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Genetic Analysis of Chocolate Spot and Rust Disease Resistance and Some Yield Related traits in Three Faba Bean Crosses

Cross Mark

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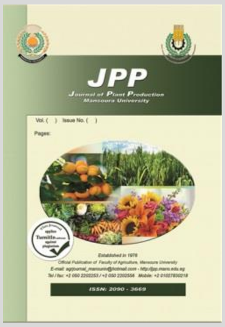

ABSTRACT

Breeding for high yield potential along with resistance to chocolate spot and rust diseases are the main target of most faba bean breeding programs. The five populations (P_1, P_2, F_1, F_2 and F_3) of three faba bean crosses (Triple White x Ohishima Zairai), (Triple White x Giza 40) and (Triple White x Foul Sbaï labiade) were evaluated during 2019 /2020 winter season at Sakha Agricultural Research Station, to study the type of gene action for foliar diseases resistance and some yield related traits. Significant differences were found among generations, *i.e.* P_1, P_2, F_1, F_2 and F_3 for the majority of studied traits of all crosses. Significant and highly significant desirable percentages of heterosis relative to mid and better parent with favorable values for inbreeding depression for most traits. Additive gene effects were positive and highly significant for chocolate spot disease reaction, rust disease reaction. However, the dominant gene effects seem to be controlling the inheritance of yield and yield component traits. Narrow-sense heritability ranged from medium to high in most cases due to the opposite directions of dominance and dominance x dominance effects. Genetic advance from selection ranged from 7.66% for flowering date to 45.65% for No. of pods plant^{-1}in cross 3. Finally; it could be concluded that cross 2 and cross 3 were the best for flowering date, seed yield/plant and 100-seed weight, while cross 3 was the best in resistance to chocolate spot and rust diseases. Therefore, selection in the advanced generations of both crosses could be effective.

Keywords: Faba bean, Five parameters model, Epistasis, Earliness, Chocolate spots and Rust diseases reaction , Yield components.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the most important legume crops in the Arabian regions of North and East Africa. In Egypt, has considerable importance as a low cost food, rich in nutritive value especially protein content that ranged from 22%-38% (Griffiths and Lawes, 1978). Chocolate spot (*Botrytis fabae*) and rust diseases (*Uromyces fabae*) are considered the most destructive diseases on faba bean in Egypt causing serious damage to the crop, especially in the northern parts, where low temperature and high relative humidity favor its spread and severity. Ibrahim *et al.*, (1979) reported that, up to 50% lose in yield under natural infection with leaf spots, rust and downy mildew. Also, Mohamed *et al.*, (1980) add that the yield losses due to the infection with foliar diseases ranged from 22 to 56% and may reach 100% under sever infection (Bouhassan *et al.* 2004, Torres *et al.*, 2004 and El-Rodeny *et al.*, 2020). Foliar diseases control management is based mainly on partial protection through fungicides application. However, the development of foliar diseases resistance faba bean cultivars is considered the practical, most efficient and economical approach, which promote the development of sustainable agriculture (Rhaïem *et al.*, 2002, Bouhassan *et al.*, 2004 and Abo Mostfa *et al.*, 2014). The yield of resistant cultivar was significantly higher compared with the susceptible ones under natural infiection with foliar diseases in north delta region (Amer *et al.*, 2002 and 2003)

The plant breeder usually has in mind an ideal plant that combines maximum No. of desirable traits. The main target of any breeding project is to increase yield. Earliness is another important character since it frees land quickly, often allowing an additional sowing of the same crop or another crop in the same year. The plant breeder is interested in the determination of gene effects to establish the most advantageous breeding programs for the improvement of the desired characters related to productivity of faba bean crop (El-Banna *et al.*, 2014).

Therefore, the objective of this work was to study the type of gene action for foliar diseases and some yield related traits through the genetic analysis of the five populations i.e. (P_1, P_2, F_1, F_2 and F_3) of three faba bean crosses.

