giza 9 and

Sinai 1 were 47.9 and 27.6 cm, respectively. The value of the least significant difference (LSD) show that all families gave taller plants than Sinai 1, but shorter than Giza 9. The plant height of family 6 was differed significantly from families 2 and 3. Comparing between means of plant height of F_4-families and F_3-base population for cross

1, the data show that the mean of F_4-families (38.3 cm) exceeded the mean of F_3-base population (31.4 cm) by 22.1%.

Family 6 show also the highest number of branches/plant (56.2) overall families and check varieties. Narrow range of plant growth vigor was observed among families, which ranged from 1-2. For days to flowering and maturity, it is clear that Sinai 1 was the earliest in flowering and maturity. In fact Sinai 1 is the earliest variety in lentil germplasm collection in Egypt **(Hamdi *et al*., 2002).**

The mean values of yield and yield components and harvest index are presented in Table (6). The data show that family no. 5 had the second highest number of pods/plant (212.7) and the highest number of seeds/plant (322.0), hence performed the highest seed yield/plant of 6.49 g. The seed yield of family 5 exceeded the seed yield of Giza 9 and Sinai 1 by 165 and 312%, respectively.

The data of cross 2 in Table (7) show that the values of plant height of the six F_4-families ranged from 27.3 to 36.3 cm with an average of 33.48 cm. Whereas, the range of number of branches/plant was 43.5 – 77.0. Narrow range of growth vigor was also observed among families, which ranged from 1-2. For days to flowering and maturity, no family showed earliness in flowering or maturity over Sinai 1, which flowered and matured at 54 and 108 days, respectively.

The mean values of yield and yield components and harvest index are given in Table (8). A wide range of number of pods/plant was observed (84.4 – 281.3) where the highest number of pods/plant occurred with family no. 4. The highest number of seeds/plant (282.1) was performed also by family no. 4. This family exceeded Giza 9 by 152 and 116% in number of pods and seeds/plant, respectively.

Therefore, this family showed the highest seed yield/plant of 6.18 g, and had also the highest average biological yield/plant. The seed yield of family 4 exceeded the seed yield of Giza 9 and Sinai 1 by 152 and 292%, respectively.

The results of cross 3 presented in Tables (9 and 10) show a narrow range of plant height (37.9 – 41.1 cm). In comparison, the plant height of the check varieties Giza 9 and Sinai 1 were 47.9 and 27.6 cm, respectively. The data show that all families gave shorter plants than Giza 9.

Family 3 show the highest number of branches/plant (68.4) overall families and check varieties. Narrow range of plant growth vigor was observed among families, which ranged from 1-1.5. For days to flowering and maturity, it is clear that Sinai 1 was the earliest in flowering and maturity.

The mean values of yield, yield components and harvest index are presented in Table (10). The data show that family no. 3, which had the highest values of plant height and number of branches/plant, showed also the highest number of pods/plant (195.2) and seeds/plant (160.4), and hence the highest seed yield/plant of 2.97g.

The data of cross 4 in Tables (11 and 12) show that the values of plant height/plant of the 17 F_4-families ranged from 24.3 to 41.6 cm with an average of 33.4 cm. whereas, the range of number of branches/plant was 38.4 – 110.1. Narrow range of growth vigor was also observed among families, which ranged from 1-2. The means of days to flowering and maturity of all families were 84.4 and 128.3 days, respectively. Again, no family proved earlier in flowering or maturity than Sinai 1, which flowered and matured at 54 and 108 days, respectively.

The mean values of yield and yield components and harvest index are given in Table (12). A wide range of number of pods/plant was

observed (min. 20.9 – mix. 355.1) where the highest number of pods/plant occurred with family no. 9. The highest number of seeds/plant (394.9) was performed also by family no. 9. This family exceeded Giza 9 by 219% and 103% in number of pods and seeds/plant, respectively. Therefore this family showed the second highest seed yield/plant of 7.45g, which exceeded the seed yield of

Giza 9 and Sinai 1 by 203% and 373%, respectively. There are two other promising families (nos. 5 and 13) that gave also considerable high seed yield/plant of 7.50 and 7.75 g, respectively (Table 12).

