GENETIC ANALYSIS OF SOME ECONOMIC CHARACTERS IN PEA

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Abstract

These experiments were carried out at Kaha Vegetable Research Farm, Qalubia Governorate, Horticulture Research Institute during the period from 2013 to 2016 to study the inheritance of some garden pea (*Pisum sativum* L.) economic characters, *viz*., plant length, number of days to flowering, green pod yield/plant, number of pods/plant, number of seeds/pod and shelling percentage. Four garden pea crosses, *viz.,* Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon and their reciprocals were produced. Then, parents, F_1, F_1r, and F_2 populations of each of the four crosses were cultivated on mid October, 2015 in a randomized complete block design (RCBD). The aim of this study was to determine genetic analysis of some economic traits in garden pea. Knowledge about genetics of particular traits is helpful to plant breeder before planning a successful breeding program. Obtained results show that maternal effect was not observed in any cross for all studied traits. Over-dominance or complete dominance was detected for high shelling percentage trait in all studied crosses. High plant length, earliness, high yielding, high no. of pods/plant and high no. of seeds/pod were dominant in some studied populations and contrary were found in others. Positive heterosis over better parent (based on early flowering parent) was noted in all studied populations for earliness and shelling percentage traits, however, negative heterosis was found in all studied populations for other traits. Minimum number of genes (MNG) was 1-5 for plant length, 1-3 for number of days to flowering, 3-4 for green pod yield/plant, 4-10 for number of pods/plant, 1-4 for number of seeds/pod and one gene for shelling percentage. Broad sense heritability (BSH) estimates were 45.52-82.47% for plant length, 65.18-90.11% for number of days to flowering, 77.12-96.10% for green pod yield/plant, 60.60-88.86% for number of pods/plant, 68.20-80.95% for number of seeds/pod and 72.21-74.91% for shelling percentage. The previous results indicate that all studied traits except no. of pods/plant are controlled by one to few numbers of genes and had moderate to high heritability, so the selection for these traits can be preferred in the early generations.

Key words: *Pisum sativum*, Dominance, Heterosis, Number of genes, Heritability.

INTRODUCTION

Garden pea (*Pisum sativum* L.) is an important vegetable crop in Egypt due to its high nutritive value. The total cultivated area grown with garden pea in 2015/2016 was 41819 feddan produced 183282 tons with an average of 4.383 tons/fed. (MaIr, 2018**).** Garden pea initial domestication lies in the Mediterranean, primarily in the Middle East. The most important aims for pea breeding are developing high yielding

cultivars with stable productivity. Its improvement is mainly based on exploiting natural germplasm sources by selection or hybridization followed by selection. Heritability is the portion of phenotypic variation which is transmitted from parent to progeny. Highly heritable variation leads to great possibility of fixing character by selection methods (Sharma and Bora, 2013).

Noser (2002), Hamed (2005) and Hamed *et al* (2015) indicated that maternal effect was not observed for plant length trait in any one of studied crosses. This could be due to nature of self pollination in pea. High positive PR values indicated over dominance and complete dominance towards the tallest parent were estimated for plant length trait (Hamed *et al*, 2015), meanwhile, El-Dakkak (2016) found partial dominance towards the tallest parent for this trait. Hamed (2005) found negative heterosis in some crosses and positive heterosis in others for plant length trait, meanwhile, El-Dakkak (2016) found negative heterosis (-16.82%) based on the tallest parent for this trait. However, Hamed *et al* (2015) found positive heterosis over better parent in all crosses for plant length in pea. Minimum number of genes (MNG) for plant length character was 1-3 pairs of genes (Hamed, 2005), 1-5 genes (Noser, 2002) and one gene (Hamed *et al,* 2015). Broad sense heritability (BSH) of plant length trait was high (Kumari *et al*, 2009 and Galal, 2014) which suggested that this trait would respond to selection. Meanwhile, Hamed (2005), Hamed *et al* (2015), El- Dakkak (2016) and Georgieva *et al* (2016) estimated BSH and it was from 54.6% to 74.2%, from 79.49% to 89.65%, from 85.92% to 98.38%, and 55%, respectively.

Khalil *et al* (2015) found that maternal effect did not affect inheritance of number of days to flowering character in all studied populations. Meanwhile, Noser (2002) found that maternal effect was existed for this trait only in one out of the six studied crosses of pea. Also, Hamed (2005) indicated that maternal effect was found only in one out of three studied crosses of garden peas. Positive PR values were calculated indicating partial dominance to late flowering parent as detected in pea populations by Hamed (2005), Abbas (2012) and Khalil *et al* (2015). Meanwhile, different types of dominance were obtained by Noser (2002). Also, Sood and Kalia (2006) found complete and over dominance for this trait. Significant positive heterosis based on early parent was observed in all garden pea crosses for days to flowering trait (Hamed*,* 2005 and Khalil *et al*, 2015). While, Noser (2002) found negative heterosis in some crosses and positive heterosis values in the others. Minimum number of genes controlling number of days to flowering trait was estimated as a single gene (Khalil *et al*, 2015), one to two pairs of genes (Noser, 2002) and two to seven pairs of genes (Hamed*,* 2005). High BSH estimates were obtained by Kumari *et al* (2009), meanwhile, it was ranged from low to moderate (Abbas, 2012). It was

estimated as 65.64% to 94.23% (Noser, 2002), 63.4% to 77.5% (Hamed, 2005), 70.88% to 91.03% (El-Dakkak *et al*, 2014), 98.0% (Galal, 2014), 93.47% to 94.74% (Khalil *et al*, 2015) and 90.37% to 98.52% (El-Dakkak, 2016).