MATERIALS AND METHODS

This work was conducted at the Experimental Farm of Sakha Agricultural Research Station, during the four winter seasons, 2016 /2017, 2017 /2018, 2018/2019 and 2019 /2020. In the first season, four parental genotypes of faba bean namely; Triple White (T.W.), Ohishima Zairai, Giza40 and Foul Sbaï labiade, diverse in their agronomic performance and reaction to foliar diseases, were sown and crossed under the isolation wire cage to produce F_1 seeds. Three crosses were produced namely; cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade). The name, origin and other agronomic characters of these parents are presented in Table 1.

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Table 1. The names, Origen, earliness and agronomic characters of four parental faba bean used in this study.

No.	Name	Origen	Earliness	Pod length	Agronomic traits	
					Seed coat color	Seed size
1	Triple White(T.W.)	Introduction from Sudan	Early	Short	White (W.H)	Small
2	Ohishima Zairai	Introduction from Japan	Medium	Short	Light brown (B.H)	Small
3	Giza40	Egyptian	Early	Medium	Light brown (B.H)	Medium
4	Foul Sbaï labiade	Introduction from Moracco	Early	long	Light yellow (B.H)	Large

In 2017/2018 season, the parents and F_1 seeds were cultivated to produce enough F_1 and F_2 seeds. In 2018/2019 season, seeds from the parents, F_1 and F_2 were sown to produce enough F_1, F_2 and F_3 seeds, where F_2 plants were individually harvested to produce enough F_3 seeds. In 2019/2020 season, parents, F_1, F_2 and F_3 plants were cultivated as single plants in randomized complete block design with three replications. Each replicate consisted of 66 ridges (2P_1, 2P_2, 2F_1, 10 F_2, 50 F_3 families) in addition to two border rows in each side. Faba bean seeds were sown on one side of ridges, three meters long and 60 cm wide, at 20 cm hill spacing with one seed per hill. All recommended cultural practices were applied at proper time according to the packages of the recommendation.

Data were recorded on individual guarded plants for each of P_1, P_2, F_1, F_2 and F_3 of each cross for the following agronomic characters: chocolate spot and rust diseases reactions, flowering date (days), plant height (cm), No. of branches plant^{-1}, No. of pods plant^{-1}, No. of seeds plant^{-1}, 100- seed weight (g) and seed yield plant^{-1} (g).

Reaction to foliar diseases was recorded on mid March for chocolate spot and rust diseases, according to the disease scales reported by Bernier *et al.,* (1993) as presented in Table 2.

Table 2. Rating scale for chocolate spot and rust

	Chocolate spot scale
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 scale
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)

Statistical and genetic procedures:

For each cross, the five populations (P_1, P_2, F_1, F_2 and F_3) were studied; the mean and the variance were calculated for each population. To determine the presence or absence of non- allelic interactions, scaling test as outlined by Mather (1949) was used. Generation mean analysis was performed according to Hayman (1958). Heritability estimates were computed in both broad (H) and narrow (h^2) senses for F_2 and F_3 generation according to Allard (1960) and Mather (1949). The expected genetic advance from selection (G_a) was calculated according to the formulae proposed by Johnson *et al.* (1955) using the selection differential (k) equal 2.06 for 5% selection intensity and heritability in narrow sense. The predicted genetic advance from selection was expressed as percentage of F_2 mean (G_a%) according to Miller *et al.* (1958). Potence ratio estimates according to Simth (1952).

RESULTS AND DISCUSSION

Mean performance:

The mean of parents, F_1's and segregating generations of the three crosses for all the studied traits are presented in Table 3.

Considerable amount of differences existed among the parents used in this study. The parent; T.W was the earliest one based on flowering date (40 days) and the highest parent for No. of pods plant^{-1} (25.97), Ohishima Zairai was the highest parent for No. of branches plant^{-1} (4.34), while Giza 40 was the highest for No. of seeds plant^{-1} (75.78) and seed yield plant^{-1} (59.92 g). However, Foul Sbaï labiade was the tallest parent for plant height (142.36 cm), 100- seed weight (128.24 g) and resistance to chocolate spot and rust diseases (3).

