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PROBABILITY OF MATERNAL EFFECTS ON FABA BEAN SEED QUALITY AND YIELD COMPONENTS

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ABSTRACT

The present research aimed to investigate possible maternal effects on the seed yield and some related traits and seed quality in the studied populations (TW and Nubaria1 + F_1's and F_2's including reciprocals) of faba bean. Genetic parameters were calculated in early segregating generation to reach the highest genetic advance. Correlation and path coefficients were also estimated for yield and its components. Significant differences were observed between mean generation for some yield traits (100-seed weight, tannin content, coat thickness and onset of flowering date) of F_1 and its reciprocal and F_2 hybrids, indicated maternal effect on faba bean seeds. Thus, selection for improving faba bean yield and seed traits should begin with the F_2 seeds to ample genetic variability in this generation. It is noticed that the highest heritability values were detected for these traits that controlled by maternal effect. Tannin content, 100-seeds weight, number of branches per plant and coat thickness had higher estimates of broad sense heritability coupled with high predicted genetic advance from selection, indicating that these traits are mainly controlled by additive genes and selection for these traits may be effective. Furthermore, number of branches, number of pods, number of seeds per plant and 100-seed weight reflected significant correlation with seed yield per plant as well as their influences whether directly or indirectly on yield and its attributes. Hence selection for each or all of these traits might be used for the improvement of seed yield in early segregating generation. Meanwhile, selection for early flowering may improve seed quality traits, as thinner coat that was accompanied by low tannin.

Keywords: ***Vicia faba, Maternal effect, Genetic parameters, Heritability, Genetic advance%, Correlation and path analysis.***

INTRODUCTION

Faba bean (*Vicia faba* L.) is a pulse crop and one of the most important legume crops in the Mediterranean basin. It is a multipurpose crop for its usage in human diet, and in animal feeding. Dried seeds have high protein content (from 28 to 36 Abdalla *et al* 1976 and from 18.6 - 41.0% of dry matter Kaul and Varid 1996). Since genotypic and environmental factors are components determining yield and quality in plants, a primary aim should be the determination of effect of genotypic factors in selection. The effect of environment on yield and quality in plants is not hereditable; effects of genotypic factors on yield and quality in plant breeding research need to be investigated.

The quality of legume seeds is affected mainly by the quality of their amino acids and presence of naturally occurring toxic constituents, especially tannins. High levels of tannin decrease protein digestibility and quality of beans. Two recessive genes, each eliminating condensed tannins from hulls and simultaneously determining a white flower, were discovered in faba bean by Duc *et al.* (1995). Zero-tannin lines had thinner testa with lower cell numbers per unit area; therefore, these seeds are more susceptible to insect or pathogenic infestation.

Seed yield is a complex character which is determined by a number of yield components. Selection is an integral part of a breeding program by which genotypes with high productivity in a given environment could be developed. However, selection for high yield is difficult because of its components of several characters, which are polygenic in nature and thus are highly influenced by environment. Therefore, only little progress could be made over a long span of time through direct selection for yield (Salama *et al* 2008, Tadesse *et al* 2011, Fares *et al* 2013 and Ghareeb *et al* 2013). But selection was effective in faba bean when practiced in several genotypes and populations (see Abdalla *et al* 2014 a, b).

Maternal effect is an important component of extra-nuclear effect in plants (Lemontey *et al* 1999). The traits of seed are influenced by maternal parameters, and its phenotypic expression is delayed for one generation (Jost *et al* 2009). Consequently, selection should be implemented among the F_3 seeds (born on F_2 plants), when genetic variability is observed. Seed coat is a maternal tissue, and the cotyledons are produced by the fertilization (Ramalho *et al* 2008).

Knowledge of heritability and genetic advance is a basic step to identify the characters amenable to genetic improvement through selection. Bakheit *et al* (2011), and Fikreselassie and Seboka (2012) emphasized that, without considering genetic advance from selection, the heritability values (h^2) would not be practically useful in breeding program depending on phenotypic selection.