No significant differences were stated between F_1's and their reciprocals for green pod yield/plant trait in all populations indicating no maternal effect (Hamed *et al*, 2015 and Kosev, 2015). However, Noser (2002) indicated that maternal effect was remarked for green pod yield/plant trait only in 2 out of 6 crosses of garden peas. Over dominance was detected for high green yield/plant trait (Hamed *et al*, 2015), meanwhile, high positive PR values indicated over dominance and partial dominance towards high yielding parent were estimated by Sood and Kalia (2006). While, Noser (2002) found different types of dominance for this trait. Noser (2002) observed significant positive heterosis of pod green yield/plant in all studied crosses estimated as 6.54% to 74.93% except in one cross which exhibited negative heterosis. Also, positive heterosis (118.29 % and 160.48%) over better parent was found in two populations for green yield/plant trait (Hamed *et al*, 2015), meanwhile, Kosev (2015) found significant positive heterosis in all studied populations. Minimum number of genes controlling green pod yield/plant was a pair of genes in all populations (Noser, 2002), meanwhile, Hamed *et al* (2015) estimated it as 2-3 pairs of genes. High BSH estimates were observed for green pod yield character (El-Dakkak *et al*, 2014 and Kosev, 2015) indicating good scope of selection for this trait. Also, heritability was estimated as 46.04% to 92.22% (El-Dakkak *et al*, 2014), 49.44% to 90.81% (Hamed
et al, 2015) and 83.33% to 95.17% (El-Dakkak, 2016).

No significant differences were noticed between F_1's and their reciprocals for number of pods/plant character in all populations indicating absence of maternal effect (Noser, 2002, Hamed *et al*, 2015 and Kosev, 2015), meanwhile, Hamed (2005) found that maternal effect was existed for this trait only in one out of four studied crosses of pea. High positive potence ratios indicating over dominance towards high parent were observed in all studied populations for number of pods per plant (Sood and Kalia, 2006 and Hamed *et al*, 2015). Also, Noser (2002) found over dominance of highest parent in three crosses and complete dominance of highest parent in three others. However, Hamed (2005) observed complete dominance of highest parent in 3 out of 4 crosses and complete dominance of lowest number of pods/plant in one cross. Positive heterosis over better parent for number of pods/plant trait was noted in all studied crosses (Noser, 2002 and Hamed *et al*, 2015). On the other hand, Hamed (2005) estimated negative heterosis values ranged from -32.7% to -2.9% in all evaluated populations. While, Kosev (2015) found positive heterosis in some populations and negative heterosis in others. The different results might be due to

using various germplasm or different environmental conditions. Minimum number of genes controlling number of pods/plant was a pair of genes in all populations (Noser, 2002). Meanwhile, Hamed (2005) and Hamed *et al* (2015) estimated it as 1-7 and 3-6 pair of genes, respectively. Kumari *et al* (2009) and Kosev (2015) estimated high values of heritability in the broad sense indicating good scope of selection for number of pods/plant trait. In the same direction, Galal (2014) estimated BSH as 90.0%- 91.5%. While, it ranged from 54.9% to 86.0%, from 37.9% to 78.8%, from 32.12% to 86.61%, from 77.30% to 79.91% and from 82.80% to 94.43% as estimated by Noser (2002), Hamed (2005), El-Dakkak *et al* (2014), Hamed *et al* (2015) and El- Dakkak (2016), respectively, however, Georgieva *et al* (2016) estimated it as 39%.

Maternal effect was existed for number of seeds/pod trait only in one out of six crosses as found by Noser (2002), meanwhile, Hamed (2005) and Khalil *et al* (2015) indicated that no maternal effect for this trait was found. This could be due to nature of self pollination in pea. Partial dominance towards high parent for number of seeds/pod trait was observed by Hamed (2005), while, Noser (2002) found different types of dominance, *viz.*, over, complete and partial dominance towards the high parent and complete dominance towards the lowest parent for this trait. Also, Sood and Kalia (2006) observed partial and over dominance for this character. Meanwhile, Khalil *et al* (2015) found complete dominance towards high parent in one population, however, absence of dominance was obtained in other one. Noser (2002) and Khalil *et al* (2015) found positive heterosis over the better parent for number of seeds/pod trait in some garden pea crosses, however, negative heterosis was exhibited in other studied crosses. Meanwhile, Hamed (2005) exhibited low negative heterosis values for this character. Hamed (2005) and Khalil *et al* (2015) estimated MNG controlling number of seeds/pod character as one pair. Meanwhile, Noser (2002) found that MNG controlling this trait was 1-7 pairs of genes. Broad sense heritability (BSH) was estimated as moderate to high (Hamed, 2005 and El-Dakkak *et al*, 2014) and high (Galal, 2014). However, Noser (2002), El-Dakkak *et al* (2014), Khalil *et al* (2015) and El-Dakkak (2016), found that BSH for this trait ranged from 14.67% to 43.47%, from 57.08% to 84.40%, from 29.22% to 59.78% and from 43.45% to 54.35%, respectively.

Noser (2002), Hamed (2005) and Khalil *et al* (2015) found that maternal effect for shelling percentage trait was not observed in any one of the studied crosses. Noser (2002) found complete dominance of better parent in all crosses for shelling percentage trait, meanwhile, Sood and Kalia (2006) and Abbas (2012) found that shelling percentage was controlled by over dominance. Also, positive potence ratios were found indicated over and complete dominance of best parent (Hamed,

2005, and Khalil *et al*, 2015). Noser (2002), Hamed (2005) and Khalil *et al* (2015) estimated positive heterosis, based on better parent, for shelling percentage trait in some studied crosses, while, negative heterosis were obtained in others. Minimum number of genes governing shelling percentage was one pair in all crosses studied by Noser (2002) and Khalil *et al* (2015). However, it was estimated as one to three pairs of genes (Hamed, 2005 and Abbas, 2012). Broad sense heritability estimated for shelling percentage trait was low to moderate (Noser, 2002 and Hamed, 2005), meanwhile, Kumari *et al* (2009) and Khalil *et al* (2015) indicated that it was moderate.

Lack of sufficient genetic variability for economically important characters of pea is the reason of doing efforts to progress in crop improvement. So, the research work in this study aims to studying inheritance of some economic traits of garden pea such as plant length, number of days to flowering, green pod yield/plant and shelling percentage which may help to select proper genotypes for future breeding programs.

