Menoufia J. Plant Prod., Vol. 5 **December** *(2020): 435 – 450* https://mjppf.journals.ekb.eg/

ESTIMATES OF HETEROSIS AND COMBINING ABILATY FOR FOLIAR DISEASES RESISTANCE, YIELD AND ITS COMPONENTES AND SEED QUILITY OF FABA BEAN

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Received: Dec. 20 , 2020 Accepted: Dec. 29 , 2020

ABSTRACT: Five diverse faba bean (*Vicia faba* L.) genotypes were crossed in half diallel method. The F_1 seeds along with their parental genotypes were sown in a randomized complete block design with three replications during 2019 /20 season at Sakha Agricultural Research Station. Analysis of variances revealed highly significant effects of genotypes for all the studied traits, providing evidence for the presence of large amount of genetic variability. The parental genotypes; Santamora and Sakha 3 were considered as good sources for resistance to chocolate spot and rust and high yield ability. Meanwhile, the parental genotypes; Giza 429 and $R.V_{323}$ considered as good sources for early flowering. Due to the significance of gca and sca variances, the additive as well as non-additive components were more important for all the studied traits under study. The estimates of GCA/SCA mean squares were more than unity for all traits, except No. of branches, pods, seeds and crude protein content, where the same ratio was less than unity. This indicated that most of the genetic variation in these traits appear to be additive. Heterotic effects over mid and better parents were detected in the crosses. Based on the two estimates of heterotic effects, the following crosses: C_1 (Giza40 x Santamora), C_8 (Giza429 x Sakha3), C_9 (Giza429 x R.V) and C_{10} (Sakha3 x R.V) exhibited significant positive heterotic effects over both mid and better parents for most studied yield characters. Progenies of these crosses will be used in bulk method selection program to produce high yield potentiality pure lines.

Key words: Faba bean, Chocolate spot, Rust, Heterosis, Combining ability.

INTRODUCTION

Faba bean (*Vicia faba* L.) is widely considered as a good source of protein, starch and minerals for humans in developing countries and its content of cellulose is also useful for animals in industrialized countries (Haciseferogullari *et al*., 2003). In 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 bidogical N_2-fixation (Lindemann and Glover, 2003).

Faba bean is a self-pollinate plant with significant levels of out-cross and inter-cross, ranging from 20 to 80% (Suso and Moreno, 1999) depending on genotype and environmental effects. The improvement of crop desired traits depends on the nature and magnitude of genetic variability and interactions involved in the inheritance of these traits which can be estimated using diallel cross technique. This technique may also result in the production of new genetic combinations whose performance, negatively or positively, may exceed that of the parents, a phenomenon known as heterosis. Exploitation of heterosis could pay off improving yield potential and its components in faba beans, where superiority of hybrids over the mid and/

or better parents for seed yield is associated with manifestation of heterotic effects in important yield components, i.e., No. of branches per plant, No. of pods per plant and seed index. These heterotic effects may range from significantly negative to significantly positive for different traits depending on genetic make-up of parents (El-Hosary *et al*., 1997, Darwish *et al*., 2005, El-Hady *et al*., 2006 and Abou-Zaid *et al*., 2018).

The improvement of various traits depends on the nature and magnitude of genetic variability in addition to hybridization which offers new recombinations and release new materials for improvement and helps the breeders to identify the best combinations to be crossed either to exploit heterosis or build up the favorable fixable genes. Therefore, yield itself may not be the best criterion for selection, so that breeding for high seed yield is associated with yield and its components; No. of branches, pods, No. of seeds plant^{-1} and 100-seed weight (Rowlands, 1955).

Faba bean is widely considered as good source of protein, starch and minerals for humans and animals in industrialized countries (Haciseferogullari *et al*., 2003). Generally research on seed quality of faba bean, has been focused on total protein and carbohydrate (Tewatia and virk, 1996). Protein content which ranges from (27 to 34%) depend on genotypes and carbohydrate content ranges between (52.3 to 64.4%) on dry weight (Salih and El- Hardallou, 1986).

The present study aimed at determining the magnitude of heterosis, general and specific combining ability of some faba bean hybrid combinations.

MATERIALS AND METHODS

Five faba bean varieties, *i.e.,* Giza 40 (P_1), Santamora 1 (P_2), Giza 429 (P_3), Sakha 3 (P_4) and R.V (P_5) were selected on the basis of the presence of wide differences among them with respect to certain economically important traits and their reaction with the foliar diseases. The second and the fourth genotypes possess variable degrees of resistance to foliar diseases (chocolate spot and rust) while another genotypes are susceptible one as shown in Table 1.

Table 1: Names, origin', botanical group, disease reactions and agronomic characters of the five parental faba bean genotypes used in this investigation.

Genotypes	Origin	Botanical group	Agronomic characters		
			Disease reactions	Flowering date	Yielding level
Giza 40	Egypt	Equina	S	Early	High
Santamora	Spain	Major	R	Medium	High
Giza 429	Egypt	Equina	S	Early	High
Sakha 3	Egypt	Equina	R	late	High
R.V_{323}	Sudan	Minor	S	Early	low

HR=High resistance to foliar diseases R = Resistant to foliar diseases
MS= Moderate susceptibility to foliar diseases S= Susceptibility to foliar diseases

In 2018/2019 season under free insect cage, all possible cross combinations excluding reciprocals (half diallel) were made among the five parents (sown in two sowing dates to avoid differences in flowering times and to secure enough hybrids seeds during this season). Parents and derived 10 F_1's were grown under the free insect cages at Sakha Agricultural Research Station Farm, Kafr El-Sheikh, Egypt during the season of 2019/2020. Fifteen genotypes were sown in a randomized complete block design with three replications under natural infection condition, surrounded by a highly foliar diseases infection variety. Seeds were sown in single seeded hills, 20 cm apart, each entry was represented by one row for parents and their F_1'^{s}. The row was 3 meters long and 60 cm in between.