Path analysis is used to determine the amount of direct and indirect effects of the variables on the effect component. Indirect selection through yield components has been proved more effective (Ford 1964). This selection criterion takes into account the information on interrelationships among agronomic characters. Nevertheless, selection for yield *via* highly correlated characters becomes easy if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey and Lu 1959).

Therefore, the present study aimed to investigate possible maternal effects on the studied traits in faba bean, estimate heritability and selection gain in early hybrid segregating generations to reach the highest genetic advance for seed quality and yield components, and determine relationships among yield and its related traits in faba bean populations**.**

MATERIALS AND METHODS

Two faba bean genotypes (Triple white and Nubaria 1) as well as their F_1's and F_2's including reciprocals (four populations) were used in this study. The origin and characteristics of the parents are shown in Table (1).

Table 1. Origin and characteristics of two faba bean parental genotypes*.

Parent	Origin	Flowering	Seed type	Special remarkable characteristics
Triple white (P1)	Sudan	Early	*Equina*	High fertile genotype, white flower with light seed coat color and colorless seed hilum.
Nubaria1 (P2)	Spain	Late	*Major*	Resistant to foliar diseases.

***Data were obtained from Leguminous Crops Research Department (LCRD), ARC.**

An interlacing method with emasculation of the flower bud was used to obtain F_1 (♀ Triple white (P_1) x ♂ Nubaria1 (P_2)) and F_1 reciprocal (♀ Nubaria1 (P_2) x ♂ Triple white (P_1)) seeds for each hybrid combination in the winter of 2011/12. In 2012/13, hybrid seeds were sown to obtain the F_2 seeds. In 2013/14, all genotypes parents, $F_1$and F_2 generations were planted under free insect cages at Giza Research station. A randomized complete block design with four replications was used. Row length was always three meters with 60cm raw spacing (approx. 15seeds/row) but the number of rows varied as follows: two rows for the non-segregating populations (P_1, P_2 and F_1) and 5 rows for F_2 generations. The sample size (number of plants analyzed) varied as follows: 10 randomly selected plants for P_1, P_2 and F_1 generations' and 100 plants for F_2 generations. Seven traits were measured on different populations, i.e. onset of flowering date, plant height, number of branches, pods and seeds per plant, seed yield weight per plant and100-seed weight.

Seed quality traits were evaluated. Tannin was determined using vanillin hydrochloric acid (V-HCl) method as described by Burn (1971). Seed coat thickness was measured with a micrometer.

Statistical manipulations

The analysis of variance was carried out to test the significance for studied traits. Mean comparisons for these traits were done according to Duncan’s Multiple Range Test at $P \leq 0.05$ (Duncan 1955). According to the methods used by Johnson *et al* (1955) and Kumar *et al* (1985), the phenotypic (PCV %) and genotypic (GCV %) coefficients of variation were estimated. The analysis of variance was carried out to test the significance of all studied traits. Heritability in broad sense and predicted genetic gain as percent of the mean assuming selection of the superior 5% of the genotypes (GA %) was calculated according to Johnson *et al* (1955) as follows:

Heritability (h_b^2) = V_g / V_{ph} *100

Genetic advance (GA) = $k * V_{ph} * h^2_b$

Genetic advance percent of population mean (GA %) = GA / $\bar{x}$ * 100

Where, V_g is genetic variance, V_{ph} is phenotypic variance, $\bar{x}$: is population mean and k: is constant = 2.06 at 5% selection intensity.

Relationships between the traits were measured through genotypic and phenotypic correlation and path coefficient. Genotypic and phenotypic correlation coefficients were calculated for each pair of traits based upon the method proposed by Falconer (1989), all correlation coefficient worked out between all possible combinations of traits. Path coefficient analysis was carried out using the general formula of Dewey and Lu (1959) to determine the direct and indirect effects of the yield components and other morphological characters on seed yield.