MATERIALS AND METHODS

This investigation was carried out during the period from 2013 to 2016. Production and evaluation of genetic populations were conducted in the open field of Kaha Vegetable Research Farm, Qalubia Governorate, Hort. Res. Institute, Agric. Res. Center, Egypt. Five garden pea cvs., *viz,* Master, PS 210713, Sugar gem, Victory freezer and 6-Lebanon were selected for genetic studies based on their yield performance and other desired economic traits, *viz.*, plant length, number of days to flowering, shelling percentage and green pod yield/plant. Seeds of these cultivars were cultivated in the open field at Kaha on mid October, 2013. Four crosses, *viz.,*

Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon and their reciprocals were produced. Seeds of the F_1 crosses were planted on mid October, 2014. Plant's flowers were left for selfing to produce F_2 seeds. In the same period, F_1 seeds production was completed.

Genetic population's evaluation was conducted at Kaha Vegetable Res. Farm. Seeds of parental, F_1, F_1r and F_2 populations of each of the four crosses were planted in a randomized complete block design with three replicates on mid October, 2015. Each replicate contained single row for each non segregating population, *i.e.,* parents, F_1 and their reciprocals and three rows for each F_2. Each row was 3.0 m long and 0.7 m wide. Seeds were planed 15 cm apart individually. Agricultural practices like fertilization, irrigation and pest control were managed as commonly followed in this region.

Data were registered for all populations in each cross on individual plants for plant length, number of days to flowering, green pod yield/plant, number of pods/plant, number of seeds/pod and shelling percentage. Traits were only

investigated in the crosses which their parents were significantly differed in such characters.

Data were recorded as follow:

Plant length was measured at the end of harvesting season from the surface of soil until highest point of stem in cm. Number of days to flowering was measured as number of days from planting to first flower anthesis. Green pod yield/plant was estimated as weight of all harvested pods. Number of seeds/pod was measured as mean number of seeds per five pods/plant. Shelling percentage was calculated for five pods/plant as follows:

Shelling percentage = (Seeds weight/total pod weight) × 100.

Genetic parameters calculated

Maternal effect was calculated by measuring significance of difference between every F_1 mean and it's reciprocal by (t) test. Potence ratio, *i.e.,* relative potency of gene set (PR) was applied to determine direction of dominance according to the formula of Smith (1952). Heterosis was estimated based on better parent using the formula of Sinha and Khanna (1975). Minimum number of genes governing character in each cross was calculated using Wright formula (Burton, 1951). Broad senses heritability (BSH) was calculated using the equation as described by Allard (1960).

RESULTS AND DISCUSSION

1- Plant length

Regarding plant length trait, data of parental, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon are given in Table 1.

In four studied crosses, parents were clearly different in plant length. Means of F_1's and F_2's were intermediate between their respective parents in all crosses. F_2 plants of each cross were widely spreaded between its two parents with transgressive segregations over highest parent in the crosses Master × Sugar gem and Victory freezer × Sugar gem.

Table 1. Distribution, mean and variance of plant length (cm) of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of plant length (cm) in class[z]								Total No. of plants	Mean $X \pm S_X$ [y]	Variance (δ^2)
	21	41.1	61.2	81.3	101.4	121.5	141.6	161.7			
Master (P_1) × PS 210713 (P_2)											
P_1	21	9							30	27.03 ± 1.71 **	87.768
P_2					8	11	11		30	123.51 ± 2.95	260.517
F_1			4	12	12	1			30	88.00 ± 2.78 NS	232.190
F_1r			4	14	9	3			30	88.67 ± 3.12	292.095
F_2	16	16	32	30	22	2	2		120	67.90 ± 2.58	796.703
Master (P_1) × Sugar gem (P_2)											
P_1	21	9							30	27.03 ± 1.71 **	87.768
P_2					9	12	9		30	121.50 ± 2.89	250.765
F_1				3	10	11	6		30	114.80 ± 3.38 NS	343.641
F_1r				2	13	10	5		30	113.46 ± 3.14	295.345
F_2	7	7	19	27	26	20	12	2	120	90.68 ± 3.05	1119.911
Victory freezer (P_1) × Sugar gem (P_2)											
P_1			7	17	4	2			30	81.97 ± 2.97 **	264.232
P_2					9	12	9		30	121.50 ± 2.89	250.765
F_1			1	10	9	8	2		30	101.40 ± 3.73 NS	417.941
F_1r			3	8	10	9			30	98.05 ± 3.62	392.401
F_2			7	21	47	29	10	6	120	106.76 ± 2.15	554.976
Victory freezer (P_1) × 6-Lebanon (P_2)											
P_1			7	17	4	2			30	81.97 ± 2.97 **	264.232
P_2					1	10	13	6	30	137.58 ± 2.95	261.910
F_1			1	1	8	12	8		30	118.15 ± 3.62 NS	392.401
F_1r			3		9	9	9		30	115.47 ± 4.43	589.297
F_2		4	19	26	43	19	5	4	120	95.54 ± 2.67	855.117

[z] Each class represents a range of 20.1 cm and class values indicated represent class centers.
[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

No significant differences were detected between F_1's and their reciprocals for plant length trait in all crosses indicating no maternal effect. These results typically agree with those of Noser (2002), Hamed (2005) and Hamed *et al* (2015) and this could be due to nature of self pollination in pea.

Quantitative genetic parameters gained for plant length trait are presented in Table 2.

Several types of dominance were obtained for plant length trait. Positive PR value indicated partial dominance of the high parent in the crosses Master × PS 210713 and Victory freezer × 6-Lebanon and complete dominance of the tallest parent in the cross Master × Sugar gem, however, partial dominance towards the shortest parent were found in the cross Victory freezer × Sugar gem. These various results might be due to using different germplasm. These results are partially agree with those of Hamed *et al* (2015) and El-Dakkak (2016) who found dominance towards high parent in some population of peas.

