Egypt. J. Plant Breed. 15 (3): 109 – 122 (2011)

HETEROSIS, INBREEDING DEPRESSION AND COMBINING ABILITY IN DIALLEL CROSS OF WHITE LUPIN

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ABSTRACT

The present investigation was carried out at Mallawi Agricultural Research Station during 2008/2009, 2009/2010 and 2010/2011 growing seasons. All F_1 and F_2 crosses, excluding reciprocals, in a diallel mating design among seven white lupin genotypes differing in origin (Piscovij, Kiev Mutant, Giza-1, Belbies-9, Mutant-23, Mutant-33 and Dijon-2) were studied to estimate the genetic parameters and combining ability for earliness, seed yield and its components. Significant differences among parents and among crosses were detected for all studied characters, indicating genetic variability for all variables. These parents and crosses would be interesting and prospective for the future in white lupin breeding aiming at improving earliness, seed yield and its components. Both general and specific combining ability variances were significant for all characters, revealing that both additive and non-additive effects were important for inheritance of these characters. The ratio of GCA/SCA exceeded the unity for all studied characters, indicating that the additive gene action was more important than dominance for these traits. Heterosis percentage of F_1 crosses relative to their respective mid and better parents were significantly positive in several crosses for plant height, number of branches, pods and seeds and seed yield per plant. Meanwhile, two crosses showed significantly positive heterosis relative to mid parents only for 100-seed weight. Negative heterosis percentage (favorable) relative to mid and better parents was significant in some crosses for days to maturity. Some crosses showed significant inbreeding depression in F_2 population for all studied characters. On the contrary, significant superiority was observed in some F_2 compared to F_1 crosses for all studied characters, except for plant height which could be attributed to trensgressive segregation. Parents Piscovij and Belbies-9 seemed to be better combiners for early maturity. Parents Dijon-2 and Giza-1 could be considered superior combiners for plant height, 100 seed weight, number of branches, pods and seeds and seed yield per plant. Moreover, the F_1 and F_2 crosses and these parents showed high SCA effects for respective traits.

Key words: ***White lupin, Diallel cross, Heterosis, Inbreeding depression, Combining ability, Lupinus albus.***

INTRODUCTION

Cultivation of white lupin (*Lupinus albus* L.) was well established in classical Greek and Roman times, and may have been practiced in Egypt as early as 2000 years B.C. (Gladstones 1970). It is considered one of the leguminous crops with a great potential because of its high seed protein content (35-45%) and its adaptation to poor soils and dry climates. The Egyptian genotypes have good productivity, but the high level of alkaloid in the seeds and their late maturity are considered the main problems of the genotypes. Crossing and selection in the segregating generations could improve these traits (Hoballah 1991).

Diallel cross technique (Abdalla *et al* 1999 and others) have been used to obtain considerable information on the magnitude of heterosis and to gain a better understanding of the nature of gene action involved in controlling quantitative characters. Agarkova *et al* (1991) reported that heterosis for yield and stem length due to the additive effect of recessive genes could be greater than that resulting from heterozygosity in intraspecific hybrids of *L. angustifolus*.

Combining ability initially is a general concept considered collectively for classifying an inbred line relative to its cross performance as well as helps the breeder to identify the best combiners which may be hybridized either to exploit heterosis or to build up the favorable fixable genes. Several investigators reported that the manifestations of heterotic and combining ability effects in lupins ranged from significantly negative to significantly positive estimates for number of days to maturity, seed yield and its components (Lukashevich 1981, Okaz *et al* 1986, Bushueva 1988, Sech and Huyghe 1991, Agarkova *et al* 1991 and El-Sayad *et al* 2002).

The main objectives of this investigation were to determine the magnitude of heterosis and inbreeding depression as well as understanding the nature of gene action and relative magnitude of combing ability influencing number of days to maturity, seed yield and major yield attributes in white lupin.

MATERIALS AND METHODS

The experiments of the present study were carried out at Mallawi Research Station, Agricultural Research Center, during 2008/2009, 2009/2010 and 2010/2011 growing seasons using the diallel mating design without reciprocals among seven widely diverse white lupin genotypes obtained from Food Legume Research Department, Field Crops Research Institute, ARC.

Four varieties: Piscovij (P_1), Kiev Mutant (P_2), Giza-1 (P_3) and Dihon-2 (P_7) along with two promising M_8 mutant lines; namely Mutant-23 (P_5) and Mutant-33 (P_6), which were assessed and selected from a previous study (El-Sayad and El-Barougy 2002) as well as Belbies-9 (P_4), which was assessed and reported elsewhere (El-Sayad *et al.* 2002), were used as parents in the current investigation. Origin, pedigree and some characters of these genotypes are presented in Table (1).

Table 1. Origin, pedigree and some characteristics of the seven white lupin genotypes used as parents in this study.