The normal equation to estimate the path coefficients is formulated in matrices as follows:

$$P = (r_{xx})^{-1}.\ r_{xy}$$

Where:

P: is the vector of path coefficients (direct effects)

$(r_{xx})^{-1}$: is the inverse of correlation matrix among the independent variables (yield components).

(r_{xy}): is the vector of correlation coefficients between the dependent variable (seed weight per plant) and each of independent variable.

RESULTS AND DISCUSSION

Mean performance

Mean comparisons in Table (2) revealed highly significant differences among the investigated generations and their respective parents.

Table 2. Mean performance of studied characters in P_1, P_2, F_1 and F_2 faba bean genotypes.

Characters	Parents		F_1 plants		F_2 plants	
	P_1	P_2	F_{1T}	F_{1N}	F_{2T}	F_{2N}
1st flower date	51.00^{d}	73.00^{a}	52.50^{cd}	65.75^{b}	57.75^{c}	66.75^{b}
Plant height *cm*	110.00^{bc}	125.00^{a}	117.50^{ab}	110.00^{bc}	101.50^{c}	106.80^{bc}
Branches/plant	2.00^{b}	5.25^{a}	4.50^{a}	5.00^{a}	4.52^{a}	5.68^{a}
Pods/plant	24.00^{ab}	18.50^{b}	31.75^{a}	26.25^{ab}	23.40^{ab}	22.25^{ab}
Seeds/plant	53.25^{b}	55.75^{b}	109.75^{a}	61.50^{b}	70.96^{b}	71.00^{b}
100-seed weight *g*	42.03^{e}	131.21^{a}	91.45^{cd}	108.80^{b}	81.16^{d}	97.59^{c}
Seed yield/plant *g*	21.40^{c}	63.18^{ab}	93.68^{a}	68.30^{ab}	57.99^{b}	69.86^{ab}
Tannin content *mg/g*	3.84^{d}	11.40^{a}	7.17^{c}	9.57^{b}	6.53^{c}	12.13^{a}
Coat thickness *µm*	11.25	20.25^{a}	13.75^{cd}	17.75^{ab}	14.25^{c}	17.25^{b}

P_1: Triple white, P_2: Nubaria1, F_{1T}: ♀ P_1× ♂ P_2, F_{1N}: ♀ P_2 × ♂ P_1, F_{2T}: F_{1T} selfed and F_{2N}:F_{1N} selfed.

Means of the same row followed by the same letter (s) are not significantly different.

Data revealed that the P_1 (Triple white) parent possessed the earliest flowering plants (51.00 days), and the lowest seed coat tannin content and thickness (3.84 mg/g and 11.25 µm), respectively. Whereas, (P_2) Nubaria1 parent possessed the tallest plants (125.00 cm) and the highest values for

100-seed weight (131.21 g). From these results, it could be concluded that the selection prospects within F_2 population may improve the performance.

A significant difference was observed between the means of F_1 and reciprocals for onset of flowering date, hundred seed weight, number of seed per plant, seed coat tannin content and coat thickness, which suggests that there was a significant maternal effect on these traits of faba bean. Meanwhile, the difference between the F_2 and F_2 reciprocal for onset of flowering date, 100-seed weight, seed coat tannin content and thickness traits mean values were significant.

Each kind of cross populations (F_1 and F_2 reciprocals) was significantly different the one from the other. The more important maternal effect was the impact of female pool on seed traits variability. Therefore, maternal variation has a large influence on progeny traits (onset of flowering date, hundred seed weight, coat thickness and tannin content). Thus, results confirmed that selection for increasing seed yield and quality in faba bean should begin with the F_2 generations because ample genetic variability was observed in this generation (Poersch *et al* 2011).