All studied crosses exhibited negative high-parent heterosis for plant length trait ranged from -28.75% to -5.51%. These results agree with those of El-Dakkak (2016) who found negative heterosis for this trait and partially agree with those of

Hamed (2005) who found negative heterosis in some crosses and positive heterosis in others for plant length character.

One pair of genes was found to be controlled plant length trait in the cross Master × PS 210713, three pairs of genes in the crosses Master × Sugar gem and Victory freezer × 6-Lebanon and five pairs in the cross Victory freezer × Sugar gem. These different results might be due to using diverse germplasm. These results are in agreement with the previous results which reported that this character was controlled by one pair (Hamed *et al,* 2015), 1-3 pairs (Hamed, 2005) and 1-5 pairs (Noser, 2002). This means that plant length in quantitavely inherited.

Table 2. Genetic parameters obtained for some characters in some garden pea crosses.

Character	Plant length				No. of days to flowering				Green pod yield/plant			
Parameter / Cross	PR	H %	MNG	BSH %	PR	H %	MNG	BSH %	PR	H %	MN G	BSH %
M × PS	0.26	-28.75	0.10	78.10	0.33	41.36	0.61	88.63	0.86	-6.13	2.39	94.48
M × Sg	0.86	-5.51	2.37	82.47	0.92	78.58	2.06	90.11	0.42	-25.52	2.33	96.10
Vf × Sg	-0.02	-16.54	4.32	45.52	-0.44	3.52	0.46	65.18	-0.12	-34.37	2.02	84.07
Vf × L	0.30	-14.12	2.04	64.85	0.71	15.04	0.55	67.67	0.10	-27.50	3.88	77.12

M= Master, PS= PS 210713, Sg = Sugar gem, Vf= Victory freezer, L=6-Lebanon
PR = Potence ratio, H = Heterosis, MNG = Minimum number of genes, BSH = Broad sense heritability.

Table 2. Continued.

Character	No. of pods/plant				No. of seeds/pod				Shelling percentage			
Parameter / Cross	PR	H %	MNG	BSH %	PR	H %	MNG	BSH %	PR	H %	MNG	BSH %
M × PS	-0.14	-51.76	9.41	88.86	-0.50	-26.74	3.18	68.20	4.30	15.32	0.02	73.31
M × Sg	-0.14	-50.63	5.51	85.00	0.08	-20.17	1.53	80.95	1.51	6.96	0.41	74.91
Vf × Sg	-0.06	-34.38	3.38	60.60	0.92	-1.18	0.44	69.23	1.46	2.80	0.06	72.81
Vf × L	-0.34	-51.63	4.18	84.90	-	-	-	-	1.21	2.21	0.23	72.21

M= Master, PS= PS 210713, Sg = Sugar gem, Vf= Victory freezer, L=6-Lebanon
PR = Potence ratio, H = Heterosis, MNG = Minimum number of genes, BSH = Broad sense heritability.

Calculated BSH for plant length trait were moderate to high being 45.52% to 82.47% (Table 2). These results are in agreement with that of Kumari *et al* (2009), Galal (2014), Hamed *et al* (2015) and El-Dakkak (2016) who found that it was high. Also, Hamed (2005) and Georgieva *et al*. (2016) who estimated it as ranged from 54.6% to 74.2%.

2- Number of days to flowering

Data on number of days to flowering trait of parental lines, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon are presented in Table 3.

Parents were highly significant diverse in this character. F_1 and F_2 means were intermediate between their respective parents in all studied crosses with tendency towards the latest parent except F_1 of the cross Victory freezer × Sugar gem and F_2 of the cross Victory freezer × 6-Lebanon which tendency towards the earliest parent.

Plants of F_2 were vastly spreaded between their parents with transgressive segregation over the earliest parent in the cross Victory freezer × 6-Lebanon.

On comparing the observed means of the studied F_1's and its reciprocals, no significant differences were noticed between F_1 and it's F_1r in number of days to flowering trait in all the studied crosses indicating absence of mother effect for this character. These results are typically in agreement with Khalil *et al* (2015) who indicated that maternal effects were absent in all studied crosses for number of days to flowering character. Also, these results are partially agree with findings of Noser (2002) and Hamed (2005) who found that maternal effect was existed only in one cross.

Quantitative genetic parameters obtained for number of days to flowering trait are presented in Table 2.

Table 3. Distribution, mean and variance of number of days to flowering of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of number of days to flowering in class[z]								Total No. of plants	Mean y $X \pm S_X$	Variance (δ^2)
	40	47	54	61	68	75	82	89			
	Master (P_1) × PS 210713 (P_2)										
P_1	8	22							30	45.13 ± 0.57 **	9.913
P_2				8	16	6			30	67.53 ± 0.88	23.430
F_1				20	8	2			30	63.80 ± 0.79 NS	18.924
F_1r			2	17	6	5			30	64.27 ± 1.10	36.271
F_2	9	11	11	21	29	29	9	1	120	64.38 ± 1.10	144.104
	Master (P_1) × Sugar gem (P_2)										
P_1	8	22							30	45.13 ± 0.57 **	9.913
P_2						4	22	4	30	82.00 ± 0.67	13.517
F_1						9	18	3	30	80.60 ± 0.78 NS	18.248
F_1r					2	1	21	6	30	82.23 ± 0.92	25.289
F_2		16	10	23	23	30	13	5	120	66.83 ± 1.07	136.157
	Victory freezer (P_1) × Sugar gem (P_2)										
P_1					12	15	3		30	72.90 ± 0.83 **	20.783
P_2						4	22	4	30	82.00 ± 0.67	13.517
F_1						28	2		30	75.47 ± 0.32 NS	3.154
F_1r					1	26	3		30	75.47 ± 0.47	6.533
F_2					8	66	35	11	120	77.86 ± .048	27.585
	Victory freezer (P_1) × 6-Lebanon (P_2)										
P_1					12	15	3		30	72.90 ± 0.83 **	20.783
P_2						4	6	20	30	85.73 ± 0.93	26.133
F_1						1	20	9	30	83.87 ± 0.67 NS	13.292
F_1r					1	1	21	7	30	82.93 ± 0.80	19.375
F_2				11	23	43	31	12	120	75.58 ± 0.71	59.775

[z] Each class represents a range of 7.0 days and class values indicated represent class centers.