Genotypes	Origin	Pedigree	Maturity	Growth habit	Alkaloid content
Piscovij (P_1)	Australia	Australian Variety	Early	Determinate	Free alkaloid (sweet lupin)
KievMutant (P_2)	Ukraine	Ukrainian Variety derived from cv. White 70 by Gamma ray.	Early	Determinate	Free alkaloid (sweet lupin)
Giza-1 (P_3)	Egypt	Local variety selected from land race	Late	Indeterminate	High alkaloid (bitter lupin)
Belbies -9 (P_4)	Egypt	Selected line from land race	Late	Indeterminate	High alkaloid (bitter lupin)
Mutant- 23 (P_5)	Egypt	M_8 induced mutant line derived from cv.Giza-1 by 2.5 KR*	Moderate	Indeterminate	Moderate alkaloid (bitter lupin))
Mutant- 33 (P_5)	Egypt	M_8 induced mutant line derived from cv.Giza-2 by 2.5 KR	Late	Indeterminate	Moderate alkaloid (bitter lupin)
Dihon- 2 (P_7)	France	French Variety	Late	Indeterminate	High alkaloid (bitter lupin)

*** KR is a dosage of gamma-rays.**

A half diallel set of crossing using these parents was carried out during 2008/2009 season. In the second season (2009/2010) hybridization was repeated in order to increase F_1 seeds and raise F_2 seeds from F_1 plants. The evaluation trial was carried out during 2010/2011 season involving the seven parents, 21 F_1 and 21 F_2 populations using a Randomized Complete Block Design (RCBD) with three replications. Experimental plot for parents F_1's and F_2's included two, one and three ridges, respectively. Each ridge was 3m long and 60 cm apart. Single seed was sown at one side of the ridge in hills 20 cm a apart. Sowing dates took place at early November. All cultural practices were followed as recommended for the production of lupin in the region. The following characters were recorded: number of days from sowing to 90% of plants reaching maturity, plant height (cm), number of branches per plant, number of pods per plant, number of seeds per plant, 100-seed weight (g) and seed yield per plant (g).

Differences among means of genotypes were tested by conducting a regular analysis of variance of RCBD on plot mean basis. Heterosis and inbreeding depression were calculated as outlined by Foolad and Bassiri (1983). Appropriate "t" test was made for the significance of the heterosis of

F_1 crosses relative to the mid and better parental values (Wynee *et al* 1970) and for the inbreeding depression in F_2 crosses relative to F_1 values (Al-Rawi and Kohel 1969). Combining ability analysis was conducted according to method 2, model 1 of Griffing (1956).

RESULTS AND DISCUSSION

Analysis of variance:

The results in Table (2) showed the significance of mean squares due to genotypes, general (GCA) and specific (SCA) combining ability for the studied characters. Highly significant differences among genotypes were detected in both F_1 and F_2 generations for all studied traits, indicating genetic variability.. Mean squares due to GCA and SCA were highly significant in both generations for all studied characters. These results revealed that both additive and non-additive effects were important for inheritance of these

Table 2. Significance of mean squares due to genotypes, general (GCA) and specific (SCA) combining ability for both F_1 and F_2 generations.

S. O. V.	Df	Days to maturity		Plant height (cm)		No. of branches/plant		No. of pods/plant	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Genotypes (G)	27	30.46^{**}	33.52^{**}	971.19^{**}	722.57^{**}	2.267^{**}	2.533^{**}	235.86^{**}	175.25^{**}
GCA	6	59.88^{**}	48.71^{**}	2248.0^{**}	1962.35^{**}	3.0504^{**}	3.99^{**}	393.65^{**}	178.27^{**}
SCA	21	22.06^{**}	29.18^{**}	606.39^{**}	368.35^{**}	2.614^{**}	2.12^{**}	190.77^{**}	174.39^{**}
Error	54	0.138	0.16	12.47	15.25	0.093	0.113	3.34	4.32
[GCA/ SCA]		2.71	1.67	3.71	5.33	1.167	1.88	2.06	1.02

S. O. V.	Df	No. of seeds/plant		100-seed weight (g)		Seed yield/plant (g)	
		F_1	F_2	F_1	F_2	F_1	F_2
Genotypes (G)	27	2503.6^{**}	1805.97^{**}	4.025^{**}	14.33^{**}	291.89^{**}	231.44^{**}
GCA	6	4384.3^{**}	2611.54^{**}	4.05^{**}	23.2^{**}	623.7^{**}	448.8^{**}
SCA	21	1966.3^{**}	1575.8^{**}	4.02^{**}	11.8^{**}	197.09^{**}	169.34^{**}
Error	54	29.73	19.98	0.013	0.0097	3.57	2.26
[GCA/ SCA]		2.23	1.66	1.01	1.97	3.16	2.65

** Indicate significance at 1% level of probability.

characters. The ratio of GCA/SCA exceeded the unity in both generations for all studied traits, indicating that the additive effect of gene action was more important than the dominance effect. Thus, selection for improving these characters would likely be effective. These findings are in accordance with those obtained by Sech and Huyghe (1991), Klochko *et al.* (1996) and El-Sayad (2006).