Genetic parameters

In general, phenotypic coefficient of variability (*PCV %*) was higher than corresponding genotypic coefficient of variability (*GCV %*) for all studied traits which demonstrated the effect of environment upon the traits (Table 3). The highest phenotypic and genotypic coefficient of variability was recorded for seed yield (35.61 and 33.84 %, respectively) tannin content (33.64 and 33.51%, respectively) and hundred seed weight (30.30 and 30.18, respectively), indicating the presence of exploitable genetic variability for these traits. Heritability (h^2 %) estimates were generally high for most studied traits and recorded values ranged from (98.52%) for tannin content to (40.58%) for number of pods per plant. In general, all the traits had higher heritable variation. Hence it can be assumed that phenotypes of almost traits are mainly determined by their genotypes. High estimates of heritability indicated that selection based on phenotypic performance may be successful in improving these traits (Attia 2007, El-Hady *et al* 2009 and Ghareeb *et al* 2013). This was proved using bulk and individual selection (Abdalla *et al* 2014 a, b).

High estimates of expected genetic advance from selection were observed for tannin content (68.27%), hundred seed weight (61.44%) and seed yield per plant (60.35%). It is noticed that the highest heritability values at all were detected for traits that controlled by maternal effect (hundred seed weight, tannin content, coat thickness and onset of flowering date with 98.52, 98.42, 97.24 and 95.50%, respectively). High heritability values coupled with high genetic advance were observed for tannin content, hundred seed weight, number of branches per plant and 100- seeds weight. From the results it can be concluded that all these traits may be controlled by additive type of gene action as reported by other workers. Similar results were also obtained by (Alghamdi 2007, El-Hady *et al* 2009, Fares *et al* 2013 and Ghareeb *et al* 2013) who reported high heritability coupled with high genetic advance for most of the quantitative characters. Improvement in these traits can be achieved through selection.

Table 3.Genetic parameters for seed studied characters of faba bean.

Characters	V_{ph}	V_g	PCV%	GCV%	h^2_b	GA	GA %
1st flower date	**74.33**	**72.62**	**14.11**	**13.94**	**95.50**	**16.96**	**27.75**
Plant height	**60.06**	**52.83**	**6.93**	**6.50**	**78.52**	**12.54**	**11.21**
Branches/plant	**1.56**	**1.45**	**27.79**	**26.83**	**87.31**	**2.24**	**49.98**
Pods/plant	**20.93**	**12.09**	**18.37**	**13.96**	**40.58**	**3.82**	**15.36**
Seeds/plant	**362.41**	**310.43**	**27.04**	**25.03**	**74.91**	**29.38**	**41.73**
100-seed weight	**777.28**	**771.09**	**30.30**	**30.18**	**98.42**	**60.59**	**61.44**
Seed yield/plant	**493.86**	**445.80**	**35.61**	**33.84**	**82.26**	**37.66**	**60.35**
Tannin	**8.68**	**8.00**	**33.64**	**33.51**	**98.52**	**6.42**	**68.27**
Thickness	**10.42**	**10.27**	**20.49**	**20.35**	**97.24**	**6.47**	**41.05**

Vph = Phenotypic variance, Vg = Genotypic variance, PCV% = Phenotypic coefficient of variability, GCV% = Genotypic coefficient of variability, h^2 = heritability, GA = Expected genetic advance and GA % = Expected genetic advance as mean percent.

Correlation analysis

The estimates of simple correlation coefficient between seed yield and some yield related traits are presented in Table (4). The results revealed that positive significant correlation coefficient values were detected between flowering date with number of branches per plant and hundred seed weight (+0.637** and +0.805**). Then, delay flowering date causes increasing the branches and hundred seed weight. Number of pods per plant was positively and highly significant correlated with number of seeds per plant (+0.625**). Seed yield per plant was positively and significantly correlated with each of number of branches per plant, number of pods per plant, number of seeds per plant and hundred seed weight (+0.651**, +0.480**, +0.776** and +0.639**, respectively). Similar results were reported by Ulukan *et al* (2003), Alghamdi (2007), Tadesse *et al* (2011), Fares *et al* (2013) and Ghareeb *et al* (2013).