The results of progeny of the cross no. 5, which consisted of 21 families are presented in Tables (13 and 14). The data show that the plant height ranged from 33.4 cm for family no. 19 to 47.3 cm for family no 15. In comparison, the plant height of the check varieties Giza 9 and Sinai 1 were 47.9 and 27.6 cm, respectively. Narrow range of plant growth vigor was also observed among families, which ranged from 1-2. The means of days to flowering and maturity of all families were 85.7 and 129.9 days, respectively. Again no family wes earlier in flowering or maturity than Sinai 1, which flowered and matured at 54 and 108 days, respectively.

The mean values of yield and yield components and harvest index are given in Table (14). A wide range of number of pods/plant observed (65.1 – 295.1). The highest number of pods and seeds/plant occurred with family no. 5, which performed 295.1 pods/plant and 415.4 seeds/plant. This family exceeded Giza 9 in number of pods and seeds/plant, by 165 and 146% respectively. Therefore this family gave the highest seed yield/plant of 99g. The seed yield of family 5 exceeded the seed yield of Giza 9 and Sinai 1 by 267 and 471%, respectively.

2.1.2. Response to selection

The response to selection was measured as the percentage increase of F_4 values over F_3 values for all studied characters. The data in Table (15) indicates the superiority of F_4 values over F_3 values for

most of the studied characters. For example, seed yield/plant in F_4, cross 1, increased by 583.64% (about six times) over the corresponding value of F_3, and the increase percentages ranged from 48.23% for cross 3 to 1856.25% for cross 2. Similarly the increase percentages of number of pods/plant of F_4 over F_3 were high and ranged from 49.02% to 548.85% (Table, 15). All other characters

showed similar superiority in F_4 over F_3 but with various values of increase, except the characters: growth vigor in crosses 2-3,4 and 5, harvest index in cross 3, and number of seeds/pod in cross 3, which showed negative response. Days to flowering and maturity showed positive response in all crosses, which means that the F_4 families were late in flowering and maturity compared to F_3 families.

Table (15). Response of selection, measured as the percentage increase of F_4 values over F_3 values for all studied characters.

Character	Cross number				
	1	2	3	4	5
Plant height	51.71	13.86	17.74	16.02	24.43
Branches/plant	93.60	128.50	11.37	136.02	49.98
No. of pods/plant	261.83	585.85	49.02	505.77	191.37
No. of seeds/plant	382.56	548.85	60.47	610.72	241.94
No. of seeds/pod	23.16	4.28	2.70	22.15	5.55
Biological yield /plant	20.82	707.26	35.63	256.83	165.86
Seed yield/plant	583.64	1856.25	48.23	726.98	316.91
Growth vigor	25.00	-7.39	-38.89	-37.5	-45.42
Flowering	38.18	7.92	0.00	8.65	58.77
Maturity	18.14	12.00	1.3	8.06	18.08
Harvest index	158.97	206.74	-0.77	84.52	56.13

2.1.3. Estimates of genetic parameters

Estimates of phenotypic variance (O^2p), genotypic variance (O^2g), environmental variance (O^2e), phenotypic coefficient of variation (P.C.V.), genotypic coefficient of variation (G.C.V.), environmental

coefficient of variation (E.C.V.), broad sense heritability (h^2) and expected genetic advance from selection as percentage of the mean (GA%) was calculated for all families in each cross. The data of these estimates are presented in Tables (16 – 20).

The genetic parameters of all characters of cross 1 are given in Table (16). Regarding morphological characters, the data in Table (16) show that plant height and number of branches/plant had relatively low phenotypic and genotypic coefficients of variation (P.C.V) of 10.94, 6.80, and 8.54 and 12.30, respectively. The broad sense heritability was greater for number of branches/plant (82.94%) than for plant height (60.99%). Also the genetic advance was higher for number of branches/plant (23.07%). For growth vigor character, despite its low heritability (50%), gave higher value of genetic advance of 30.71% than those obtained for plant height and number of branches/plant due to its greater estimate of O^2p.

Broad sense heritability of plant height ranged from 58% to 84% **(Nazeem *et al.*, 1983). El-Titi (1988)** found that broad sense heritability of number of branches/plant, in irrigated lentil in Egypt, varied widely from 2% to 87%, which is in the range of the heritability estimate in this study. Estimates of genetic advance for plant height in previous studies varied from 7% to 30% with an average of 18.4%, which is comparable with genetic advance calculated for plant height in this study.