Mean performance

The mean performance of the seven parents and their F_1 and F_2 crosses for different characters are presented in Table (3). The sweet lupin variety Piscovij was the earliest parent in maturity and had the lowest values of plant height, number of branches, pods and seeds and seed yield per plant. Meanwhile, Dijon-2 recorded the highest value of plant height,100-seed weight, number of pods and seeds and seed yield per plant followed by Giza-1. Moreover, Mutant-23 gave the highest number of branches per plant and Mutant-33 was the latest parent in maturity. With respect to the tested crosses in both F_1 and F_2 generation, all hybrids tended to be late in maturity as compared to the earliest parents except the cross (P_4 x P_7) which was insignificantly earlier than parents. Three crosses, P_2 x P_5, P_2 x P_6 and (P_5 x P_6) exceeded significantly the tallest parent. The crosses (P_1 x P_2), (P_2 x P_5), (P_2 x P_6), (P_2 x P_7) and (P_5 x P_6) exceeded significantly the best parent in both number of pods and number of seeds per plant. Concerning seed yield per plant, the crosses (P_1 x P_2), (P_1 x P_6), (P_2 x P_5), (P_2 x P_6) and (P_4 x P_5) outyielded significantly the highest parent. It could be concluded that the previously mentioned parents and crosses would be useful and prospective for the future in white lupin breeding for improving earliness and productivity.

Heterotic effects

Estimates of heterosis percentage relative to mid (MP) and better (BP) parents are given in Table (4). Regarding the number of days to maturity, the results showed that five crosses were highly significant earlier than their to respective mid parents with heterotic effect ranging from – 1.3 to – 3.8%. At the same time, heterosis percentage relative to mid parents was significant or highly significant and positive in nineteen crosses for plant height (11.1- 55.1%), in sixteen crosses for number of branches per plant (0.8– 50.5%), in twenty crosses for number of pods per plant (10.7–102.7%), in sixteen crosses for number of seeds per plant (44.1– 93.0%), in two crosses for 100-seed weight (0.36–1.30%) and in eighteen crosses for seed yield per plant (6.– 81.1%).

However, heterosis percentages relative to better parent were highly significant and negative in three crosses and ranged from -0.9 to -3.0% for number of days to maturity. Meanwhile,(heterobeltiosis relative to better parent) was significant or highly significant and positive in ten, twelve,

Table 3. Mean performance of the parents and their crosses in F_1's and F_2's for various studied traits.

Parent	Days to maturity		Plant height (cm)		No. of branches/plant		No. of pods/ plant		No. of seeds/ plant		100-seed weight (g)		Seed yield/plant (g)	
Piscovij (P_1)	159.5		52.5		3.90		13.5		46.5		34.70		16.15	
Kiev Mutant (P_2)	167.0		65.0		5.55		17.5		61.0		36.45		22.20	
Giza-1 (P_3)	165.5		95.0		5.60		29.0		101.0		37.15		37.55	
Belbies-9 (P_4)	160.5		87.5		5.55		27.0		90.5		33.95		30.65	
Mutant-23 (P_5)	164.5		70.0		6.70		17.5		63.5		34.20		21.70	
Mutant-33 (P_6)	168.5		85.0		6.10		19.5		67.0		35.50		23.80	
Dijon-2 (P_7)	166.5		102.5		6.60		37.0		122.0		38.85		47.55	
Mean(parents)	164.6		79.6		5.71		23.0		78.79		35.83		28.51	
Crosses	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
$P_1 \times P_2$	167.0	168.0	77.5	57.5	7.1	6.1	27.0	31.0	91.0	83.5	33.50	33.85	30.50	28.30
$P_1 \times P_3$	168.5	167.0	100.0	80.0	7.2	5.9	37.0	28.0	125.5	92.5	34.10	34.05	42.80	30.80
$P_1 \times P_4$	166.5	163.0	90.0	72.5	5.9	6.8	32.0	28.0	108.0	90.0	34.45	33.85	37.15	31.0
$P_1 \times P_5$	162.5	162.0	95.5	80.0	7.6	4.5	30.5	26.5	97.5	67.5	34.50	33.25	33.60	22.45
$P_1 \times P_6$	168.0	163.5	87.5	100.0	6.0	6.1	30.0	24.5	99.5	82.5	35.55	34.30	35.30	28.30
$P_1 \times P_7$	167.0	165.0	115.0	72.5	6.6	5.9	33.0	26.0	146.5	87.5	33.75	35.15	49.4	30.60
$P_2 \times P_3$	167.5	166.5	100.0	83.5	6.1	6.9	43.0	31.0	143.5	108.0	34.45	33.95	49.45	36.65
$P_2 \times P_4$	165.5	166.0	90.5	86.5	6.8	5.8	40.0	25.5	131.5	87.0	34.05	32.75	44.75	28.55
$P_2 \times P_5$	159.5	164.0	92.5	87.5	5.1	5.1	30.0	32.5	101.5	90.0	34.25	34.50	35.75	31.10
$P_2 \times P_6$	169.5	160.5	100.5	105.0	7.0	5.9	37.5	27.5	123.5	103.5	33.75	28.85	41.65	29.85
$P_2 \times P_7$	164.5	167.0	121.5	106.5	6.6	5.3	46.0	44.0	152.5	144.5	34.20	33.65	52.15	48.65
$P_3 \times P_4$	160.5	169.0	115.5	95.0	5.8	8.0	31.0	38.0	105.0	121.5	34.35	35.65	36.15	43.35
$P_3 \times P_5$	165.5	168.5	97.0	93.0	6.2	6.9	27.5	30.5	90.0	105.5	35.25	35.45	31.95	37.45
$P_3 \times P_6$	170.5	167.0	120.0	95.5	7.9	5.2	43.5	25.0	138.0	85.5	33.70	34.40	46.55	29.40
$P_3 \times P_7$	166.5	170.5	136.0	102.5	7.0	6.3	48.5	29.5	161.0	98.0	34.85	37.07	56.10	36.60
$P_4 \times P_5$	163.0	168.5	88.5	77.5	5.4	6.6	35.0	31.5	116.0	103.0	34.00	35.70	39.45	36.80
$P_4 \times P_6$	165.5	160.5	87.5	85.5	7.1	6.4	22.0	43.5	78.0	140.5	34.35	33.65	26.85	47.15
$P_4 \times P_7$	159.5	159.5	105.5	110.5	5.1	8.1	37.5	19.0	119.5	63.5	34.20	34.85	40.85	22.15
$P_5 \times P_6$	169.5	169.5	112.0	100.5	5.4	6.7	32.5	28.5	106.0	96.5	34.05	27.65	36.15	26.50
$P_5 \times P_7$	167.5	170.5	109.0	112.0	6.7	7.0	31.0	43.0	103.0	141.5	34.30	34.15	35.35	48.35
$P_6 \times P_7$	165.0	163.0	110.5	97.5	6.3	6.7	42.3	31.5	136.5	103.5	34.35	35.50	46.85	36.75
Mean (crosses)	165.7	165.7	102.5	90.5	6.4	6.6	36.51	30.69	117.79	99.79	34.28	33.92	40.42	33.85
Overall mean	165.15	165.15	91.05	85.05	6.06	6.16	29.76	26.85	98.29	89.29	35.06	34.88	34.47	31.18
$LSD_{0.05}$	1.05	1.13	10.01	11.07	0.86	0.95	5.18	5.89	15.45	12.67	0.32	0.28	5.35	4.26