[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

Several types of dominance were obtained for number of days to flowering character. Positive PR values (0.92 and 0.71) were calculated indicating complete

dominance of the late parent in the crosses Master × Sugar gem and Victory freezer × 6-Lebanon. Meanwhile, the mean of the cross Master × PS 210713 lied between those of MP and late parent, indicating partial dominance for the late parent. However, negative PR value (-0.44) was estimated indicating partial dominance for the early parent in the cross Victory freezer × Sugar gem. These results partially confirm previous reports of Noser (2002), Hamed (2005), Sood and Kalia (2006), Abbas (2012) and Khalil *et al* (2015) who observed different types of dominance for this trait. These various results might be due to using different germplasm in each study.

Positive average degrees of heterosis based on early parent were estimated in all studied crosses for number of days to flowering trait ranging from 3.52% to 78.58% (Table 2). These results agree with the findings of Hamed (2005) and Khalil *et al* (2015) who found positive heterosis in all studied crosses, meanwhile, Noser (2002) found negative heterosis in some crosses and positive heterosis values in the others for this character.

Minimum number of genes governing number of days to flowering trait was calculated as a pair of genes in all studied crosses except in the cross Master × Sugar gem which controlled by three pairs of genes (Table 2). These results are partially in agreement with those of Noser (2002), Hamed (2005) and Khalil *et al* (2015).

Estimates of BSH for number of days to flowering trait (Table 2) ranged from 65.18% to 90.11% indicating high heritability estimates for this trait. These results indicated the importance of genetic effect in controlling inheritance of this character. These results partially agree with the previous results which indicated that it was high (Noser, 2002, Hamed, 2005, Kumari *et al,* 2009, El-Dakkak *et al,* 2014, Galal, 2014, Khalil *et al,* 2015 and El-Dakkak, 2016).

3- Green pod yield/plant

Data obtained on green pod yield/plant trait of parental, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon are presented in Table 4.

Parents were highly significant various in this character. Means of F_1 and F_2 were intermediate between their respective parents in all studied crosses except F_2 of the cross Victory freezer × 6-Lebanon which was less than the low yielding parent. F_2 plants were greatly spreaded between their parents with transgressive segregation over the high yielding parent in the cross Master × PS 210713.

Non significant differences were noticed between F_1's and their F_{1r}'s for this character in all crosses indicating no maternal effect. Previous results typically agree

with the findings of Hamed *et al* (2015) and Kosev (2015) who indicated that maternal effects were absent for this character.

Genetic parameters obtained for green pod yield/plant are presented in Table 2.

Several types of dominance were noticed for this character. Positive PR value (0.86) were calculated indicating complete dominance towards highest yielding parent in the cross Master × PS 210713. Partial dominance to high yielding parent showed for the crosses Master × Sugar gem and Victory freezer × 6-Lebanon. However, negative PR value (-0.12) was calculated indicating partial dominance to lowest parent in the cross Victory freezer × Sugar gem. These results agree with previous results of Noser (2002) who noticed different types of dominance for this trait. These different results might be due to using various germplasm.

Table 4. Distribution, mean and variance of green pod yield/plant of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of total green pod yield/plant (g) in class[z]												Total No. of plants	Mean $\bar{y}$ $X \pm S_X$	Variance (δ^2)
	35.0	65.1	95.2	125.3	155.4	185.5	215.6	245.7	275.8	305.9	336.0	366.1			
Master (P_1) × PS 210713 (P_2)															
P_1	29	1											30	36.00 ± 1.00 **	30.200
P_2							4	10	12	4			30	261.75 ± 4.94	733.139
F_1					2	3	4	11	6	2	2		30	245.70 ± 8.29 NS	2061.954
F_1r						5	4	7	9	4	1		30	251.72 ± 7.69	1774.530
F_2	23	20	17	18	14	8	4	7	4	3		2	120	124.30 ± 7.35	6475.025
Master (P_1) × Sugar gem (P_2)															
P_1	29	1											30	36.00 ± 1.00 **	30.407
P_2								5	6	15	3	1	30	294.86 ± 5.49	904.969
F_1					6	8	4	4	4	4			30	219.61 ± 9.54 NS	2732.609
F_1r					2	9	6	6	7				30	222.62 ± 7.17	1542.300
F_2	26	13	10	10	11	10	8	8	7	6	6	5	120	156.91 ± 9.49	10808.928
Victory freezer (P_1) × Sugar gem (P_2)															
P_1		6	11	5	5	3							30	113.26 ± 7.01 **	1474.609
P_2								5	6	15	3	1	30	294.86 ± 5.49	904.969
F_1				2	9	7	5	5	2				30	193.53 ± 7.76 NS	1807.854
F_1r				2	8	6	6	7	1				30	196.54 ± 7.57	1717.253
F_2	20	30	16	15	2	6	4	6	13	6	2		120	132.57 ± 8.38	8420.500
Victory freezer (P_1) × 6-Lebanon (P_2)															
P_1		6	11	5	5	3							30	113.26 ± 7.01 **	1474.609
P_2								1	15	11	3		30	291.85 ± 4.01	483.205
F_1					1	12	9	6	2				30	211.59 ± 5.54 NS	920.589
F_1r						10	9	5	1	3			30	213.59 ± 9.00	2432.689
F_2	39	16	25	20	9	5	1	1	2	1	1		120	93.95 ± 5.63	3797.565

[z] Each class represents a mean pod weight of 30.1 g and class values indicated represent class centers.
[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

Negative high-parent heterosis values were estimated for all studied crosses ranged from -34.37% to -6.13% for green pod yield trait. These results dissagree with

those obtained by Noser (2002), Hamed *et al* (2015) and Kosev (2015). These various results might be due to using various germplasm or planting under several environmental conditions for the different studies.