The F_2 and F_3 populations mean performance values were less than F_1 mean performance for most studied traits. Cross 1 and cross 2 were superior in No. of branches plant^{-1}, No. of pods plant^{-1}, No. of seeds plant^{-1}, but more susceptible to foliar diseases than cross 3. However, cross 3 was the highest for 100- seed weight and resistance to chocolate spot and rust diseases reactions, also it was the earliest cross and recorded 42 days in F_2 and 40.95 days in F_3. Cross 3 recorded the highest value for seed yield plant^{-1} (61.31 g) in F_2 and (58.61g) for F_3. While cross 2 ranked the second in seed yield plant^{-1} which recorded 62.52 g in F_2 and 54.40 g in F_3.

Heterosis, potence ratio and inbreeding depression: Heterosis over mid-parents and better parent, potence ratio and inbreeding depression are presented in Table 4. The data indicated highly significant heterosis over mid-parents in favorable direction for all traits, except for chocolate spot and rust diseases reactions in cross 2 and flowering date in crosses 1 and 2. However, the cross 1 behaved as more resistance to rust disease due to its superiority over better parent heterosis as a result of over-dominance and potence ratio pointed out (-1.60). The crosses; 1 and 3 had highly significant mid-parental heterosis in negative direction for chocolate spot disease reaction due to partial dominance (P = -0.60 and -0.53, respectively) and the crosses; 1 and 3 had highly significant mid-parental heterosis in negative direction for rust disease reaction due to over-dominance and complete dominance in cross 2. Highly significant positive heterotic effect values were obtained for yield and its components in the three crosses over the better parent, except for 100-seed weight in the cross 3. Meanwhile, negative and highly significant heterosis over better parent was obtained for rust disease reaction in cross 1. However, with respect to seed yield and its related traits, it could be observed from the data listed in Table 4 that highly significant mid and better parents hetrotic effects were detected for all studied traits in the three crosses and over-dominance was responsible for heterosis in all cases (P > +1). These results are in agreement with those reported by Hendawy (1994), El - Hosary *et al*., (1997); El-Hady *et al*., (1998), Toker (2004), Attia *et al*., (2006) and Abou-Zaid (2018).

The inbreeding depression, measures the extent of reduction of the F_2 generation due to inbreeding. It was highly significant positive in favorable direction for chocolate spot reaction in all crosses and rust reaction in crosses 1 and 2.

Table 3. Mean ($\bar{X}$), variance (S^2) and Coefficient of variation (C.V.%) for P_1, P_2, F_1, F_2 and F_3 populations of three faba bean crosses for all studied traits.

Traits	Cross	Statistical Parameter	P_1	P_2	F_1	F_2	F_3
Chocolate spot reaction (scale 1 to 9)	Cross 1	$\bar{X}$	6.00	5.00	5.20	4.93	4.85
		S^2	0.09	0.11	0.08	0.85	0.46
		C.V.%	5.00	6.66	5.28	29.22	17.69
	Cross 2	$\bar{X}$	6.00	5.60	6.10	5.54	5.76
		S^2	0.09	0.16	0.15	1.14	0.58
		C.V.%	5.00	6.56	6.42	19.26	13.24
	Cross 3	$\bar{X}$	6.00	3.00	4.70	4.69	4.00
		S^2	0.09	0.12	0.15	1.12	0.71
		C.V.%	5.00	11.30	8.33	22.57	20.99
Rust reaction (scale 1 to 9)	Cross 1	$\bar{X}$	7.00	6.00	5.70	4.14	4.84
		S^2	0.07	0.15	0.09	0.79	0.52
		C.V.%	3.78	6.41	5.38	21.46	14.95
	Cross 2	$\bar{X}$	7.00	6.70	7.00	6.38	6.23
		S^2	0.07	0.16	0.18	0.97	0.53
		C.V.%	3.78	5.95	6.00	15.43	11.64
	Cross 3	$\bar{X}$	7.00	3.00	4.46	5.40	4.46
		S^2	0.07	0.19	0.18	1.07	0.86
		C.V.%	3.78	14.34	9.42	19.16	20.81
Flowering date (days)	Cross 1	$\bar{X}$	40.00	65.00	57.00	55.01	54.92
		S^2	1.55	1.46	1.84	48.86	28.09
		C.V.%	3.11	1.86	2.38	12.71	9.65
	Cross 2	$\bar{X}$	40.00	47.78	47.33	47.52	47.59
		S^2	1.55	0.92	1.65	24.74	15.68
		C.V.%	3.11	2.01	2.71	10.47	8.32
	Cross 3	$\bar{X}$	40.00	45.25	42.00	40.95	41.38
		S^2	1.55	0.85	1.65	9.44	14.84
		C.V.%	3.11	2.04	3.06	7.50	9.31
Plant height (cm)	Cross 1	$\bar{X}$	112.50	132.14	150.33	124.76	122.53
		S^2	3.94	3.21	4.59	109.37	69.91
		C.V.%	1.77	1.35	1.42	8.38	6.82
	Cross 2	$\bar{X}$	112.50	133.15	142.50	125.12	128.95
		S^2	3.94	2.36	3.44	144.22	87.40
		C.V.%	1.77	1.15	1.30	9.60	7.25
	Cross 3	$\bar{X}$	112.50	142.36	148.17	125.60	119.30
		S^2	3.94	1.61	3.44	169.33	109.38
		C.V.%	1.77	0.89	1.25	10.36	8.77
No. of branches plant^{-1}	Cross 1	$\bar{X}$	3.90	4.34	5.02	3.56	3.48
		S^2	0.07	0.29	0.07	1.47	1.09
		C.V.%	6.59	10.78	6.97	33.98	30.01
	Cross 2	$\bar{X}$	3.90	3.22	4.57	3.08	3.23
		S^2	0.07	0.13	0.08	0.96	0.65
		C.V.%	6.59	11.35	6.06	31.82	25.03
	Cross 3	$\bar{X}$	3.90	4.12	4.60	3.63	3.00
		S^2	0.07	0.06	0.08	1.95	0.82
		C.V.%	6.59	5.95	6.02	38.49	30.21

Cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade)

Table 3. cont.:

Traits	Cross	Statistical Parameter	P_1	P_2	F_1	F_2	F_3
No. of pods plant^{-1}	Cross 1	$\bar{X}$	25.97	23.14	29.20	28.57	28.49
		S^2	1.47	1.70	1.80	54.75	37.34
		C.V.%	4.66	5.63	4.60	25.90	21.45
	Cross 2	$\bar{X}$	25.97	25.22	43.90	30.22	27.56
		S^2	1.47	1.55	1.70	89.07	56.96
		C.V.%	4.66	4.93	2.97	31.23	27.38
	Cross 3	$\bar{X}$	25.97	11.78	46.15	28.31	21.58
		S^2	1.47	1.41	1.70	117.95	30.72
		C.V.%	4.66	10.08	2.82	38.36	25.68
No. of seeds plant^{-1}	Cross 1	$\bar{X}$	66.00	68.79	79.76	78.76	77.29
		S^2	11.60	3.00	12.20	445.58	251.99
		C.V.%	5.16	3.10	4.38	26.80	20.54
	Cross 2	$\bar{X}$	66.00	75.78	89.13	83.87	74.53
		S^2	11.60	5.05	10.44	647.99	405.31
		C.V.%	5.16	2.97	3.62	30.35	27.01
	Cross 3	$\bar{X}$	66.00	45.61	97.45	70.65	61.90
		S^2	11.60	6.58	10.44	1028.03	161.55
		C.V.%	5.16	5.62	2.75	45.38	24.97
Seed yield plant^{-1} (g)	Cross 1	$\bar{X}$	40.72	46.80	59.58	52.31	49.45
		S^2	6.65	2.18	7.09	212.88	130.77
		C.V.%	6.33	4.24	4.47	23.42	19.91
	Cross 2	$\bar{X}$	40.72	59.92	76.46	61.31	58.61
		S^2	6.65	4.35	7.20	226.04	132.77
		C.V.%	6.33	3.48	3.51	24.52	19.66
	Cross 3	$\bar{X}$	40.72	58.49	91.05	62.52	54.40
		S^2	6.65	4.74	7.20	461.62	85.60
		C.V.%	6.33	3.72	2.95	38.70	19.94
100-seed weight (g)	Cross 1	$\bar{X}$	60.85	68.03	76.74	66.42	63.98
		S^2	2.63	2.27	3.08	134.35	92.39
		C.V.%	2.66	2.38	2.29	14.19	12.48
	Cross 2	$\bar{X}$	60.85	78.03	85.78	75.30	80.09
		S^2	2.63	2.43	2.76	281.58	157.33
		C.V.%	2.66	2.00	1.94	22.28	15.66
	Cross 3	$\bar{X}$	60.85	128.24	93.43	88.50	87.89
		S^2	2.63	1.52	2.76	584.34	266.00
		C.V.%	2.66	0.96	2.14	29.10	16.86

Cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade)

Table 4. Heterosis, inbreeding depression and potence ratio in three faba bean crosses for all studied traits.