Measurements were taken on the basis of individual plant as follows:

Chocolate spot and rust disease reactions, flowering date, plant height, No. of branches plant^{-1}, No. of pods plant^{-1}, No. of seeds plant^{-1}, 100-seed weight, seed yield plant^{-1}, crude protein % and carbohydrate %.

The choice of parents was based on: a) genetic diversity. b) differences in growth habit and disease reactions and c) differences in yielding ability. The pedigree, disease reactions, agronomic characters and yielding level are presented in Table 1.

The disease severity of chocolate spot and rust diseases was recorded at mid-February and mid-March, respectively using the scale of Bernier *et al*. (1984), as shown in Table 2.

Table 2: Chocolate spot and rust diseases scale.

	Chocolate spot
1	No disease symptoms or very small specks (highly resistance)
3	Few small disease lesions (resistant)
5	Some coalesced lesions, with some defoliation (moderately resistant)
7	Large coalesced sporulating lesions, 50% defoliation and some dead plants (susceptible)
9	Extensive, heavy sporulation, stem girdling, blackening and death of more than 80% of plants (highly susceptible)
	Rust
1	No pustules or very small non-sporulating flecks (highly resistant)
3	Few scattered pustules covering less than 1% of the leaf area and few or no pustules on stem (resistant)
5	Pustules common on leaves covering 1-4% of leaf area, little defoliation and some pustules on stem (moderately resistant)
7	Pustules very common on leaves covering 4-8% of leaf area, some defoliation and many pustules on stem (susceptible)
9	Extensive pustules on leave, petioles and stem covering 8-10% of leaf area, many dead leaves and several defoliation (highly susceptible)

Seed quality:

Some seed properties were carried out at Sakha Seed Technology Research Department as follow :

Chemical composition including crude protein and carbohydrate content were determined according to the methods described in the AOAC (2006).

Mean squares and expected mean square of RCBD analysis of variance are presented in Table 3.

Where: r is the number of replication; E is the number of entries; σ^2E and σ^2e refer to genotypic and error variance, respectively . The difference between any two means was tested according to the least significant difference (LSD) at both 5% and 1% levels of significance as follows:

LSD : $P \leq 0.05$= t 0.05 (d.f) x S_d

$P < 0.01$= t 0.01 (d.f) x S d

Where: r is the number of replications and Ms_e : is the mean squares of error

Estimation of combining ability analysis:

The sum of squares among entries (genotypes) is in turn partitioned into parents and crosses and the latest is partitioned into general combining ability (GCA) and specific combining ability (SCA) and t is the tableted t at the degrees of freedom of error. The combining ability analysis of variance and the expectation of mean squares are given in Table (3) according to model 1 method 2 of Griffing approach (1956). The effects of parental varieties and crosses were considered as fixed effects.

The mathematical model for the combining ability analysis is assumed to be:

$X_{ijk} = u + \hat{g}_i + \hat{g}_j + \hat{S}_{ij} + r_k + e_{ijk}$

where: xij, is the performance of the i th parent mated to the j th parent in block k. u is the population mean, ĝi is the gca effect of the i th parental variety, Ŝ ij is the interaction of the i th and j th parents or sca effect of the crosses between them r k is the block effect and eijk is the random efect of the indvidual observation.

The restrictions: $\Sigma i\, (\hat{g}) = 0$ and $\Sigma j(\hat{S}_{ij}+\hat{S}_{ii}) = 0$ (for each i) are imposed on the combining ability effects.

Heterosis:

Heterosis was determined as outlined by Foolad and Bassiri (1983). Appropriate t-test was made for the significance of the F_1's from the mid and better parent (heterobeltiosis superiority of F_1 hybrids over the best parent) values (Wynne *et al*., 1970).

Table 3: The analysis of variance and the expected mean of square (EMS)

S.O.V	d f	MS	EMS
Replication	r-1	M r	
Genotypes	(E-1)	ME	$\sigma^2 e + r\,\sigma^2 g$
G.C.A	P-1	Mg	$\sigma^2 e + (p+1)(1/p-1)\,\Sigma^2_{gi}$
S.C.A	P(P-1)/2	Ms	$\sigma^2 e + 2/p(p-1)\,\Sigma_i \Sigma_j s^2_{ij}$
Error	(r-1) (E-1)	MS e	$\sigma^2 e$
Error term	(r-1) (E-1)/3	Me	$\sigma^2 e / r$

The amount of heterosis was expressed as the percentage deviation of F_1 mean performance from the mid – parent and better parent as follows:

Heterosis over mid – parent % (M.P) =

$$(\bar{F}_1 - \bar{MP}) / \bar{MP} \times 100$$

Heterosis over better – parent % (B.P) =

$$(\bar{F}_1 - \bar{BP}) / \bar{BP} \times 100$$

LSD for mid-parent $(\bar{F}_1 - \bar{M.P}) = t\,(3MSe/2r)^{1/2}$

LSD for better-parent $(\bar{F}_1 - \bar{B.P}) = t\,(2MSe/r)^{1/2}$

Potence ratio:

This parameter was calculated according to Wigan(1944) and Mather and Jinks (1971) as follows:

$$P.R = \bar{F}_1 - \bar{MP} / 1/2\,(HP - LP)$$

Where: F_1=Mean of the F_1 performance.
M.P = Mid-parent value = P_1+P_2/2.
H.p = The hiegher parent value.
L. P = The lower parent value.

Absence of dominance is consider when (p) is zero, and partial dominanance is assumed when (p) is between less than +1 and more than -1 but not equal zero, complete dominance is considered when (P) is equal +1 or -1 and over–dominance is considered when (P) is > +1 or < -1.