The data of phenological characters indicated that days to maturity was highly affected by environmental effects, and hence its (G.C.V) estimate was equal to zero, with zero heritability and genetic advance. Days to flowering had moderate PCV and very high heritability estimate of (90.17%), thus it had moderate genetic advance value of 37.55%. In this regard **Hamdi (1987)** found in lentil that the genotype-year interaction variance component for time to flowering was equal to only 3% of the overall phenotypic variance, whereas this ratio was greater, 21%, for time to maturity, indicating

that this character was much more influenced by seasons than time to flowering. **Erskine and Goodrich (1988)** obtained high value of broad sense heritability for time to flowering (99%), which is in agreement with the results in this study. For time to maturity, broad sense heritability ranged from low values of 46% and 59% **(Sakar, 1983)** to a high estimate of 96% **(Prem Sagar, 1980).** The heritability estimation of time to maturity in the present experiment was varied than those values. In previous studies, **Prem Sagar (1980)** reported that the genetic advance of time to flowering was low; again it is in agreement with this study.

The number of pods/plant, number of seeds/plant and number of seeds/pod were studied as yield component characters. Number of pods/plant showed the widest phenotypic and genotypic variations (Table, 16). Both characters had similar genetic component estimates. For example, the P.C.V. estimates of both characters were 31.21 and 31.94, respectively. Similarly, their heritability and genetic advance values were 78.03%, 77.39%, and 50.17, 50.92, respectively. These results obviously indicate that number of pods and seeds/plant had high estimates of genetic advance due to their high estimates of broad sense heritability and genotypic coefficient of variation. Broad sense heritabilities estimated in this study were in agreement with the estimates found by many workers. Broad sense heritabilities of number of pods/plant were previously reported as 45% **(Muehlbauer, 1974),** 57% **(Dixit and Dubey, 1985),** 80% **(Nadan and Pandya, 1980),** and 98.5% **(Rajput and Sarwar, 1989)**. Number of seeds/pod had a broad sense heritability value of 31 % **(Nadan and Pandya, 1980),** which was higher than the value estimated in this study. The expected genetic advance for number of pods/plant was found to vary from 7 to 55% **(El-Titi, 1988)** 25% **(Sindhu and Misra, 1982)** and 89% **(Rajput and Sarwar, 1989)**.

For biological and seed yield/plant and harvest index characters the results presented in Table (16) show that the genetic variance component comprised the major proportion of the phenotypic variance component for biological and seed yield characters. Seed yield/plant

had the highest broad sense heritability (93.06%) among all traits, and biological yield had also a high heritability estimate (86.74%). In addition, seed yield/plant had the higher coefficient of genetic variation, consequently higher genetic advance than biological yield/plant. Harvest index had moderate heritability (57.78%) and coefficient of genetic variation, thus moderate estimate of expected genetic advance (27.32%). High broad sense heritability values of seed yield/plant have been reported by **Raslan (2001),** (h^2= 93% and 97%).

On the basis of the relatively high heritability, coefficient of genetic variation and genetic advance, pronounced progress should be expected from selection for seed yield/plant, biological yield/plant and number of pods and seeds/plant. Moderate progress from selection between families should be expected with days to flowering and vigor. However, lower genetic advance should be expected from selection between families for plant height.

The genetic parameters of all characters of cross 2 are given in Table (17). Phenotypic and genotypic coefficients of variation were high for biological yield/plant (94.92 and 86.44) and seed yield/plant (68.35 and 60.53), moderate for no. of pods/plant, no. of seeds/plant, no. of branches/plant and harvest index. While the other characters had relatively low P.C.V and G.C.V. estimates. The broad sense heritability was greater for plant height, number of branches/plant and harvest index. The genetic advance was high for pods/plant, harvest index and no. of branches/plant. For number of seeds/plant, despite its low heritability (53.18%), it gave relatively high value of genetic advance of 50.99% than that obtained for days to flowering due to its greater estimate of P.C.V and G.C.V. Broad sense heritability of plant height was found to be high by **El-Titi (1988);** his estimate of heritability was 92%. **Ramgiry *et al.* (1989)** estimated a broad sense heritability number of branches/plant of 96%, which is equal to the heritability estimate in this study. Estimates of genetic advance for plant height in previous studies varied from 19.2% to 28.84%, which is comparable with genetic advance calculated for plant height in this study. The mentioned results of cross 2 indicate that, pronounced

progress should be expected from selection for biological and seed yield/plant, number of pods/plant and harvest index. Moderate progress from selection between families should be expected with number of seeds/plant and number of branches/plant.