Traits	Cross	Heterosis %		Inbreeding	Potence
		MP	BP	depression ID %	Ratio P
Chocolate spot reaction	Cross 1	-5.45**	4.00**	5.13**	-0.60
	Cross 2	5.17**	8.93**	9.19**	1.50
	Cross 3	-14.55**	56.67**	0.21**	-0.53
Rust reaction	Cross 1	-12.31**	-5.00**	27.37**	-1.60
	Cross 2	2.19**	4.48**	8.83**	1.00
	Cross 3	-31.38**	48.67**	-21.08	-1.02
Flowering date	Cross 1	8.57**	42.50**	3.5	0.36
	Cross 2	7.84**	18.33**	-0.40**	0.88
	Cross 3	-20.00**	5.00**	2.5	-4.00
Plant height	Cross 1	22.90**	13.77**	17.01	2.85
	Cross 2	16.02**	7.02**	12.2	1.91
	Cross 3	21.13**	4.08**	15.23	1.73
No. of branches plant^{-1}	Cross 1	24.88**	15.67**	28.99**	4.55
	Cross 2	28.37	17.18**	32.58**	2.97
	Cross 3	3.14**	11.65**	21.09**	1.27
No. of pods plant^{-1}	Cross 1	18.92**	12.44**	2.17	3.28
	Cross 2	71.52	69.04**	31.16**	48.81
	Cross 3	87.95**	77.71**	38.66**	3.04
No. of seeds plant^{-1}	Cross 1	18.35**	15.95**	1.26	8.86
	Cross 2	25.73	17.62**	5.9	3.73
	Cross 3	92.87**	77.95**	27.5	4.08
Seed yield plant^{-1}	Cross 1	36.15**	27.31**	12.21	5.20
	Cross 2	51.95**	27.60**	19.82	2.72
	Cross 3	141.13**	55.67**	31.33	4.66
100-seed weight	Cross 1	19.08**	12.80**	13.54	11.71
	Cross 2	23.54**	9.94**	12.22	1.90
	Cross 3	24.83**	-39.54**	5.28	0.03

Cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade)

However, it was negative and highly significant for flowering date in cross 2 and was highly significant positive in unfavorable direction for No. of branches plant^{-1} in all crosses and No. of pods plant^{-1} in crosses 2 and 3. Therefore, it is logic to anticipate that heterosis in the F_1 will be followed by an appreciable reduction in the F_2

performance due to the effect of homozygosity. Also, reduction in values of non- additive genetic components is expected caused by means of inbreeding depression. Low inbreeding depression for the traits; plant height, No. of seeds plant^{-1}, seed yield plant^{-1} and 100-seed weight suggests that, increasing in vigor in F_2 is expected to be mainly due to accumulation of favorable additive gens (Shukla and Gautam, 1990). The obtained results herein were in agreement with this anticipation. These results are in harmony with those reported by Hendawy (1994), El - Hosary *et al*., (1997), El-Hady *et al*., (1998), Toker (2004), Attia *et al*., (2006), Abo Mostafa *et al*., (2009), El-Hady *et al*., (2009) and Abou-Zaid (2018).

Estimation of type of gene action: testing for non- allelic interactions with the five-parameter model and type of epistasis given in Table 5. Scaling test was significantly differed from zero for all traits in all crosses, indicating the presence of all types of non-allelic interactions (Mather, 1949). The estimated mean effects (m) which reflect the contribution due to overall mean plus the locus effects and interaction of the fixed loci, were highly significant for all traits in the all crosses.

Table 5. Scaling test and type of gene action estimated by generation mean of the three faba bean crosses for all the studied traits.