RESULTS AND DISCUSSION

The analysis of variance for all studied traits are presented in Table 4. The results revealed that, mean squares due to genotypes were highly significant for all the studied traits, providing evidence for presence of large amount of genetic variability, which is considered adequate for further biometrical assessment. In addition, mean squares of GCA and SCA were significant and highly significant for all the studied traits.

The significance of GCA and SCA indicates the presence of both additive and non-additive gene effects in the genetic system controlling these traits. The mean squares of GCA/SCA ratio were more than one for chocolate and rust disease reactions, flowering date, plant height, seed yield plant^{-1} and 100-seed weight, indicating that additive type of gene effects play the major role in the inheritance of these traits. However, the same ratio was less than one for No. of branches plant^{-1}, No. of pods and seeds plant^{-1}, crude protein and carbohydrate (%) , may indicat that non-additive genes were responsible for the inheritance of these traits. These results confirmed those findings reported by Darwish *et al*., (2005), Attia and Salem (2006), El-Hady *et al*., (2007), Ibrahim (2012), Ghareeb and Helal (2014), Abdalla *et al*., (2017) and Abou-Zaid *et al*., (2018).

Table 4: Analysis of variance for yield and its components of faba bean in the F_1 generation.

S.O.V	df	Chocolate spot disease reaction	Rust disease reaction	Flowering date (day)	Plant height (cm)	No. of branches plant^{-1}
Reps	2	0.11	0.07	1.7	3.77	0.06
Genotypes	14	2.13**	3.00**	135.62**	756.28**	2.75**
GCA	4	1.50**	2.23**	97.32**	535.06**	0.63**
SCA	10	0.39**	0.51**	24.36**	138.91**	1.03**
Error	24	0.14	0.11	1.82	9.26	0.32
Error term		0.05	0.04	0.61	3.09	0.11
GCA/ SCA		3.84	4.37	3.99	3.85	0.61

*and** significant at0.05 and 0.01 levels of probability, respectively

Table 4: Cont.

S.O.V	df	No. of pods plant^{-1}	No. of seeds plant^{-1}	Seed yield plant^{-1} (gm)	100-seed weight (gm)	crude protein %	Carbohydrate %
Reps	2	3.81	18.91	6.73	0.24	0.38	0.42
Genotypes	14	73.47**	868.05**	839.19**	486.19**	11.98**	14.12**
GCA	4	3.76*	93.70**	352.12**	427.01**	3.11**	4.51**
SCA	10	32.78**	367.61**	250.78**	56.09**	4.35**	4.79**
Error	24	4.04	17.71	8.71	2.83	0.45	0.48
Error term		1.35	5.9	2.9	0.94	0.15	0.16
GCA/ SCA		0.11	0.25	1.40	7.61	0.71	0.94

*and** significant at0.05 and 0.01 levels of probability, respectively

Mean performance:

Mean performance of parental varieties and their F_1' s for all the studied traits are presented in Table 5. Results revealed that, the relative ranking scores of tested parental genotypes in descending order for chocolate spot and rust diseases resistance were Santamora (P_2) and Sakha3 (P_4) as resistant genotypes with (4.0 and 3.33), respectively, while Giza 40 (P_1), Giza 429 (P_3) and R.V (p_5) were susceptible with values (5.81 and 6.0), (5.81 and 6.0) and (5. 09 and 5.70), respectively. The absence of complete resistance and susceptibility suggests the involvement of polygenic system (Abo-El-Zahab *et al*., 1994). Crosses involving the highly resistant parents exhibited the highest levels of resistance, C_6 (Santamora x Sakha3) with (2.86 and 3.33) followed by C_3 (Giza40 x Sakha3) (2.7 and 3.5) in chocolate spot and rust, respectively. However, cross involving the susceptible parents C_2 (Giza40 x Giza429) showed the least level of resistance (5. 56 and 5. 97), respectively.

Highly significant differences between genotypes were found for flowering date revealed that the means of the parental varieties; Giza 429 and R.V were the earliest varieties (41.46 and 38.18 day, respectively). On the other hand, the parental variety; Sakha3 was the latest variety (58.57 day), While, the crosses; C2 (Giza 40 x Giza 429), C4 (Giza 40 x R.V_{323}) and C_9 (Giza 429 x R.V_{323}) were considered as the earliest crosses. On the other side, C_1 (Giza40 x Santamora) behaved as the latest cross.

The variety; Santamora was the heaviest parent for seed yield plant^{-1} and 100-seed weight (80.79 g plant^{-1} and 94.08 g) followed by Sakha3 with values (70.10 g plant^{-1} and 85.34 g), while the parental variety; R.V was the lowest (38.12 g and 38.27) for seed yield and 100-seed weight respectively. On the other hand, the crosses; C_1 (Giza40 x Santamora), C_8 (Giza429 x Sakha3) and C_{10} (Sakha3 x R.V_{323}) were the highest crosses for seed yield plant^{-1} (87.68, 105.17 and 91.45 g, respectively). The crosses; C_3 (Giza40 x Sakha3) and C_4 (Giza40 x R.V_{323}) performed as low yield crosses (57.15 and 57.78 g, respectively). For crude protein %, Santamora containing of (27.45 %) and R.V_{323} (27.75%) had the highest parental values of crude protein %, while C_4 (Giza 40 x R.V_{323}) and C_6 (Santmora x sakha 3) were the highest crosses (31.26 and 29.25 %, respectively). Giza 429 behaved as the highest parent for carbohydrate (61.33 %) followed by Sakha3 (60.90%), also C_1, C_2 and C_5 behaved as the high carbohydrate % content (61.93, 60.25 and 60.59 %, respectively).

Table 5: Mean performance of parents and their crosses of faba bean genotypes for studied traits.