Table 4. Heterosis percentage relative to mid (MP) and better (BP) parent for different studied traits.

Crosses	Days to maturity		Plant height (cm)		No. of branches/plant		No. of pods/plant		No. of seeds/plant		100-seed weight (g)		Seed yield/plant (g)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
P_1 x P_2	2.30^{**}	4.7^{**}	31.9^{**}	19.2^{**}	50.3^{**}	27.9^{**}	74.2^{**}	54.3^{**}	69.3^{**}	49.2^{**}	-5.30^{**}	-8.10^{**}	59.1^{**}	37.4^{**}
P_1 x P_3	3.70^{**}	5.6^{**}	35.6^{**}	5.3	50.5^{**}	27.7^{**}	74.1^{**}	27.6^{**}	70.2^{**}	24.3^{**}	-5.10^{**}	-8.20^{**}	59.4^{**}	13.2^{**}
P_1 x P_4	4.10^{**}	4.4^{**}	28.6^{**}	2.9	23.8^{**}	5.4^{**}	58.0^{**}	18.5^{**}	57.8^{**}	19.3^{**}	0.36^{*}	-0.72^{**}	58.8^{**}	21.2^{**}
P_1 x P_5	0.31	1.9^{**}	55.1^{**}	26.3^{**}	42.5^{**}	12.7^{**}	96.8^{**}	74.3^{**}	77.3^{**}	53.5^{**}	0.15	-0.58^{**}	77.5^{**}	54.8^{**}
P_1 x P_6	2.40^{**}	5.3^{**}	27.3^{**}	2.9	19.0^{**}	-2.5^{**}	81.8^{**}	53.8^{**}	75.3^{**}	48.5^{**}	1.30^{**}	0.14	76.7^{**}	48.3^{**}
P_1 x P_7	2.60^{**}	4.7^{**}	48.4^{**}	12.2^{*}	25.7^{**}	0.0	30.7^{**}	-10.8^{**}	73.4^{**}	19.6^{**}	-8.20^{**}	-13.10^{**}	55.1^{**}	3.9
P_2 x P_3	0.80	1.2^{**}	-18.8^{**}	-31.6^{**}	9.4^{**}	8.9^{**}	84.9^{**}	48.3^{**}	77.2^{**}	42.1^{**}	-6.40^{**}	-7.30^{**}	65.5^{**}	31.7^{**}
P_2 x P_4	1.10^{*}	3.1^{**}	18.7^{**}	3.3	22.5^{**}	22.5^{**}	79.8^{**}	48.1^{**}	73.6^{**}	45.3^{**}	-3.30^{**}	-6.60^{**}	69.3^{**}	46.0^{**}
P_2 x P_5	$- 3.80^{**}$	-3.0^{**}	37.0^{**}	32.1^{**}	-17.6^{**}	-24.6^{**}	71.4^{**}	71.4^{**}	73.1^{**}	59.8^{**}	-0.21	-3.30^{**}	62.9^{**}	61.0^{**}
P_2 x P_6	1.00^{*}	1.5^{**}	34.0^{**}	18.2^{**}	19.3^{**}	13.9^{**}	102.7^{**}	92.3^{**}	93.0^{**}	84.3^{**}	-6.20^{**}	-7.40^{**}	81.1^{**}	75.0^{**}
P_2 x P_7	-1.30^{**}	-1.2^{**}	45.1^{**}	18.5^{**}	7.8^{**}	7.4^{**}	68.8^{**}	24.3^{**}	66.2^{**}	24.5^{**}	-9.20^{**}	-12.00^{**}	49.5^{**}	9.7^{**}
P_3 x P_4	-1.50^{**}	0.0	26.6^{**}	21.6^{**}	4.0^{**}	3.6^{**}	10.7^{**}	-16.2^{**}	9.7	4.0	-3.40^{**}	-7.50^{**}	6.0^{*}	-3.7
P_3 x P_5	0.30	0.6	17.8^{**}	2.1	0.8^{*}	-7.46^{**}	18.3^{**}	-5.2^{*}	9.4	-10.9	-1.20^{**}	-5.10^{**}	7.8^{**}	-14.9^{**}
P_3 x P_6	2.10^{**}	3.0^{**}	33.9^{**}	26.8^{**}	35.0^{**}	29.5^{**}	79.4^{**}	50.0^{**}	64.3^{**}	36.6^{**}	-7.20^{**}	-9.30^{**}	51.8^{**}	24.0^{**}
P_3 x P_7	0.50	0.0	37.7^{**}	32.7^{**}	13.9^{**}	5.3^{**}	47.0^{**}	31.1^{**}	44.1^{**}	31.4^{**}	-8.30^{**}	-10.30^{**}	31.8^{**}	18.0^{**}