Correlation coefficient values between traits controlled by maternal effect (onset of flowering date, hundred seed weight, tannin content and thickness) were detected. Flowering date and hundred seed weight were positively and highly significant correlated with seed tannin content (+0.874** and +0.883**, respectively); and seed coat thickness (+0.825** and +0.834**, respectively). In addition, tannin content was positively and highly significant correlated with coat thickness (Ghareeb 2006).

Table 4. Simple correlation coefficient among studied traits of faba bean across all studied populations.

Characters	Flowering date	Plant height	Branches /plant	Pods/ plant	Seeds/ plant	100-seed weight	Tannin
Plant height	**0.294**						
Branches /plant	**0.637****	**0.226**					
Pods/ plant	**-0.351**	**-0.049**	**0.034**				
Seeds/ plant	**-0.268**	**0.052**	**0.251**	**0.625****			
100-seed weight	**0.805****	**0.395**	**0.670****	**-0.096**	**0.099**		
Seed yield /plant	**0.301**	**0.21**	**0.651****	**0.480****	**0.776****	**0.639****	
Tannin content	**0.874****					**0.883****	
Coat thickness	**0.825****					**0.834****	**0.859****

*** and ** indicate significant at 0.05 and 0.01 level of probability, respectively**

Generally, the highly significant positive relationship between any pair of characters indicates that the improvement predicted under selection for one of them, would automatically extended to the other.

These findings indicate that indirect selection for each or all of: number of branches, number of pods, number of seeds per plant and hundred seed weight would be accompanied by high yield and more effective for the improvement of seed yield in faba bean. Meanwhile, selection for early flowering may improve seed quality traits, as thinner coat accompanied by low tannin.

Path analysis

The path coefficients analysis appeared to provide clue to the contribution of various components of yield to over all seed yield in the genotype under study. It provides an effective way of finding out direct and indirect sources of correlation. Direct and indirect effects for different six yield-related traits on seed yield are summarized in Table (5). It's noticed that the seed yield recorded positive values with all traits except plant height (-0.049). The results indicated that number of seeds per plant (0.622) exerted the highest positive direct effect followed by hundred seed weight, number of pods per plant and number of branches per plant (0.444, 0.156 and 0..149, respectively). Tadesse *et al* (2011), Fares *et al* (2013) and Ghareeb *et al* (2013) also reported positive direct effect of number of seeds and 100-seed weight which is in agreement with the present finding.

Table 5. Direct (diagonal) and indirect effects of components traits attributing to seed yield in all studied populations of faba bean.

Characters	Flowering date	Plant height	Branches /plant	Pods/ plant	Seeds/ plant	100-seed weight	Correlation
Flowering date	**0.085**	-0.014	0.095	-0.055	-0.167	0.357	**0.301**
Plant height	0.025	**-0.049**	0.034	-0.008	0.032	0.175	**0.210**
Branches/plant	0.054	-0.011	**0.149**	0.005	0.156	0.297	**0.651****
Pods/plant	-0.030	0.002	0.005	**0.156**	0.389	-0.043	**0.480****
Seeds/plant	-0.023	-0.003	0.037	0.098	**0.622**	0.044	**0.776****
100-seed weight	0.068	-0.019	0.100	-0.015	0.062	**0.444**	**0.639****

Residual effect = 0.215.

Days to flowering also showed positive direct effect (0.085) on seed yield per plant, but plant height showed negative direct effect on seed yield per plant (-0.049). From the results it can be concluded that seed yield can be increased by selecting genotypes having more number of seeds per plant, heavy hundred seed weight, more pods per plant and more branches per plant.