Minimum number of genes controlling green pod yield/plant trait (Table 2) was estimated as 3 pairs in the crosses Master × PS 210713, Master × Sugar gem and Victory freezer × Sugar gem and 4 genes in the cross Victory freezer × 6-Lebanon indicating polygenic effect of green pod yield character. These results agree with previous results of Hamed *et al* (2015) who estimated it as 2-3 pairs of genes.

Estimates BSH for this character ranged from 77.12% to 96.10% indicating low environmental effect on this trait. These results were in agreement with those estimated by El-Dakkak *et al*. (2014), Hamed *et al*. (2015), Kosev (2015) and El- Dakkak (2016) who estimated high heritability for green pod yield trait.

4- Number of pods / plant

Concerning number of pods / plant trait, data of parental, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon are showed in Table 5.

In each studied cross, parents were clearly various in number of pods / plant. Means of F_1's and F_2's were intermediate between their parents in all studied crosses with tendency of F_2's towards the lowest parent. In each cross, F_2 plants were greatly spreaded between its two parents with transgressive segregation over highest parent in the cross Master × PS 210713.

No significant differences were noticed between F_1's and their F_{1r}'s for this character in all obtained crosses indicating absence of mother effect. Previous results typically agree with those of Noser (2002), Hamed *et al* (2015) and Kosev (2015) who reported that maternal effect was not observed in any one of the studied crosses for this trait. This could be due to nature of self pollination in peas.

Quantitative genetic parameters obtained for number of pods / plant are presented in Table 2.

Partial dominance towards low parent was found in all studied crosses for number of pods / plant trait. These results disagree with the results of Noser (2002), Hamed (2005), Sood and Kalia (2006) and Hamed *et al* (2015) who found dominance of the highest parent in all studied crosses. These diverse results might be due to the various germplasm or unlike environmental conditions in each study.

Data on heterosis (Table 2) showed that the four studied crosses exhibited negative heterosis values ranged from -51.76% to -34.38%. These results typically agree with finding results of Hamed (2005) who estimated negative heterosis values

ranged from -32.7% to -2.9% in all evaluated crosses. However, Kosev (2015) calculated positive heterosis in some studied crosses and negative heterosis in others.

Table 5. Distribution, mean and variance of number of pods/plant of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of number of pods/plant in class[z]										Total No. of plants	Mean $\bar{X} \pm S_{\bar{X}}$	Variance (δ^2)
	8	23	38	53	68	83	98	113	128	143			
Master (P_1) × PS 210713 (P_2)													
P_1	28	2									30	9.00 ± 0.69 **	14.483
P_2						4	19	7			30	99.50± 1.66	83.017
F_1		2	12	12	2	2					30	48.00 ± 2.63 NS	206.897
F_1r		8	5	5	7	3	2				30	52.00 ± 4.37	573.103
F_2	42	36	20	8	9	2	1	1	1		120	28.88 ± 2.17	564.564
Master (P_1) × Sugar gem (P_2)													
P_1	28	2									30	9.00 ± 0.69 **	14.483
P_2				4	5	15	5	1			30	80.00 ± 2.73	223.448
F_1		7	17	3	2	1					30	39.5 ± 2.63 NS	207.155
F_1r		12	9	4	3		2				30	41.00 ± 3.90	456.207
F_2	56	23	20	9	5	3	3	1			120	26.75 ± 2.20	583.298
Victory freezer (P_1) × Sugar gem (P_2)													
P_1	6	11	10	3							30	28.00 ± 2.53 **	191.379
P_2				4	5	15	5	1			30	80.00 ± 2.73	223.448
F_1		3	6	11	9	1					30	52.50 ± 2.83 NS	240.259
F_1r		2	10	9	7	2					30	51.50 ± 2.91	253.707
F_2	40	28	26	6	16	2	1	1			120	31.13 ± 2.14	551.707
Victory freezer (P_1) × 6-Lebanon (P_2)													
P_1	6	11	10	3							30	28.00 ± 2.53 **	191.379
P_2							1	12	13	4	30	123.00 ± 2.08	129.310
F_1			8	9	7	4	2				30	59.50 ± 3.35 NS	336.466
F_1r		1	6	9	8	4		2			30	61.00 ± 3.86	445.862
F_2	31	23	21	12	6	6	9	8	3	1	120	45.25 ± 3.34	1342.374

[z] Each class represents a range of 15 pods and class values indicated represent class centers.

[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

Minimum number of genes controlling number of pods / plant trait was estimated as four pairs in the cross Victory freezer × Sugar gem, five pairs in the cross Victory freezer × 6-Lebanon, six pairs in the cross Master × Sugar gem and ten pairs in the cross Master × PS 210713. These results are partially in agreement with those found by Hamed (2005) and Hamed *et al* (2015) who estimated it as 1-7 and 3- 6 pairs of genes for this character, respectively.

Broad sense heritability estimated for number of pods / plant was moderate to high and ranged from 60.60% to 88.86% indicating good scope for selection for number of pods/plant trait. These results agree with those obtained by Noser (2002),

Hamed (2005), Kumari *et al* (2009), El-Dakkak *et al* (2014), Galal (2014), Hamed *et al* (2015), Kosev (2015) and El-Dakkak (2016) who estimated high values of heritability in the broad sense for this character.

5- Number of seeds/pod

Data obtained on number of seeds/pod trait of parental, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem and Victory freezer × Sugar gem are presented in Table 6.

In the three studied crosses, parents were highly significant different in this trait. Means of F_1's and F_2's were intermediate between their parents in all three studied crosses except the F_2 of the cross Master × PS 210713 which was lower than the low parent. F_2 populations of all crosses were greatly spreaded between its two parents with transgressive segregations over highest parent in the crosses Master × Sugar gem and Victory freezer × Sugar gem.