Genotypes	Chocolate spot disease	Rust disease	Flowering date	Plant height	No. branches	No. Pods	No Seeds	Seed yield	100-seed	crude protein	Carbo-hydrate
P_1 (Giza40)	5.81	6.00	47.78	135.74	3.52	27.11	86.22	60.68	70.79	24.40	59.77
P_2 (Santamora)	4.00	3.33	53.18	147.73	2.91	28.12	85.64	80.79	94.08	27.45	55.31
P_3 (Giza429)	5.81	6.00	41.46	132.60	3.67	30.94	91.23	63.42	69.80	24.26	61.33
P_4 (Sakha3)	4.00	3.33	58.57	160.00	3.43	24.38	82.62	70.10	85.34	25.85	60.90
P_5 (R.V$_{323}$)	5.70	5.09	38.18	92.12	3.82	26.76	89.18	38.12	38.27	27.75	57.80
Giza40 x Santamora (C1)	5.13	3.79	60.42	150.83	4.50	39.34	117.96	87.68	75.29	25.33	61.93
x G429 (C2)	5.97	5.56	43.72	152.95	4.33	31.05	91.39	59.10	64.92	27.42	60.25
x Sakha 3 (C3)	3.67	3.11	44.81	136.67	3.67	34.67	82.52	57.15	70.28	27.66	56.75
x R.V$_{323}$ (C4)	4.44	4.22	43.15	135.19	3.67	29.41	87.52	57.78	66.37	31.26	55.58
Santamora x G429 (C5)	4.19	3.92	42.36	139.72	4.11	30.17	95.83	71.06	72.93	23.55	60.59
x Sakha3 (C6)	3.33	2.86	51.67	148.53	3.69	31.25	93.33	83.59	89.75	29.25	55.74
x R.V$_{323}$ (C7)	4.67	4.30	51.83	147.00	3.70	30.60	89.64	67.63	75.95	26.02	59.72
Giza429 x Sakha3 (C8)	4.67	4.13	53.13	151.25	5.63	41.23	138.13	105.17	78.70	27.82	59.86
x R.V$_{323}$ (C9)	5.00	4.00	40.95	130.48	4.43	34.00	104.90	76.87	73.57	27.05	59.03
Sakha3 x R.V$_{323}$ (C10)	5.33	4.67	51.67	147.08	6.75	39.33	127.25	91.45	70.38	26.95	58.82
LSD 0.05	0.36	0.32	1.30	2.94	0.54	1.94	4.06	2.85	1.62	0.65	0.67
LSD 0.01	0.49	0.44	1.76	3.96	0.73	2.62	5.48	3.84	2.19	0.88	0.90

Combining ability:

The estimates of GCA effects (ĝi) listed in Table 6, where differed from one individual parent to another and from trait to trait. The parental genotypes Santamora (P_2) had highly significant negative (favorable) (ĝi) for chocolate spot and rust with -1.48 and -0.60, respectively and high significance positive (ĝi) for plant height (5.48), seed yield plant^{-1} (6.19) and 100 seed weight (9.07). Giza429 (P_3) had highly significant negative (favorable) (ĝi) for flowering date (-3.73) and high significant positive (ĝi) for No. of pods (1.0), No. of seeds plant^{-1} (3.91), seed yield plant^{-1} (1.54) and carbohydrate % (1.29). Sakha3 (p_4) had highly significant negative (favorable) (ĝi) effects for chocolate spot and rust with -0.53 and -0.61 respectively and high significance positive (ĝi) for plant height (8.63), No. of branches (0.27), No. of seed plant-1 (3.02) seed yield plant^{-1} (7.05), 100 seed weight (5.89) and crude protein % (0.37). R.V_{323} (p_5) had highly significant negative (favorable) (ĝi) for flowering date (-3.60) and high significant positive (ĝi) for crude protein % (0.85). H0wever, the parental genotypes; Sakha 3 had significant (ĝi) values in favorable direction for eight traits out of eleven ones and Santamora and Giza 429 had significant (ĝi) values for five out of eleven traits in favorable directions which may indicate that, these parents behaved as good combiners for the traits in question in the environmental condition of the present study. Therefore, these parents are favorable for inclusion in the production of synthetic varieties and choosing the roper breeding scheme. Similar trend of these findings was earlier reported by Drwish *et al*., (2005), El-Hady *et al* (2007and 2008), El-Bramawy and Osman (2012) and Abou-Zaid *et al*., (2018).

Table 6: Estimates of parental general combining ability effects for yield and its components, Carbohydrates and Crude Protein content (in the F_1 generation).

Genotypes	Chocolate spot disease reaction	Rust disease reaction	Flowering date	Plant height	No. of branches plant^{-1}	No. of Pods plant^{-1}	No. of Seeds plant^{-1}	Seed yield plant^{-1}	100-seed weight	crude protein content	Carbohy-drate %
P1 (Giza40)	0.31**	0.42**	-0.21	0.57	-0.22	-0.38	-4.79**	-6.45**	-2.88**	-0.05	0.10
P2(Santamora)	-0.48**	-0.60**	3.36**	5.48**	-0.42**	-0.54	-2.47**	6.19**	9.07**	-0.25	-0.68**
P3 (Giza429)	0.40**	0.55**	-3.73**	-0.51	0.16	1.00*	3.91**	1.54*	-1.26**	-0.92**	1.29**
P4 (Sakha3)	-0.53**	-0.61**	4.18**	8.63**	0.27*	0.56	3.02**	7.05**	5.89**	0.37**	-0.05
P_5 (R. V_{323})	0.31**	0.23**	-3.60**	-14.17**	0.21	-0.64	0.33	-8.32**	-10.82**	0.85**	-0.66**
LSD 0.05	0.15	0.13	0.54	1.22	0.23	0.80	1.68	1.18	0.67	0.27	0.28
0.01	0.20	0.18	0.73	1.64	0.30	1.08	2.27	1.59	0.91	0.36	0.37