Days to flower affects seed yield positively and indirectly through hundred seed weight trait (0.357); but it was negatively through number seeds per plant trait (-0.167). And only one considerable component of indirect effect was recorded for plant height *via* hundred seed weight (0.175). Number of branches per plant recorded positive indirect effect (0.267 and 0.156) *via* hundred seed weight and number of seeds per plant traits. Indirect effect was recorded for number of pods per plant (0.389) only *via* seeds per plant. It is observed that the indirect effects of number of seeds per plant on seed yield were tiny for all traits. Meanwhile, indirect effects of hundred seed weight on seed yield *via* number of branches per plant were positive and low (0.100).Then the indirect effects for earliness, plant height**,** number of branches per plant and number of pods per plant were less important compared to direct effects. Indirect effect of number of seeds per plant and hundred seed weight were more important. Then, there is large scope of simultaneous improvement in faba bean seed yield as well as other yield components through selection taking into consideration these pairs of traits.

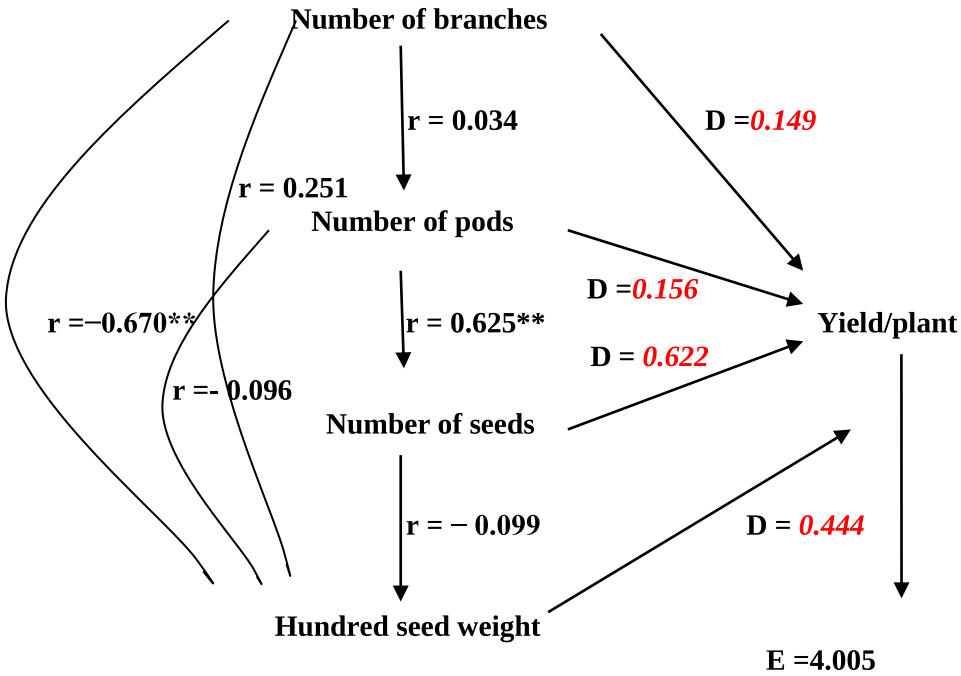
The coefficients of determination and relative importance according to path analysis of seed yield and its components are shown in Table (6). The results indicated that seeds per plant and hundred seed weight showed highest direct effects on seed yield per plant recording the greatest relative contribution to the total variation of yield as 33.541 and 17.055, respectively. The high contribution of these traits on seed yield/plant and its simple selection make them most important traits in selection program

Table 6. The coefficients of determination (CD) and relative importance (RI %) according to path analysis of seed yield and its components in faba bean.

Component	Characters	Association	CD	RI%
Direct effects	Flowering date		0.007	0.624
	Plant height		0.002	0.206
	Branches/plant		0.022	1.926
	Pods/plant		0.025	2.121
	Seeds/plant		0.387	33.541
	100-seed weight		0.197	17.055
Total (direct)			**0.640**	**55.472**
Indirect effects	**Flowering date *via***	Plant height	-0.002	0.211
		Branches/plant	0.016	1.396
		Pods/plant	-0.009	0.808
		Seeds/plant	-0.028	2.452
		100-seed weight	0.061	5.251
	Plant height *via*	Branches/plant	-0.003	0.285
		Pods/plant	0.001	0.065
		Seeds/plant	-0.003	0.272
		100-seed weight	-0.017	1.479
	Branches/plant *via*	Pods/plant	0.002	0.135
		Seeds/plant	0.047	4.033
		100-seed weight	0.089	7.679
	Pods/plant *via*	Seeds/plant	0.122	10.544
		100-seed weight	-0.013	1.157
	100-seed weight *via*	Seeds/plant via	0.055	4.755
Total (indirect)			**0.468**	**40.523**
Total (direct+ indirect)			**1.108**	**95.995**
Residuals			**0.046**	**4.005**
Absolute total			**1.154**	**100**