Table 6. Distribution, mean and variance of number of seeds/pod of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of number of seeds/ pod in class[z]								Total No. of plants	Mean $\bar{y}$ $X \pm S_X$		Variance (δ^2)
	2.5	3.6	4.7	5.8	6.9	8.0	9.1	10.2				
Master (P_1) × PS 210713 (P_2)												
P_1				2	4	21	3		30	7.82 ± 0.14	**	0.591
P_2		6	9	15					30	5.03 ± 0.16		0.764
F_1		4	4	15	4	3			30	5.73 ± 0.22	NS	1.497
F_1r		7	4	9	4	6			30	5.73 ± 0.29		2.498
F_2	20	24	25	25	19	6	1		120	4.89 ± 0.15		2.759
Master (P_1) × Sugar gem (P_2)												
P_1				2	4	21	3		30	7.82 ± 0.14	**	0.591
P_2		12	14	4					30	4.41 ± 0.14		0.579
F_1			6	12	6	6			30	6.24 ± 0.21	NS	1.302
F_1r			5	13	9	3			30	6.17 ± 0.18		0.946
F_2	7	16	18	18	24	21	14	2	120	6.21 ± 0.18		4.007
Victory freezer (P_1) × Sugar gem (P_2)												
P_1			4	13	11	2			30	6.20 ± 0.16	**	0.791
P_2		12	14	4					30	4.41 ± 0.14		0.579
F_1			8	8	11	3			30	6.13 ± 0.20	NS	1.181
F_1r		1	8	9	9	3			30	5.98 ± 0.21		1.342
F_2	12	18	18	44	14	12	2		120	5.38 ± 0.15		2.647

[z] Each class represents a range of 1.1 seeds and class values indicated represent class centers.

[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

Non-significant differences were showed between F_1's and their reciprocals for this trait in the three crosses indicating no maternal effect. These results typically agree with those of Hamed (2005) and Khalil *et al* (2015) who reported that maternal

effect was not observed in any one of studied crosses. This could be due to nature of self pollination in pea.

Genetic parameters obtained for number of seeds/pod are presented in Table 2.

Several types of dominance were noticed for this trait. Positive PR values (0.92 and 0.08) were estimated indicating complete and partial dominance to highest parent in the crosses Victory freezer × Sugar gem and Master × Sugar gem, respectively. However, negative PR value (-0.50) was calculated indicating partial dominance towards lowest parent in the cross Master × PS 210713. Obtained results agree with previous results of Noser (2002) who found different types of dominance for this trait. These different results might be due to using various germplasm.

All studied crosses exhibited negative heterosis values ranging from -26.74% to -1.18% (Table 2). These results are typically in agreement with results of Hamed (2005) who estimated negative heterosis for this character. Also, Noser (2002) and Khalil *et al* (2015) found negative heterosis in some crosses.

Minimum number of genes governing number of seeds/pod trait was calculated as a pair in the cross Victory freezer × Sugar gem, two pairs in the cross Master × Sugar gem and four genes in the cross Master × PS 210713. Also, Noser (2002) estimated minimum number of genes governing this trait as 1-7 pairs of genes, meanwhile, Hamed (2005) and Khalil *et al* (2015) estimated it as a single pair of genes.

Broad sense heritability estimated for number of seeds/pod was high and estimated as 68.20% to 80.95%. These results agree with those obtained by Hamed (2005), El-Dakkak *et al* (2014) and Galal (2014) who estimated high heritability for this character. However, Noser (2002), Khalil *et al* (2015) and El-Dakkak (2016) found that BSH for this trait ranged from 14.67% to 43.47%, from 29.22% to 59.78% and from 43.45% to 54.35%, respectively. Previous various results might be due to using another germplasm or various environmental conditions.

6- Shelling percentage:

Data recorded on shelling percentage of parental, F_1, F_1r and F_2 populations of the crosses Master × PS 210713, Master × Sugar gem, Victory freezer × Sugar gem and Victory freezer × 6-Lebanon are presented in Table 7.

Parents in all four crosses were greatly differing in shelling percentage. Means of F_1's were greater than their high parents in all studied crosses. Means of F_2's were intermediate between their respective parents in all studied crosses except the F_2 of the cross Victory freezer × Sugar gem which was higher than the high parent. F_2 populations of all crosses were widely spreaded between their parents with transgressive segregations over high parents in four studied crosses.

Data showed non-significant differences between F_1's and their F_{1r}'s for this character in four studied crosses indicating no mother effect. These results typically agree with previous results obtained by Noser (2002), Hamed (2005) and Khalil *et al* (2015).

Genetic parameters calculated for shelling percentage are presented in Table 2.

Positive PR values (4.30 and 1.51) were estimated indicated over dominance of high parent in the crosses Master × PS 210713 and Master × Sugar gem, respectively. Meanwhile, complete dominance to high parent in the crosses Victory freezer × Sugar gem and Victory freezer × 6-Lebanon were found. These crosses showed insignificant differences with the high parent. These results typically agree with those obtained by Noser (2002), Hamed (2005), Sood and Kalia (2006), Abbas (2012) and Khalil *et al* (2015) who found that over dominance and complete dominance of best parent were obtained for this trait.

Table 7. Distribution, mean and variance of shelling percentage (%) of parental, F_1, F_1r and F_2 populations of some garden pea crosses.