The data of genetic parameters of all characters of cross 3 are shown in Table (18). Number of branches/plant and number of pods/plant had the highest phenotypic coefficients of variation (P.C.V) of 34.14 and 34.09, respectively. The values of (P.C.V) were moderate for no. of seeds/plant, seed yield/plant, no. of seeds/pod, biological yield/plant and harvest index, while the other characters had low P.C.V estimates, which ranged from 0.0 to 3.52. The broad sense heritability was greater for number of branches/plant (70.69%). The genetic advance was 49.71% for number of branches/plant. Other characters had low values of genetic advance (0.0–10.56%), indicating that genetic improvement of the studied characters in this cross is difficult.

The genetic parameters of all characters of cross 4 are given in Table (19). Phenotypic coefficients of variation ranged from (104.24) for seed yield/plant to 0.0 for plant vigor. Similar trend was observed for genotypic coefficients of variation for studied characters. The broad sense heritability was high for most characters, for example the characters; biological yield/plant, days to maturity, harvest index, and plant height had heritability estimates above 80%. The genetic advance was high for pods/plant, seeds/plant, biological yield/plant, seed yield/plant, and harvest index. The mentioned results of cross 4 indicate that, improvement in this cross by selecting the best families. Is feasible Hence, pronounced progress should be expected from selection for biological, seed yield/plant, number of pods/plant and harvest index.

The genetic parameters of all characters of cross 5 are given in Table (20). Phenotypic coefficients of variation ranged from (42.84) for seed yield/plant to (2.31) for days to maturity. Genotypic coefficients of variation ranged from (15.37) for days to flowering to (0.0) for number of branches/plant, biological yield/plant and harvest index. The highest heritability estimate occurred with days to

flowering (90.05%). The genetic advance was generally low with the highest value of 30.04%, recorded by days to flowering. The mentioned results of cross 5 indicate, low chance for improvement in this cross by selecting the best families. However, pronounced progress would be expected from selection for days to flowering. **El-Hady (1983)** reported moderate value of broad sense heritability for time to flowering, which agrees, with the present results.

The above results of all crosses indicate that there are highly significant differences among families for several characters, which make it clear that there are opportunities for improving those characters by selection within the population. Estimates of broad sense heritability showed that seed yield/plant, time to flowering, biological yield/plant and number of branches/plant had high values of >80%. Heritability is useful for comparing traits with respect to their usefulness as aids to selection. Low to moderate estimates of broad sense heritabilities for seed yield/plant have been reported by by **Muehlbauer, (1974), Nadan and Pandya (1980), Sindhu and Misra (1982), Dixit and Dubey (1985), Erskine *et al.* (1985), Hamdi (1987), Erskine and Goodrich (1988), El-Titi (1988), Ramgiry *et al.* (1989), and Hamdi *et al.* (1991 a).** These estimations were comparable with broad sense values estimated in this study. The broad sense heritability of harvest index was estimated by **Prem Sagar (1980)** was (h^2_73%).

The genetic advance from selection depends on the heritability estimate, the magnitude of phenotypic variance **(Falconer, 1981).** In order to determine the validity of selection, expected genetic advance should be obtained. In addition, **Johnson *et al.* (1955)** stated that heritability estimates together with genetic gains are more useful than the heritability values alone in predicting the resultant effect of selecting the best individuals. In cross 1, number of branches/plant, which had high broad sense heritability (82.94%) had low genetic advance (23.07%) because its coefficient of genetic variation was low (12.30). In comparison plant growth vigor, which had a lower heritability (50.0%), had a high genetic advance percentage of 30.71% due to its high coefficient of genetic variation (21.08%).