Trait	cross	Scaling test		Gene action				
		d	c	m	a	d	aa	dd
Chocolate spot reaction	Cross 1	-1.91**	-8.79**	4.93**	0.50**	0.40**	1.7**	0.59ns
	Cross 2	0.35ns	-1.64**	5.54**	0.20**	-0.21ns	-0.11	2.66**
	Cross 3	-2.36**	0.36ns	4.69**	1.50**	1.84**	4.64**	-3.63**
Rust reaction	Cross 1	-1.94**	-7.84**	4.14**	0.50**	-0.82**	0.98**	7.87**
	Cross 2	-1.56**	-2.17**	6.38**	0.15**	0.83**	0.98**	0.82ns
	Cross 3	-2.97**	2.68**	5.40**	2.00**	1.89**	6.43**	-7.54**
Flowering date	Cross 1	4.68**	1.03ns	55.01**	-12.50**	1.55ns	-27.95**	4.87
	Cross 2	7.52**	7.64**	47.52**	-3.89**	-0.30	-11.52**	-0.16
	Cross 3	-1.63ns	-5.45**	40.95**	-2.63**	-0.44ns	-5.07**	5.09**
Plant height	Cross 1	-4.06*	-46.25**	124.76**	-9.82**	23.01**	-24.64**	56.26**
	Cross 2	19.89**	-30.16**	125.12**	-10.33**	1.39ns	-38.93**	66.73**
	Cross 3	-28.87**	-48.80**	125.60**	-14.93**	31.85**	-18.75**	26.57**
No. of branches plant^{-1}	Cross 1	-2.13**	-2.34**	3.56**	-0.12*	1.20**	-0.04ns	3.43**
	Cross 2	-0.36ns	-3.93**	3.08**	0.34**	0.59**	0.26	4.77**
	Cross 3	-3.30**	-2.70**	3.63**	-0.11**	2.34**	1.53**	-0.80ns
No. of pods plant^{-1}	Cross 1	7.73**	6.76**	28.57**	1.42**	0.62ns	-1.20ns	1.30ns
	Cross 2	-1.38ns	-18.11**	30.22**	0.38*	16.21**	-1.35ns	22.30**
	Cross 3	-8.05**	-16.81**	28.31**	7.10**	29.84**	16.75**	11.68*
No. of seeds plant^{-1}	Cross 1	29.85**	33.71**	78.76**	-1.4**	4.59ns	-10.57**	-5.15ns
	Cross 2	-11.41**	15.46*	83.87**	-4.89**	28.43**	0.41	-35.83**
	Cross 3	-5.31ns	-23.91**	70.65**	10.20**	41.20**	19.94**	24.80ns
Seed yield plant^{-1}	Cross 1	29.65**	54.54**	52.31**	-3.04**	12.84**	-9.28**	4.14
	Cross 2	11.20**	-8.34*	61.31**	-9.60**	17.29**	-28.05**	26.04**
	Cross 3	-6.64*	-31.22**	62.52**	-8.89**	40.67**	-18.55**	32.77**
100-seed weight	Cross 1	20.63**	49.01**	66.42**	-3.59**	13.39**	-6.09**	14.51*
	Cross 2	30.87**	-9.24*	75.30**	-8.59**	-5.78*	-39.30**	53.48**
	Cross 3	-14.53**	-21.95**	88.50**	-33.69**	4.91ns	-61.36**	9.89*

Cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade)

The data shown in Table 5 pointed out that highly significant additive (a) and dominance (d) genetic variances were observed in crosses; 1 and 2 for chocolate spot disease reaction; all crosses for rust disease reaction; crosses 1 and 2 for plant height; cross 3 for No. of pods plant^{-1}; crosses 2 and 3 for No. of seeds plant^{-1}; all crosses for seed yield plant^{-1} and the crosses 1 and 2 for 100-seed weight. This might indicate that, both additive and dominance in different proportion were involved in the in inheritance of these traits in these crosses.

Additive genetic variance (a) was larger than the corresponding dominance one (d) for rust disease reaction in the cross 3; flowering date in all crosses; plant height in the cross 2; No. of pods plant^{-1} in cross1 and 100-seed weight in crosses 2 and 3. This might be indicate that selection could be done in early segregating generations for these traits in these crosses due to the presence of additive genes and pedigree method would be more useful (El-Hady *et al*., 2009 and Abou-Zaid 2018).