P_4 x P_5	0.30	1.6^{**}	12.4^{**}	1.1	-11.8^{**}	-19.4^{**}	57.3^{**}	29.6^{**}	50.6^{**}	28.2^{**}	-0.22	-0.58^{**}	50.7^{**}	28.7^{**}
P_4 x P_6	0.60	3.1^{**}	1.5	0.0	21.9^{**}	16.4^{**}	-5.4^{*}	-18.5^{**}	-0.95	-13.8	-1.10^{**}	-3.20^{**}	-1.4	-12.4^{**}
P_4 x P_7	-2.50^{**}	-0.6	11.1^{*}	2.9	-16.1^{**}	-22.7^{**}	17.2^{**}	1.4	12.2	-2.5	-6.00^{**}	-12.00^{**}	4.5	-14.1^{**}
P_5 x P_6	1.80^{**}	3.1^{**}	44.5^{**}	31.8^{**}	-16.4^{**}	-20.2^{**}	75.7^{**}	66.7^{**}	62.5^{**}	58.2^{**}	-2.30^{**}	-4.10^{**}	58.9^{**}	51.9^{**}
P_5 x P_7	1.20^{*}	1.8^{**}	26.4^{**}	9.3	0.8^{*}	0.0	13.8^{**}	-16.2^{**}	10.8	-13.5	-6.10^{**}	-11.70^{**}	2.1	-25.7^{**}
P_6 x P_7	-1.50^{**}	-0.9^{**}	17.9^{**}	7.8	-0.8^{*}	-4.6^{**}	49.7^{**}	14.3^{**}	44.1^{**}	11.4	-7.60^{**}	-11.60^{**}	31.3^{**}	-1.5

* and ** indicate significance at 5% and 1% level of probability, respectively.

fifteen, fifteen and fourteen crosses with a range of 12.2-32.7, 3.6-29.5, 14.3-92.3, 19.6-84.3 and 9.7-75.0% for plant height, number of branches, number of pods, number of seeds and seed yield per plant, respectively. The high magnitudes of hetrotic values found in these materials are expected to be due to the diversity of the parents. Therefore, improvement would be expected from selection in the advanced segregating generations. These results are in general agreement with those reported by Agarkova *et al* (1991), Sech and Huyghe (1991), El-Sayad *et al* (2002) and El-Sayad (2006).

Inbreeding effects

Results of inbreeding effects in F_2 generation for the studied characters are presented in Table (5). Concerning the number of days to maturity, seven crosses showed significant or highly significant depression in F_2 population as a result of inbreeding with values ranging from -1.2 to -5.3%. Moreover, seven, two, seven, nine, eight and ten crosses expressed significant or highly significant inbreeding depression for plant height, number of branches, number of pods, number of seeds, 100-seed weight and seed yield per plant with a range of 17.7-37, 34.8 - 41.1, 25.5-49.3, 24.7-46.9, 1.6-18.8 and 21.6-36.8%, respectively. On the other hand, significant superiority gain was observed in some F_2 over their F_1crosses for all studied characters, except plant height which could be attributed to transgressive segregations. The results of El-Sayad *et al* (2002) supported the forementioned findings.