*and** significant at0.05 and 0.01 levels of probability, respectively

The SCA effects (Ŝij) are presented in Table 7. Significant and highly significant negative (favorable) (Ŝij) for chocolate spot were observed for the crosses; C_3, C_4, C_5 C_6 and C_9. Also, significant and highly significant negative (Ŝij) for rust were observed for the crosses; C_3, C_4 and C_9. For flowering date, highly significant negative (favorable) (Ŝij) were observed for the crosses; C_1, C_3, C_5 and C_6. While, the (Ŝij) for seed yield plant^{-1} a highly significant positive (Ŝij) were observed for the crosses; C_1, C_3, C_8, C_9 and C10. For crude protein % the crosses; C_2, C_4, C_6 and C_8 exhibited a highly significant positive (Ŝij). With respect to carbohydrate % the crosses; C_1, C_8 and C_{10} gave a highly significant positive (Ŝij). However, the cross; Sakha3 x R.V_{323} had significant and/or highly significant(Ŝij) for seven traits out of eleven ones i.e., plant height, No. of branches plant^{-1} , No. of pods plant^{-1}, No. of seeds plant^{-1} , seed yield plant^{-1}, 100-seed weight and carbohydrate % ; the cross; Giza429 x Sakha3 had highly significant (Ŝij) for six traits i.e., No of branches plant^{-1}, No, of pods plant-1, No of seeds plant -1, seed yield plant^{-1},crude protein % and carbohydrate %; the cross; Giza40 x Santamora had highly significant (Ŝij) for five traits i.e., plant height, No of branches plant^{-1},No.of pods plant^{-1}, No. of seeds plant^{-1}, seed yield plant-1 and carbohydrate %.These crosses could be used with follow suitable breeding method in segregating generations to obtain same line (s) characterized by high yielding ability and high carbohydrate%. On the other hand, the cross Giza40 x Sakha3 had highly significant (Ŝij) for chocolate spot and rust diseases and flowering date; the crosses; Giza40 x R.V_{323} and Giza429 xR.V_{323} had highly significant (Ŝij) for chocolate spot and rust diseases, therefore, it could be use the progenies of these crosses in the segregating generations to generate line (s)with high tolerate to these diseases .

Combining ability analysis helps the breeders to identify the best combiners which may be hybridized either to exploit heterosis or to build up the favorable fixable genes. GCA effects provide appropriate criterion for detecting the validity of a genotype in hybrid combinations. While SCA effects may be related to heterosis. The results revealed that GCA effects, for some traits, were related to several SCA values of their corresponding crosses. This may indicate, in such combinations, that additive and non-additive genetic systems present in the crosses are acting in the same direction to maximize the characters in view. These findings are in agreement with Darwish, *et al*. (2005), Attia and Salem (2006) and El-Hady, *et al*. (2007 and 2008).

Heterosis:

The results in Table 8 showed that, the crosses; Giza 40 x Sakha 3, Giza 40 x R.V323 and Santa Mora x Sakha 3 had significant mid - parental heterotic effects in negative direction due to over-dominance , while partial dominance was responsible to the mid-parental heterosis in the cross Santamora x Giza429. For rust disease reaction, the crosses; Giza 40 x Sakha3 and Giza40 x R.V_{323} had highly significant mid-parental heterosis in negative direction (favorable) due to over–dominance, while the crosses; and Santa mora x Sakha 3 and Giza429 x Sakha3 had highly significant mid–parental heterosis due to partial– dominance as potence ratio pointed out.

For flowering date, the crosses; Giza 40 x Sakha3 and Giza429 x R.V_{323} showed highly significant mid-parental heterosis in negative direction (favorable) due to over–dominance and the cross; Santamora x Giza429 expressed highly significant mid - parental heterosis due to partial– dominance .The crosses ;Giza40 x Santamora and Giza40 xGiza429 had

Table 7: Estimates of specific combining ability effects for yield and its components, carbohydrates and crude protein (%) in the F_1 generation.

Genotypes	Chocolate spot disease reaction	Rust disease reaction	Flowering date	Plant height	No. of branches plant-1	No. of Pods plant^{-1}	No. of Seeds plant^{-1}	Seed yield plant^{-1}	100-seed weight	crude protein content	Carbohy-drate %
Giza40 x Santamora (C1)	0.52**	-0.32	9.08**	4.26**	1.01**	8.36**	27.67**	16.58**	-4.00**	-1.17**	1.01**
x G429 (C2)	0.49*	0.30	-0.54	12.36**	0.27	-1.46	-5.29*	-7.36**	-4.04**	1.59**	0.27
x Sakha 3 (C3)	-0.89**	-0.99**	-7.35**	-13.05**	-0.50	2.60*	-13.27**	-14.81**	-5.83**	0.54	-0.50
x R.V$_{323}$ (C4)	-0.95**	-0.72**	-1.23	8.26**	-0.45	-1.46	-5.58*	1.18	6.97**	3.65**	-0.45
Santamora x G429 (C5)	-0.50*	-0.33	-5.46**	-5.78**	0.25	-2.19*	-3.16	-8.05**	-7.97**	-2.08**	0.25
x Sakha3 (C6)	-0.44*	-0.21	-4.06**	-6.10**	-0.29	-0.66	-4.77*	-1.02	1.70	2.33**	-0.29
x R.V$_{323}$ (C7)	0.06	0.38*	3.88**	15.16**	-0.21	-0.11	-5.78*	-1.61	4.61**	-1.38**	-0.21
Giza429 x Sakha3 (C8)	0.02	-0.10	4.48**	2.61	1.08**	7.79**	33.65**	25.20**	0.98	1.57**	1.08**
x R.V$_{323}$ (C9)	-0.48*	-1.08**	0.08	4.62**	-0.06	1.75	3.11	12.28**	12.57**	0.32	-0.06
Sakha3 x R.V$_{323}$ (C10)	0.77**	0.76**	2.89**	12.10	2.15**	7.53**	26.34**	21.36**	2.22*	-1.07**	2.15**
LSD (Sca)											
(0.05)	0.39	0.35	1.39	3.14	0.58	2.07	4.34	3.05	1.74	0.69	0.58
(0.01)	0.52	0.47	1.88	4.24	0.79	2.80	5.86	4.11	2.34	0.94	0.79
LSD (Sij-Skij)											
(0.05)	0.582	0.520	2.089	4.708	0.872	3.111	6.515	4.569	2.603	1.040	1.069
(0.01)	0.785	0.702	2.818	6.352	1.117	4.197	8.789	6.164	3.512	1.404	1.442

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

Table 8: Heterotic effects relative to mid, better parent and potence ratios.