On the other hand, it could be observed that dominance effects are larger than additive one for chocolate spot disease reaction in cross 3; rust reaction in crosses 1 and 2; plant height in crosses 1and 3; No. of branches plant^{-1} in all crosses; No. of pods in crosses 2 and 3; No. of seeds plant^{-1} and seed yield plant^{-1} in all crosses and 100-seed weight in cross 1. This might indicate that dominance gene effects ply the major role in controlling the genetic variance of these traits in the referred crosses and to improve these traits, intensive selection through later generations using bulk method is needed.

For non-allelic interaction i.e, additive × additive (aa) and dominance × dominance (dd) , data in Table 5 revealed that, aa dominance epistatic effect was more important and higher in magnitude than (dd) in the inheritance of chocolate spot reaction in crosses 1 and 3; flowering date in all crosses; No. of pods plant^{-1} in cross 3; No. of seeds plant^{-1} in cross 1; seed yield plant^{-1} in crosses 1 and 2; 100-seed weight in cross 3. However, in the presence of additive gene effect as predominance, the selection would be more effective in the early segregating generation. On the other hand, (dd) was more important and larger in magnitude than (aa) genetic variance for rust reaction in cross 1; plant height in all crosses; No. of branches plant^{-1} in crosses 1 and 2; No. of pods plant^{-1} in the cross 2; No. of seeds plant^{-1} in crosses 2 and 3; seed yield plant^{-1} in cross 3 and 100-seed weight in crosses 1 and 2. Therefore, selection of these traits in the referred crosses would be more effective if delayed till dominance and epistatic effects would be reduced to the minimum through the following of bulk method. The type of gene action reported by El-Hosary (1981), Hendawy (1994) Attia *et al*. (2006), El –Hady *et al*. (2009) and Abou-Zaid (2018) were rather confirmed by the type of variation found in the present study.

With regard to the negative values observed in most cases either with main effect; (a) and (d) or the non-allelic interactions; (aa) and (dd), this might indicate that, the allelic responsible for low values of these traits was over-dominance over the alleles controlling the high values.

Heritability and genetic advance from selection:

Heritability in broad, narrow senses, expected and predicted genetic advances for the studied traits are presented in Table 6.

Broad sense heritability values (H^2) estimates were generally higher than the corresponding narrow-sense heritability (h^2), indicating the presence of non-additive gene action. Broad-sense heritability values were high in all crosses for all studied traits ranging from 85.72% for flowering date to 99.40% for 100- seed weight in cross 3. Narrow-sense heritability ranged from medium to high in most cases due to the opposite directions of dominance and dominance x dominance effects with values; 32.61% for chocolate spot reaction in cross 2 to 57.76% for No. of pods plant^{-1} in cross 3. Genetic advance from selection ranged from 7.66 % in cross 3 for flowering date to 45.65% for No. of pods plant^{-1}. The high percentage of expected genetic advance would help the breeder in improving the trait of interest via few cycles of selection. These results are in good agreement with those reported by Abo Mostafa *et al*. (2009), El -Hady *et al* (2009) and Abou-Zaid (2018).

Table 6. Heritability percentage in broad (h^2_b) and narrow (h^2_n) senses and expected genetic advance from selection (Ga%) in three faba bean crosses for all the studied traits.

Trait	cross	h^2_b	h^2_n	Ga	Ga %
Chocolate spot reaction	Cross 1	89.15	41.17	0.78	15.84
	Cross 2	88.33	32.61	0.72	12.94
	Cross 3	89.34	48.19	1.05	22.40
Rust reaction	Cross 1	86.83	55.48	1.02	24.53
	Cross 2	86.06	36.32	0.74	11.54
	Cross 3	86.55	46.80	1.00	18.47
Flowering date	Cross 1	96.70	42.21	6.08	11.05
	Cross 2	94.46	51.36	5.26	11.07
	Cross 3	85.72	49.57	3.14	7.66
Plant height	Cross 1	96.42	50.92	10.97	8.79
	Cross 2	97.75	47.49	11.75	9.39
	Cross 3	98.23	52.76	14.14	11.26
No. of branches plant^{-1}	Cross 1	90.22	54.30	1.35	38.01
	Cross 2	90.42	54.35	1.10	35.63
	Cross 3	96.54	46.02	1.32	36.49
No. of pods plant^{-1}	Cross 1	96.98	56.31	8.58	30.05
	Cross 2	98.24	51.74	10.06	33.29
	Cross 3	98.71	57.76	12.92	45.65
No. of seed plant^{-1}	Cross 1	97.99	42.24	18.37	23.32
	Cross 2	98.61	50.18	26.31	31.37
	Cross 3	98.85	41.10	24.36	34.48
Seed yield plant^{-1}	Cross 1	97.51	48.64	14.62	27.95
	Cross 2	97.31	45.02	13.94	22.74
	Cross 3	98.29	35.14	13.76	22.02
100-seed weight	Cross 1	98.02	57.76	13.79	20.77
	Cross 2	99.07	41.09	14.21	18.86
	Cross 3	99.40	48.46	19.57	22.11