General combining ability effects

The estimated effects and significance of general combining ability (gi) for each trait of the seven parents are presented in Table (6). High positive GCA effects were found for all traits except number of days to maturity, where the high negative effects would be useful from the breeder's point of view. Therefore, the results suggested that the parents Piscovij and Belbies-9 were good combiners for earliness. They gave highly significant negative GCA effects for number of days to maturity. Meanwhile, the parents Dijon-2 and Giza-1 could be considered superior combiners for plant height, 100 seed weight, number of branches, number of pods, number of seeds and seed yield per plant. They exhibited highly significant and positive GCA effects for these traits. However, the parents Piscovij and Kiev Mutant were considered better combiners for short plants. They exhibited highly significant and negative GCA effects for this trait. The detection of the general combining ability of the parental genotypes provides better information not only for selecting the parents for hybridization but also in choosing the proper breeding scheme. El-Sayad (2006) indicated that Dijon-2 was a super general combiner for plant height, number of branches as well as seed yield and its components.

Table 5. Inbreeding effects (%) in F_2 for various studied traits.

F_2Crosses	Days to maturity	Plant height (cm)	No. of branches/p	No. of pods/plant	No. of seeds/plant	100-seed weight (g)	Seed yield /plant (g)
$P_1 \times P_2$	-0.6	25.8**	14.8	-14.8	8.2	-1.0	7.2
$P_1 \times P_3$	0.9	20.0**	18.2	24.3	26.3**	0.15	28.0**
$P_1 \times P_4$	2.1**	19.4**	-16.2	12.5	16.7	1.7*	16.6
$P_1 \times P_5$	0.3	16.2	41.1**	13.1	30.8**	3.6**	33.2**
$P_1 \times P_6$	2.7**	-14.3	-2.5	18.3	17.1	3.5**	19.8
$P_1 \times P_7$	1.2*	37.0**	10.6	21.2	40.3**	-4.1**	38.1
$P_2 \times P_3$	0.6	16.5	-13.9	27.9*	24.7**	1.5	25.9**
$P_2 \times P_4$	-0.3	4.4	14.0	36.3**	33.8**	3.8**	36.2**
$P_2 \times P_5$	-2.8**	5.4	-0.99	-8.3	11.3	-0.73	13.0
$P_2 \times P_6$	5.3**	-4.5	15.1	26.7*	16.2	14.5**	28.3**
$P_2 \times P_7$	-1.5*	12.3	19.8	4.3	5.2	1.6*	6.7
$P_3 \times P_4$	-5.3**	17.7*	-37.9**	-22.6	-15.7	-3.8**	-19.9
$P_3 \times P_5$	-1.8**	4.1	11.3	-10.9	-17.2	-0.6	-17.2
$P_3 \times P_6$	2.1**	20.7**	34.8**	42.5**	38.0**	-2.1**	36.8**
$P_3 \times P_7$	-2.4**	24.6**	10.1	39.2**	39.1**	-6.4**	34.8**
$P_4 \times P_5$	-3.4**	12.4	-21.3	10.0	11.2	-5.0**	6.7
$P_4 \times P_6$	3.0**	2.3	10.6	-97.7**	-80.0**	2.0**	-75.6**
$P_4 \times P_7$	0.0	-4.7	-57.8**	49.3**	46.9**	-1.9*	45.8**
$P_5 \times P_6$	0.0	10.3	-24.3	12.3	9.0	18.8**	26.7*
$P_5 \times P_7$	-1.8**	-2.8	-4.5	-38.7*	-37.4**	0.44	-36.8**
$P_6 \times P_7$	1.2*	11.8	-5.6	25.5*	24.2**	-3.35**	21.6*

* and ** indicate significance at 5% and 1% level of probability, respectively.

Table 6. Estimates of general combining ability effects (gi) of the parental genotypes in F_1 and F_2 generation for the studied characters.

Parents	Days to maturity		Plant height (cm)		No. of branches/p		No. of pods/ plant		No. of seeds/plant		100-seed weight (g)		Seed yield/plant (g)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Piscovij (P_1)	-0.516**	-1.738**	-11.53**	-14.99**	-0.205**	-0.680**	-4.446**	-4.349**	-11.492**	-17.80**	-0.266**	-0.144**	-4.275**	-6.261**
Kiev Mutant (P_2)	0.484**	0.317**	-6.865**	-5.10**	-0.021*	-0.319**	0.221	-0.405	0.119	-1.95	0.051**	-0.521**	-0.098	-1.40**
Giza-1 (P_3)	0.762**	1.817**	9.413**	4.12**	0.162**	0.137**	3.554**	1.095*	11.175**	6.29**	0.373**	1.079**	4.286**	3.25**
Belbies-9 (P_4)	-2.405**	-1.738**	-2.421*	0.01	-0.299**	0.403**	-0.557	1.040*	-2.825	3.35	-0.483**	-0.088**	-1.448**	1.133**
Mutant-23 (P_5)	-0.738**	0.984**	-4.421*	-1.33	-0.021*	0.109**	-3.890**	-0.294	-13.714**	-2.82	-0.210**	-0.671**	-4.875**	-1.561**
Mutant-33 (P_6)	2.429**	-0.238**	1.579	5.73**	0.212**	-0.008	-1.079**	-1.183**	-5.437	-1.19	-0.099**	-1.088**	-2.064**	-1.617**
Dijon-2 (P_7)	-0.016*	0.595**	14.246**	11.56**	0.173**	0.359**	6.198**	4.095**	22.175**	14.12**	0.634**	1.434**	8.475**	6.456**
S.E.gi	0.0131	0.0152	1.188	1.452	0.009	0.011	0.3181	0.4113	2.8311	1.902	0.0012	0.0009	0.3397	0.215
S.E.gi-gj	0.0307	0.0356	2.772	3.389	0.021	0.025	0.742	0.9597	6.606	4.439	0.0029	0.0022	0.7926	0.502

* and ** indicate significance at 5% and 1% level of probability, respectively.