It's cleared that pods per plant recorded the greatest values for the indirect effects on seed yield *via* seeds per plant (10.544). This was followed by the joint effect of branches/plant and flowering date *via* hundred seed weight (7.679 and 5.251, respectively). Generally, these studied traits recorded 95.995% of seed yield variation. The residual component (4.005%) may be contributed to unknown variation (other traits that were not considered in this study).

Figure (1) shows the obtained results from path analysis of yield's components. Thereafter, number of branches per plant, number of pods per, number of seeds per plant and hundred seed weight represented most part in yield.



D: Direct effect, r: Correlation and E: Residual.

Fig.1. Diagrammatic representation of direct and indirect influences of independent variables on dependent variable across all populations.

Selection for each or all of number of branches per plant, number of pods per plant, number of seeds per plant and hundred seed weight per plant would be accompanied by high yield of faba bean. Meanwhile, selection for early flowering may improve seed quality traits, as thinner coat and low tannin.

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احتمالية وجود تأثيرات أمية على صفات جودة بذور
الفول البلدى ومكونات المحصول

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أجرى هذا البحث لدراسة احتمال وجود تأثيرات أمية على المحصول وبعض الصفات المتعلقة به وجودة البذرة فى العشائر تحت الدراسة (الأبوان TW و نوبارية1 + الهجين وعكسه فى الجيلين الأول والثاني) من الفول البلدى. تم تقدير المقاييس الوراثية فى الأجيال الهجينية الانعزالية المبكرة لتسجيل أعلى تحسن وراثى للمحصول ومكوناته. وقد لوحظ وجود اختلافات معنوية بين متوسطات العشائر تحت الدراسة لبعض الصفات (وزن –100بذرة – محتوى التانين – سمك القصرة – ميعاد أول زهرة) للهجين وعكسه للجيلين الأول والثانى مما يرجح وجود تأثيرات أمية على بذور الفول البلدى. وعليه فإن الانتخاب خلال الجيل الثانى يمكن أن يساعد فى تحسين المحصول وصفات البذرة لوجود وفرة فى التباين الوراثى فى هذا الجيل. وقد أظهرت الدراسة أن الصفات المتأثرة بالأم سجلت أعلى كفاءة توريث بالمعنى الواسع. كما أن صفات محتوى التانين, ووزن الـ 100 بذره, عدد الأفرع/النبات و سمك القصرة أفضل صفات التى قد يعول عليها تحسين صفات المحصول والجودة بالانتخاب من خلالها ؛ حيث سجلت هذه الصفات أعلى درجة من كفاءة التوريث بالمعنى الواسع والمقترنة بقيم عالية من التحسين الوراثى المتوقع بالانتخاب . بالإضافة الى أن صفات عدد الأفرع/النبات، وعدد القرون/النبات، وعدد البذور/النبات، ووزن–100بذرة تعكس أعلى ارتباط معنوى مع محصول البذرة على النبات ، بالإضافة لمساهمتها سواء بطريق مباشر أو غير مباشر فى المحصول ومكوناته. وعليه يتم أخذ هذه الصفات فى الاعتبار عند تنفيذ برامج التربية لتحسين انتاجية الفول البلدى بالانتخاب لهذه الصفات فى الأجيال المبكرة. فى حين الانتخاب للتزهير المبكر ربما يحسن جودة البذرة من محتوى التانين المنخفض المصاحب لسمك القصرة الاقل لهذه التراكيب الوراثية.

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