Cross 1 (T.W. x Ohishima Zairai), cross 2 (T.W. x Giza 40) and cross 3 (T.W. x Foul Sbaï labiade)

Finally; it could be concluded that the improvement degree of the studied traits are based on the high heritability and positive values of genetic advance as shown in the different traits, especially; chocolate spot and rust disease reactions. Cross 3 found to be the best cross in resistance to chocolate spot and rust diseases, flowering date and 100- seed weight. For seed yield cross 2 and cross 3 were found to be higher in magnitude, which expressed high genetic advance associated with high heritability and would be of interest in breeding programs for improving the studied traits.

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التحليل الوراثى لمقاومة مرضى التبقع الشوكلاتى والصدأ والمحصول وبعض مكوناته لثلاثة هجن من الفول البلدى

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التربية للمحصول العالى بالاضافة للمقاومة لمرضى التبقع الشوكلاتى والصدأ هى الهدف الرئيسى لمعظم برامج تربية محصول الفول البلدى, تم تقييم العشائر الخمسة (P_1, P_2, F_1, F_2 and F_3) لثلاثة هجن من الفول البلدى (Triple White x Ohishima Zairai) , (Triple White x Giza 40)و (Triple White x Foul Sbaï labiade) فى محطة البحوث الزراعيه بسخا- كفرالشيخ – مصر، خلال موسم 2020/2019 لدراسة طبيعة التأثير الجينى لصفات المقاومة للامراض الورقية وبعض الصفات المرتبطة بمحصول البذور. تم العثور على اختلافات كبيرة بين الاباء والجيل الاول والثانى والثالث لغالبية الصفات المدروسة لجميع الهجن. أظهرت قوة الهجين بناء على متوسط الأباء والاب الافضل والتدهور الراجع الى التربية الداخليه قيما مرغوبة لمعظم الصفات المدروسة. كما كانت القيم الخاصة بالفعل الجينى المضيف معنوية سالبة لصفة ميعاد التزهير، كما اظهرت النتائج ان الفعل الجينى السيادى هو المتحكم فى وراثة صفة المحصول ومكوناتة. اما بالنسبه لدرجة التوريث فى المعنى الضيق فتراوحت من متوسطة الى مرتفعة وتراوحت القيم ما بين 32.61% بالنسبه لصفة المقاومة للتبقع الشوكلاتى فى الهجين الثانى الى 57.76% بالنسبة لصفة عدد قرون النبات فى الهجين الثالث. وتراوحت قيم التحسين الوراثى المتوقع نتيجة الانتخاب ما بين 7.66 لصفة ميعاد التذهير الى 45.65% لصفة عدد قرون النبات فى الهجين الثالث. ويمكن تلخيص اهم النتائج فى الأتى: يعتبر الهجينين الثانى والثالث هما الافضل بالنسبه لصفات ميعاد التذهير ووزن الـ 100 بذرة ومحصول بذور النبات، كما ان الهجين الثالث كان الأفضل فى المقاومة لمرضى التبقع الشوكلاتى والصدأ. لذلك فإن الانتخاب فى الاجيال المتقدمة لكل من الهجينين يمكن أن يكون فعال لتحسين صفات المقاومة لمرضى التبقع الشوكلاتى والصدأ بالاضافة لبعض الصفات المرتبطة بالمحصول.