Crosses	Chocolate spot disease reaction			Rust disease reaction			Flowering date		
	MP	PR	BP	MP	PR	BP	MP	PR	BP
Giza40 x Santamora (C1)	4.43	0.23	28.13**	-18.75**	-0.68	13.75	19.68**	3.68	26.45**
x G429 (C2)	2.76	138.85	2.78	-7.26	-27.15	-7.26	-2.02	-0.28	5.45*
x Sakha 3 (C3)	-25.28**	-1.37	-8.33*	-33.33**	-1.16	-6.67	-15.72**	-1.55	-6.20*
x $R.V_{323}$ (C4)	-22.78**	-22.26	-21.99**	-23.86**	-2.84	-17.06**	0.39	0.04	13.01**
Santamora x G429 (C5)	-14.51*	-0.82	4.86	-16.07**	-0.58	17.50*	-10.48**	-0.85	2.18
x Sakha3 (C6)	-16.67*	-41.00	-16.67*	-14.12	-29.24	-14.12	-7.53	-1.56	-2.85
x $R.V_{323}$ (C7)	-3.75	-0.24	16.67*	2.09	0.08	29.00**	13.47**	0.82	35.75**
Giza429 x Sakha3 (C8)	-4.88	-0.26	16.67*	-11.61*	-0.41	23.75**	6.22**	0.36	28.14**
x $R.V_{323}$ (C9)	9.89	2.62	33.25	-5.04	-0.47	-21.43**	-15.35**	-4.53	7.26*`
Sakha3 x $R.V_{323}$ (C10)	-1.44	0.09	33.33**	5.07	0.26	40.00**	4.80*	0.23	35.32**
LSD 0.05	0.546		0.628	0.489		0.561	1.954		2.257
0.01	0.736		0.845	0.660		0.757	2.637		3.456

*and** significant at0.05 and 0.01 levels of probability, respectively.

Table 8: Cont.

Crosses	Plant height			No. of branches plant^{-1}			No. of pods plant^{-1}		
	MP	PR	BP	MP	PR	BP	MP	PR	BP
Giza40 x Santamora (C1)	6.42**	1.52	2.10	40.02**	4.22	27.89*	42.44**	23.18	39.88**
x G429 (C2)	13.99**	11.97	12.68**	20.62	10.00	18.18	6.99*	1.06	0.37
x Sakha 3 (C3)	-7.58**	-0.92	-14.58**	5.56	4.29	4.21	45.12**	6.54	27.87**
x $R.V_{323}$ (C4)	18.66**	0.97	-0.41	-0.05	-0.01	-3.97	9.18*	14.04	8.47
Santamora x G429 (C5)	-0.32	-0.06	-5.42**	25.04*	2.17	12.12	2.16	0.45	-2.49
x Sakha3 (C6)	-3.47	-0.87	-7.17**	16.33	1.99	7.52	19.06**	2.68	11.14
x $R.V_{323}$ (C7)	22.58**	0.97	-0.49	10.00	0.74	-3.10	11.52*	4.64	8.81
Giza429 x Sakha3 (C8)	3.38*	0.36	-5.47	58.56**	17.45	53.41**	49.08**	4.14	33.28**
x $R.V_{323}$ (C9)	3.50	0.22	-1.60	22.22*	10.63	15.99	32.97**	4.03	9.90
Sakha3 x $R.V_{323}$ (C10)	21.08**	0.75	-8.07**	86.46**	13.30	76.79**	53.81**	5.29	46.97**
LSD 0.05	4.406		5.088	0.817		0.943	2.442		3.361
0.01	5.944		6.864	1.102		1.272	3.295		4.535

*and** significant at0.05 and 0.01 levels of probability, respectively.

Table 8: Cont.

Crosses	No. of seeds plant^{-1}			Seed yield plant^{-1}			100-seed weight		
	M.P	P.R	B.P	M.P	P.R	B.P	M.P	P.R	B.P
Giza40 x Santamora (C1)	37.28**	109.15	36.81**	23.96**	1.69	8.53**	-8.67**	-0.61	-19.97**
x G429 (C2)	3.00	1.06	0.17	-4.75	-2.15	-6.81	-7.65**	-10.85	-8.29**
x Sakha 3 (C3)	-2.25	-1.05	-4.30	-12.59**	-1.75	-18.47**	-9.97**	-1.07	-17.65**
x $R.V_{323}$ (C4)	-0.21	-0.12	-1.87	16.96**	0.74	-4.78	21.71**	0.73	-6.24**
Santamora x G429 (C5)	8.37*	2.65	5.05*	-1.45	-0.12	-12.05**	-10.99**	-0.74	-22.48**
x Sakha3 (C6)	10.94**	6.10	8.99*	10.79**	1.52	3.46	0.05	0.01	-4.60**
x $R.V_{323}$ (C7)	2.55	1.26	0.51	13.74**	0.38	-16.29**	14.78**	0.35	-19.27**
Giza429 x Sakha3 (C8)	58.91**	11.90	51.41**	57.53**	11.50	50.03**	1.46*	0.15	-7.78**
x $R.V_{323}$ (C9)	22.12**	18.56	14.99**	42.07**	1.80	21.21**	19.04**	1.04	5.41*
Sakha3 x $R.V_{323}$ (C10)	48.13**	7.22	42.69**	45.39**	1.79	30.47**	23.96**	0.58	-17.53**
LSD 0.05	6.095		6.819	4.274		4.934	2.435		2.812
0.01	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]

*and** significant at0.05 and 0.01 levels of probability, respectively

Table 8: Cont.