Specific combining ability effects

The estimates and significance of specific combining ability effects (Sij) for different crosses are presented in Table (7). Regarding the number of days to maturity in F_1 and F_2, four crosses, (P_1xP_5, P_2xP_5, P_4xP_7 and P_6xP_7) expressed negative (favorable) significant SCA effects. There are also negative significant SCA effects in the F_1 crosses (P_2xP_7) and (P_3xP_4) as well as in those crosses of F_2 (P_2xP_3), (P_2xP_6) and (P_4xP_6) for this trait. The three crosses, (P_1xP_2), (P_1xP_3) and (P_5xP_7) showed positive significant SCA effects for number of branches per plant in both F_1 and F_2 generations. All crosses had insignificant SCA effects for plant height in both F_1 and F_2 generations. Meanwhile, the three crosses (P_2xP_4), (P_3xP_6), (P_4xP_5) in F_1, two crosses (P_4xP_6), (P_5xP_7) in F_2 and one cross (P_2xP_7) in both F_1 and F_2 recorded positive and highly significant SCA effects for number of pods per plant. On the other hand, three crosses (P_2xP_7), (P_4xP_6) and (P_5xP_7) expressed positive and significant SCA effects for number of seeds per plant in F_2 only. Four crosses showed significant and positive SCA effects for seed index, (P_1xP_6, P_2xP_5, P_3xP_5 and P_4xP_6) in both F_1 and F_2 generations. With respect to seed yield per plant, the three crosses: (P_2xP_7), (P_3xP_7) and (P_4xP_5) exhibited significant positive SCA effects in both F_1 and F_2 generations. These results are in general agreement with those obtained by Bushueva (1988), Sech and Huyghe (1991) and El-Sayad (2006).

From the breeding point of view, the parents characterized by good general combining ability for earliness, yield and its components along with high heterosis and high SCA effects in their hybrid combinations are very useful. A great deal of interest had been aimed at selecting the crosses involving good combiner parents or at least one good combiner parent having high SCA effects as well as high heterosis in hybrid combinations. Therefore, most of the crosses made in this research could be of importance in white lupin breeding programs.

Table 7. Estimates of specific combining ability effects (sij) in F_1 and F_2 crosses for the studied traits.

Cross	Days to maturity		Plant height (cm)		No. of branches/p		No. of pods/plant		No. of seeds/plant		100-seed weight (g)		Seed yield/plant (g)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
P_1 x P_2	1.64**	4.03**	-0.89	-10.21	1.10**	0.92**	-0.84	6.99*	-5.68	8.75	-0.99**	0.12**	-2.57	3.45
P_1 x P_3	2.86**	1.53**	5.33	3.069	0.96**	0.26**	5.83	2.49	17.76	9.17	-0.71**	-1.28**	5.35	1.30
P_1 x P_4	4.03**	1.08**	7.17	-0.319	0.12	0.94**	4.94	2.54	14.26	9.95	0.49**	-0.31**	5.43	3.62
P_1 x P_5	-1.64**	-2.64**	14.67	8.514	1.55**	-1.11**	6.77*	2.38	14.65	-6.38	0.27**	-0.33**	5.31	-2.24
P_1 x P_6	0.69**	0.08	0.67	21.458	-0.29**	0.65**	3.46	1.26	8.38	6.99	1.21**	1.14**	4.20	3.67*
P_1 x P_7	2.14**	0.75**	15.5	-11.87	0.40**	0.09	-0.82	-2.51	27.76	-3.66	-1.32**	-0.53**	7.76**	-2.11
P_2 x P_3	0.86**	-1.03**	0.67	-3.32	-0.27**	1.00**	7.16*	1.54	24.15	9.15	-0.68**	-1.00**	7.82**	2.29
P_2 x P_4	2.03**	2.03**	3.00	3.79	0.89**	-0.37**	8.27**	-3.90	26.15	-8.90	-0.22**	-1.03**	8.85**	-3.70*
P_2 x P_5	-5.64**	-2.69**	7.00	6.13	-1.14**	-0.82**	1.61	4.43	7.04	0.26	0.70**	1.30**	3.28	1.55
P_2 x P_6	1.19**	-4.97**	9.00	16.57	0.53**	0.09	6.29*	0.32	20.76	12.13	-0.91**	-3.93**	6.37*	0.35
P_2 x P_7	-1.36**	0.69**	17.33	12.24	0.17*	-0.92**	7.52**	11.54**	22.15	37.82*	-1.19**	-1.66**	6.33*	11.08**
P_3 x P_4	-3.25**	3.53**	11.72	3.07	-0.29**	1.33**	-4.06	7.10*	-11.40	17.36	-0.25**	0.27**	-4.13	6.45**
P_3 x P_5	0.08	0.31*	-4.78	2.40	-0.17*	0.52**	-4.23	0.93	-15.51	7.52	0.38**	0.65**	-4.90	3.25
P_3 x P_6	1.92**	0.03	12.72	-2.15	1.30**	-1.11**	8.96**	-3.68	24.21	-14.11	-1.28**	0.02*	6.89*	-4.75*
P_3 x P_7	0.36**	2.69**	15.56	-0.99	0.39**	-0.38**	6.68	-4.46	19.6	-16.92	-0.86**	0.14**	5.90*	5.62**
P_4 x P_5	0.75**	3.86**	-1.44	-8.99	-0.51**	-0.10	7.38**	1.99	24.49	7.97	-0.01	2.07**	8.33**	4.72*
P_4 x P_6	0.08	-2.92**	-8.44	-8.04	0.96**	-0.18	-8.43**	14.88**	-21.79	43.51**	0.23**	0.43**	-7.08**	15.12**
P_4 x P_7	-3.47**	-4.75**	-3.11	11.13	-1.00**	1.15**	-0.21	-14.9**	-7.90	-48.48**	-0.66**	-0.89**	-3.62	-17.95**
P_5 x P_6	2.42**	3.36**	18.06	8.29	-1.07**	0.42**	5.41	1.21	17.10	5.67	-0.35**	-4.98**	5.65	-2.84
P_5 x P_7	2.86**	3.53**	2.39	13.96	0.32**	0.40**	-3.37	10.43**	-13.51	35.69*	-0.83**	-1.01**	-5.69	10.94**
P_6 x P_7	-2.81**	-2.75**	-2.11	-7.6	-0.32**	0.17	5.12	-0.18	11.71	-3.94	-0.89**	0.76**	3.00	-0.60
SEsij	0.1112	0.129	10.049	12.285	0.075	0.091	2.690	3.479	23.95	16.092	0.0104	0.008	2.873	1.818
SEsij-sik	0.2453	0.285	22.18	27.111	0.165	0.200	5.938	7.678	52.846	35.512	0.023	0.017	6.341	4.013
SEsij-skl	0.2147	0.249	19.405	23.722	0.145	0.175	5.195	6.718	46.241	31.073	0.020	0.015	5.549	3.511