Population	Frequency of shelling percentage (%) in class[z]								Total No. of plants	Mean $\bar{X} \pm S_{\bar{X}}$	y	Variance (δ^2)
	28.5	35.6	42.7	49.8	56.9	64.0	71.1	78.2				
					Master (P_1) × PS 210713 (P_2)							
P_1			5	17	6	2			30	50.98 ± 1.03 **	}	31.579
P_2		2	12	15	1				30	46.25± 0.88		23.467
F_1				3	18	7	2		30	58.79 ± 0.96 NS	}	27.581
F_1r			1	2	15	9	3		30	59.50 ± 1.15		39.922
F_2		20	27	28	24	17	3	1	120	50.04 ± 0.92		102.458
					Master (P_1) × Sugar gem (P_2)							
P_1			5	17	6	2			30	50.98 ± 1.03 **	}	31.579
P_2	2	20	8						30	37.02± 0.71		15.297
F_1			3	8	15	4			30	54.53 ± 1.09 NS	}	35.924
F_1r		1	4	14	9	2			30	51.46 ± 1.16		40.618
F_2	7	30	36	21	15	8	3		120	45.24 ± 0.93		103.189
					Victory freezer (P_1) × Sugar gem (P_2)							
P_1	1	9	12	7	1				30	42.23 ± 1.18 **	}	41.487
P_2	2	20	8						30	37.02± 0.71		15.297
F_1		6	19	2	2	1			30	43.41 ± 1.20 NS	}	42.935
F_1r		4	18	4	2	2			30	45.07 ± 1.33		53.307
F_2	13	37	22	27	11	8	2		120	43.77 ± 0.96		110.690
					Victory freezer (P_1) × 6-Lebanon (P_2)							
P_1	1	9	12	7	1				30	42.23 ± 1.18 **	}	41.487
P_2			3	11	13	3			30	53.59± 1.06		33.838
F_1			3	4	22	1			30	54.77 ± 0.91 NS	}	24.857
F_1r		1	4	5	18	2			30	53.59 ± 1.21		44.268
F_2	8	28	42	17	12	7	5	1	120	45.24 ± 0.99		117.592

[z] Each class represents a range of 7.1% and class values indicated represent class centers.

[y] Pairs of means were either highly significant (**), significant (*), or not significant (NS) different from each other according to (t) test.

Positive high-parent heterosis values ranging from 2.21% to 15.32% were estimated in all the studied crosses for shelling percentage character. These results partially agree with that noticed by Noser (2002), Hamed (2005) and Khalil *et al* (2015) who estimated positive heterosis, based on the highest parent, for shelling percentage character in some crosses.

Minimum number of genes governing shelling percentage character was calculated as a single pair of genes in all four studied crosses (Table 2). Similar results were obtained by Noser (2002) and Khalil *et al* (2015) who estimated it as one pair in all studied crosses. Meanwhile, it was 1 to 3 genes as assessment by Hamed (2005) and Abbas (2012).

Results in Table 2 showed that calculated BSH for shelling percentage character ranging from 72.21% to 74.91%, indicating low environmental influence on this character. These results disagree with those obtained by Noser (2002), Hamed (2005), Kumari *et al* (2009) and Khalil *et al* (2015) who noticed that it was low or moderate. These several results could be due to using various germplasm or unlike environmental conditions by different researchers.

CONCLUSION

The previous results indicate that all studied traits except no. of pods/plant are controlled by one to few numbers of genes and had moderate to high heritability, so the selection for these traits can be preferred in the early generations.

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التحليل الوراثى لبعض الصفات الإقتصادية في البسلة

انتصار مصطفى اسماعيل أبوحمده

قسم بحوث تربية الخضر والنباتات الطبية والعطرية - معهد بحوث البساتين - مركز البحوث الزراعية - مصر

أجريت التجارب الخاصة بهذه الدراسة بمزرعة بحوث الخضر بقها بمحافظة القليوبية التابعة لمعهد بحوث البساتين خلال الفترة من 2013 إلى 2016 و ذلك بهدف دراسة وراثة بعض الصفات الاقتصادية في البسلة الخضراء مثل طول النبات ، وعدد الأيام حتى أول زهرة ، ومحصول القرون الأخضر للنبات ، وعدد القرون بالنبات ، وعدد البذوربالقرن ، ونسبة التصافى. تم انتاج 4 هجن من البسلة الخضراء هم ماستر × بى اس 210713 ، وماستر × شوجر جيم ، وفيكتورى فريزر × شوجر جيم ، وفيكتورى فريزر × 6لبنان. درست وراثة بعض الصفات الاقتصادية في عشائر كل من الآباء والجيل الأول والجيل الأول العكسي والجيل الثاني لكل الهجن فى تجربة زرعت فى منتصف اكتوبر 2015 فى قطاعات كاملة العشوائية. وقد أوضحت النتائج عدم وجود تأثير للأم فى كل الصفات المدروسة. وجدت سيادة فائقة وتامة لصفة نسبة التصافى فى كل الهجن المدروسة ، بينما فى باقى الصفات وجدت سيادة للأب الأعلى فى الصفة فى بعض الهجن بينما وجد العكس فى بعض الهجن الأخرى. أعطت صفتى عدد الأيام حتى ظهور أول زهرة (مقارنة بالأب المبكر) ، ونسبة التصافى مقارنة بالأب الأعلى تفوقا موجبا فى جميع الهجن المدروسة ، بينما أعطت صفات طول النبات ، ومحصول القرون الأخضر للنبات ، وعدد القرون بالنبات ، وعدد البذوربالقرن قوة هجين سالبة فى كل الهجن المدروسة. قدر عدد أزواج الجينات المتحكمة فى الصفات المدروسة بـــ 1-5 لصفة طول النبات ، و1-3 لصفة عدد الأيام حتى ظهور أول زهرة ، و-4 3 لصفة محصول القرون الأخضر للنبات ، و 4-10 لصفة عدد القرون بالنبات ، و 1-4 لصفة عدد البذوربالقرن ، وزوج واحد فقط من الجينات لصفة نسبة التصافى. قدرت درجة التوريث على النطاق العريض فكانت 45.52٪-82.47٪ لصفة طول النبات ، 65.18٪-90.11٪ لصفة عدد الأيام حتى ظهور أول زهرة ، 77.12٪-96.10٪ لصفة محصول القرون الأخضر للنبات ، 60.60٪-88.86٪ لصفة عدد القرون/النبات ، 68.20٪-80.95٪ لصفة عدد البذور بالقرن ، 72.21٪-74.91٪ لصفة نسبة التصافى. وتجمل الدراسة أنه من النتائج السابقة يتضح أن جميع الصفات المدروسة ماعدا صفة عدد القرون بالنبات يتحكم فيها عدد قليل من الجينات ودرجة توريثها متوسطة إلى عالية وبالتالى يمكن إجراء الإنتخاب لهذة الصفات فى الأجيال المبكرة.