Crosses	Crude protein content			Carbohydrate %		
	M.P	P,R	B.P	M,P	P.R	B,P
Giza40 x Santamora (C1)	-2.28	-0.39	-7.71**	7.63**	1.97	3.61**
x G429 (C2)	12.69**	43.60	12.37**	-0.50	-0.39	-1.77
x Sakha 3 (C3)	10.10**	3.51	7.03**	-5.95**	-6.35	-6.82**
x $R.V_{323}$ (C4)	19.89**	3.10	12.66**	-5.46**	-3.25	-7.02**
Santamora x G429 (C5)	-8.93**	-1.45	-14.22**	3.90	0.75	-1.21
x Sakha3 (C6)	9.77**	3.24	6.56**	-4.07**	-0.85	-8.47**
x $R.V_{323}$ (C7)	-5.71*	-10.61	-6.22**	5.59**	2.54	3.32**
Giza429 x Sakha3 (C8)	11.03**	3.48	7.62**	-2.06*	-5.85	-2.40*
x $R.V_{323}$ (C9)	0.94	0.14	-2.52	-0.54	-0.18	-3.76**
Sakha3 x $R.V_{323}$ (C10)	1.53	0.43	-2.89	-1.74*	-0.67	-3.42**
LSD 0.05 0.01	0.974 1.314		1.124 1.516	0.999 1.348		1.153 1.556

*and** significant at0.05 and 0.01 levels of probability, respectively

highly significant mid-parental heterosis in positive direction (favorable) for plant height due to over–dominance, while the crosses; Giza 40 x $R.V_{323}$, Santa Mora x x $R.V_{323}$, Giza429 x Sakha3 and Sakha3 x $R.V_{323}$ expressed mid- parental heterosis for the trait in view due to partial–dominance. For No, of branches plant^{-1}, the crosses; Giza40 x Santamora, Santamora x Giza429,Giza429 x Sakha3, Giza429 x $R.V_{323}$ and Sakha3 x $R.V_{323}$ had significant mid-parental heterosis due to over–dominance (PR>+1). For No. of pods plant^{-1}, all crosses, except the cross; Santamora x Giza429expressed significant and /or highly significant mid-parental heterosis due to over-dominance.

For No. of seeds plant^{-1}, the crosses; Giza40 x Santamora, Santamora x Giza429, Santamora x Sakha3, Giza429 x Sakha3, Giza429 x $R.V_{323}$ and Sakha3 x $R.V_{323}$ exposed significant mid- parental heterosis due to over- dominance. For seed yield plant^{-1} all crosses, except for Giza40 x Giza429, Giza40 x Sakha3 and Santamora x Giza429 had highly significant mid- parental heterosis due to over- dominance in the crosses; Giza40 x Santamora, Santamora x Sakha3, Giza429 x Sakha3 Giza429 x Sakha3, Giza429 x $R.V_{323}$ and Sakha3 x $R.V_{323}$, the heterotic effects in the rest crosses were affected by partial dominance.

For 100-seed weight, the crosses; Giza 40 x $R.V_{323}$, Santamora x $R.V_{323}$, Giza429 x Sakha3 and Sakha3 x $R.V_{323}$ showed significant mid-parental heterosis due to partial-dominance, the cross; Giza429 x$R.V_{323}$ was the only one which heterotic effects were due to over-dominance .For crude protein content,the crosses; Giza40 x Giza429, Giza40 x Sakha3, Giza 40 x $R.V_{323}$ Santamora x Sakha3 and had highly significant mid-parental heterosis a result of over-dominance as potence ratio pointed out and for carbohydrate% where the crosses; Giza40 x Santamora, Santamora x $R.V_{323}$ expressed highly significant mid-parental heterosis due to over-dominance.

Better-parent heterosis as the results presented in Table 8 had significant and highly significant in the cross; Giza40 x Santa Mora for No. of branches plant^{-1}, No. of podsplant^{-1}, No. of seedsplant^{-1}

,seed yield plant^{-1}and carbohydrate%; in the cross; Giza429 x Sakha3 for No of branches plant^{-1}, No. of podsplant^{-1}, No. of seedsplant^{-1}, seed yield plant^{-1} and crude protein content; in the cross; Giza40 x Sakha3 for chocolate spot disease reaction, flowering date , No. of pods plant^{-1} and crude protein content; in the cross; Giza 429 x R.V$_{323}$ for rust disease reaction, No. of pods plant^{-1}, No. of seeds plant^{-1} , seed yield plant^{-1}and100-seed weight; in the cross; Sakha3 x R.V$_{323}$ for No. of branches plant^{-1}, No. of pods plant^{-1}, No. of seeds plant^{-1} and seed yield plant^{-1} ;in the cross; Giza 40 x R.V$_{323}$ for chocolate spot and rust disease reactions and crude protein content and in the cross; Santamora x Sakha3 for chocolate spot disease reaction, No. of seeds plant^{-1} and crude protein content.

It should be noticed that, these is an approximately accordance between specific combining ability effects in the present study and heterosis over better-parent, which pointed out the important role of non-additive gene effects in controlling the inheritance of these traits in question, and this may confirm the obtained results mentioned before.

These data suggest that heterotic effects for seed yield plant^{-1}were associated with other yield components, in several crosses, such as 100-seed weight and No. of pods plant^{-1}. Moreover, various cross combinations exhibited different degrees of crosses superiority in some traits based on the genes in parental combinations that may contribute directly, or indirectly, to the expression of these traits. In addition, the heterosis estimates, compared to either MP or BP, for seed yield plant^{-1} and its major yield components traits indicated that there was sufficient genetic variability among the assessed parents to favor efficient breeding for these traits. Therefore, the progenies of these crosses could be used in the segregating generations to regenerate new genotypes characterized by high yielding potentiality and high protein content and resistance to foliar diseases. These results are in good agreement with those reported by Darwish *et al* (2005), Attia *et al*., (2006), Farag (2007), El-Hady *et al*., (2008), Farag and Afiah (2012), Ahmed (2016), Abdalla *et al*., (2017) and Abou-Zaid *et al*., (2018).