* and ** indicate significance at 5% and 1% level of probability, respectively.

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قوة الهجين وتأثير التربية الذاتية والقدرة على التآلف للهجن التبادلية فى الترمس

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أجريت هذه الدراسة بمحطة البحوث الزراعية بملوى على سبعة آباء (Piscovij، Kiev Mutant، جيزة-١، بلبيس-٩، الطفرة-٢٣، الطفرة-٣٣، Dijon-2) من الترمس وجميع الهجن التبادلية بينها ماعدا الهجن العكسية فى الجيل الأول والثانى خلال المواسم ٢٠٠٨/٢٠٠٩، ٢٠٠٩/٢٠١٠، ٢٠١٠/٢٠١١ بهدف تقدير قوة الهجين والتدهور نتيجة التربية الذاتية والقدرة العامة والخاصة على الإئتلاف لصفات عدد الأيام من الزراعة حتى النضج، طول النبات، عدد الأفرع للنبات، عدد القرون للنبات، عدد البذور للنبات، وزن ١٠٠ بذرة ووزن محصول النبات وتم تحليل النتائج حسب مااقترحه العالم جريفنج (١٩٥٦)، ويمكن تلخيص النتائج كما يلى:

أظهر التباين الراجع للتراكيب الوراثية معنوية لكل الصفات تحت الدراسة وكذلك التباين الراجع للقدرة العامة أو الخاصة على الإئتلاف كان معنوى لكل الصفات فى كلاً من الجيل الأول والثانى مما يشير الى أهمية كل من التأثير المضيف وغير المضيف للفعل الجينى على توريث هذه الصفات.

أوضحت النتائج تفوق بعض هجن الجيل الأول تفوقاً معنوياً على متوسط الأبوين وعلى الأب الأحسن، كذلك حدث تدهور معنوى فى نباتات الجيل الثانى لبعض الهجن نتيجة للتربية الذاتية فى كل الصفات ولو أن بعض الصفات تحسنت فى الجيل الثانى عن الأول فى بعض الهجن.

أظهرت الآباء Piscovij ، بلبيس-٩ قدرة عامة مرغوبة لصفة التبكير فى النضج كما تفوقت الآباء Dijon-2، جيزة-١ فى قدرتها العامة لصفات طول النبات وعدد الأفرع للنبات وعدد القرون والبذور للنبات ووزن ١٠٠ بذرة وكذلك لوزن محصول النبات كما أوضحت الهجن الناتجة من كلاً منهما تقديرات عالية للقدرة الخاصة على الإئتلاف لتلك الصفات مما يؤكد تميز هذه التراكيب الوراثية من الأباء والهجن وامكان استخدامها فى تحسين محصول الترمس.

المجله المصريه لتربية النبات ١٥(٣): ١٠٩ - ١٢٢ (٢٠١١)