The difference in percent heterosis might be due to genetic differences of the parents used and or non- allelic interaction which can either increase or decrease the expression of heterosis (Cress, 1966). Aabdalla (1977) reported that, heterosis was very pronounced in F_1 especially among widely divergent materials but was less manifested in hybrids between local varieties.

Heterosis over better parent is more important than heterosis over mid-parent from the breeder point of view, especially if the heterotic effects are due to over-dominance (P>+1or <-1), the case which allow the breeder to searched out the transgressive segregates in the segregating generations.

In conclusion, the results revealed that several crosses are highly promising to breed new faba bean genotypes possessing genetic factors for resistance to chocolate spot and rust foliar diseases, earliness and high yielding ability.

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تقدير قوة الهجين والقدرة على التألف لصفات مقاومة الأمراض الورقية، المحصول ومكوناته وصفات الجودة في الفول البلدي

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الملخص العربي

تم التهجين بين خمسة أصناف مختلفة في الفول البلدي بنظام التهجين النصف دائري خلال موسمي ٢٠١٨/٢٠١٩ بمحطة البحوث الزراعية بسخا– كفر الشيخ –مصر. تم تقيم الآباء مع الهجن الناتجة في تجربه مصممه في القطاعات كاملة العشوائية ذات الثلاث مكررات في الموسم ٢٠١٩/٢٠٢٠ .أستخدم تحليل التهجينات الدائرية بناء على اقتراح Griffing,1957 لتقدير القدرة العامة والخاصة على التألف . أظهر الهجين جيزه٤٠ x سخا٣ و سنتامورا x جيزة ٤٢٩ قيما معنويه لكل من قوة الهجين بناء على متوسط الأبوين والأب الأفضل لصفات التبقع البنى والصدأ وصفه التزهير . وأظهرت الهجن جيزه٤٠ x سنتامورا ، جيزه ٤٢٩ x سخا٣ ، جيزة ٤٢٩ x $R.V_{323}$، سخا٣ x $R.V_{323}$ قيما معنويه لقوة الهجين بناء على متوسط الأبوين والأب الأفضل لصفات عدد الأفرع بالنبات ،عدد القرون بالنبات ومحصول البذور للنبات وأظهر الهجين جيزه٤٢٩ x $R.V_{323}$ قيما معنويه لقوة الهجين بناء على متوسط الأبوين والأب الأفضل لصفات التبقع البنى والصدأ ،التزهير ،عدد الأفرع بالنبات ،عدد البذور بالنبات ومحصول البذور للنبات ،كما أظهرت الهجن جيزه٤٠ x جيزة ٤٢٩، جيزة ٤٠ x سخا٣، جيزه٤٠ x $R.V_{323}$, جيزة ٤٢٩ x سخا٣ قيما معنويه لكل من قوة الهجين بناء على متوسط الأبوين والأب الأفضل لصفة النسبة المئوية للبروتين الخام .

* كانت النسبة بين تباين القدرة العامة الي القدرة الخاصة أكبر من الواحد الصحيح لجميع الصفات ماعدا عدد الفروع والقرون والبذور بالنبات والنسبة المئوية للبروتين الخام كانت أقل من الواحد الصحيح مما يدل على أن الفعل الجيني المضيف كان الأكثر أهميه في توارث هذه الصفات .
* كان الصنفان سنتامورا وسخا٣ لهما قدرة عالية على التألف في تحسين صفة المقاومة للتبقع البني والصدأ، عدد الفروع ومحصول البذور ووزن ال١٠٠ بذرة بينما أظهرا الصنفان جيزة ٤٢٩ و$R.V_{323}$ قدرة عاليه على التالف لصفة التبكير.
* كان الهجين جيزة ٤٠ x $R.V_{323}$ ذو قدرة ائتلافيه خاصة عالية لصفات تحمل الإصابة بالتبقع البنى والصدأ ، طول النبات ، ووزن ١٠٠ بذرة والنسبة المئوية للبروتين الخام بينما أظهر الهجين جيزة ٤٢٩ x سخا٣ قدرة ائتلافيه خاصة عالية وأيضا قيما عالية المعنوية لقوة الهجين بناءا على الأب الأفضل ومتوسط الأبوين لصفا ت عدد الفروع والقرون والبذور للنبات ومحصول النبات والنسبة المئوية للبروتين الخام والكربوهيدرات في حين أظهر الهجين جيزة ٤٢٩ x R.V323 قدرة ائتلافيه خاصة عالية لصفات تحمل الإصابة بالتبقع البني والصدأ ، محصول النبات ووزن ١٠٠ بذرة يتضح لنا من هذه النتائج أن هذه الهجن يمكن زراعتها فى الأجيال الأنعزاليه المبكرة باستخدام طريقة الانتخاب التجميعي لإنتاج سلالات عاليه في المحصول والمقاومة للأمراض.
* أظهرت الهجن : جيزه ٤٠ x سنتامورا ، جيزة ٤٢٩ x سخا٣ ، جيزة ٤٢٩ x $R.V_{323}$, سخا٣ x $R.V_{323}$ قيما عالية المعنوية لقوة الهجين بناء على متوسط الأبوين والأب الأفضل لمعظم الصفات تحت الدراسة ولذا يجب الانتخاب للصفات المرغوبة بالنسل الناتج من هذه التراكيب الوراثية خلال الاجيال الانعزالية المتعاقبة.

السادة المحكمين

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