ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 42 (3): 1215-1232, (2004).

GENETIC STUDIES ON COLD TOLERANCE IN SNAP BEAN (*Phaseolus vulgaris* L.)

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ABSTRACT

Crosses between snap bean cultivars, *i.e.,* Paulista, Oxyra and Bronco (tolerant to cold) and Primera, Samantha and Giza-6 (susceptible to cold) were made to study the inheritance and nature of cold tolerance and some related characters. Cold tolerance, Earliness and total green pod yield per plant were found to be inherited quantitatively. Partial dominance were detected for high cold tolerance, high number of days calculated from sowing date to the first flower bud anthesis and high total green pod yield per plant over low levels of these characters. The estimates of broad sense heritability ranged from 47.59% to 82.47%, 47.00% to 63.46% and 58.67% to 60.95%, while those of the narrow sense heritability ranged from 39.44% to 58.01%, 9.73% to 38.05% and 24.90 to 40.27% for cold tolerance, earliness and total green pod yield per plant, respectively. The minimum number of effective gene pairs controlling cold tolerance, earliness and total green pod yield per plant ranged from 1 to 4, 1 to 4 and 1 to 5 gene pairs, respectively. There were highly significant differences between parents, F_1, F_2, Bc_1 and Bc_2 populations of the crosses Paulista × Samantha and Oxyra × Giza-6 in photosynthetic pigments (chlorophyll a, b and total carotenoides) and sugars content (reducing, non-reducing and total). The cultivar Oxyra, which was tolerant to low temperature, had the highest contents of photosynthetic pigments and sugars, while the cultivar Giza-6, which was susceptible to low temperature, had the lowest content. Cold tolerance was positively correlated with each of number of days from planting date to the first flower bud anthesis, number of branches per plant, number of pods per plant, fruit set percentage and total green pod yield per plant in the F_2 populations of all crosses, and with each of reducing, non-reducing and total sugars, chlorophyll a, b and total carotenoides in the F_2 populations of the crosses Paulista × Samantha and Oxyra × Giza-6. In the crosses Paulista × Primera and Bronco × Giza-6, number of days from planting date to the first flower bud anthesis, number of branches per plant, number of pods per plant, fruit set percentage, and total green pod yield per plant were found to have a significant combined effect on cold tolerance. Moreover, in the crosses Paulista × Samantha and Oxyra × Giza-6, the combined effect of number of days from planting date to the first flower bud anthesis, number of branches per plant, number of pods per plant, fruit set percentage, total green pod yield per plant, total sugars and chlorophyll a was significantly correlated with cold tolerance.

INTRODUCTION

Snap bean (*Phaseolus vulgaris* L.) is one of the most popular vegetable crops in Egypt which is important for both local market and export. There were highly shortage in cultivars which can be cultivated under cold conditions and produce high yield and good quality. Thus, breeding for cold tolerance to improve local cultivars is very important. Genetic differences in cold tolerance between snap bean cultivars and lines were reported by Hardwick and Andrews (1981), Klein (1981), Farlow (1983), Drijfhout (1984), Hennig and Dube (1988), Santos *et al.* (1990), Chalyk (1991), Santos *et al.* (1993), Zaiter *et al.* (1994), Melo *et al.* (1997) and Ferrao *et al.* (2002).

Klein (1981) showed that cold tolerance during germination was inherited as a recessive character when the maternal parent was more susceptible than the pollinator to cold. In the reciprocal cross, tolerance in the F_1 was intermediate. He also found that, cold tolerance at the seedling stage tended to be inherited as a dominant character. In addition, Dickson and Petzoldt (1987) mentioned that cold tolerance at different stages was inherited quantitatively and independently. The ability to set pods at 16°C behaved as a recessive, quantitatively inherited character. Narrow sense heritabilities for seed germination at 5°C, seedling vigour and days to flowering at 16°C were 28, 56 and 45%, respectively. Chalyk (1991) mentioned that differences in cold resistance in the varieties studied were conditioned by 2 genes that differed in dominance depending on the cross. Melo *et al.* (1997) observed genetic differences among *Phaseolus* germplasm concerning flowering period and grain yield under low temperature conditions at the adult phase. In addition, additive effects of the genes were observed for the flowering period under such conditions.

Narikawa and Muira (1974) found that the reduction of photosynthetic efficiency by low temperature was due to a reduction in leaf chlorophyll content. Wu (1978) showed that the area, dry weight and chlorophyll concentration of leaves of 15 cultivars grown at low temperature in the field were lower than in control plants grown at normal temperature in the greenhouse. In addition, Badr (2003) on tomato, mentioned that highly significant positive correlations between foliage cold tolerance and chemical composition of plant foliage, *i.e.*, chlorophyll a, b and total carotenoides as well as reducing, non-reducing and total sugars were detected.

Wu (1978) found that soyabean seed yield was positively correlated with chlorophyll concentration of leaves. Ferrao *et al.* (2002) showed that grain yield and number of pods per plot were the less important characteristics influencing genetic diversity. However, as they showed low genotypic correlation with the other characteristics.

The main objective of this research was to study the inheritance and nature of cold tolerance in snap bean and the genetic behavior of some related characters under low temperature conditions in order to develop a dependable selection index for cold tolerance under winter conditions of Egypt.

MATERIALS AND METHODS

This study was carried out in the experimental Research Farm and germplasm preservation Laboratory, Department of Horticulture, College of Agriculture, Moshtohor, Zagazig University, Benha Branch, during the seasons of 2000 to 2003.

On October 14, 2000, thirty snap bean (*Phaseolus vulgaris* L.) genotypes were evaluated for resistant to low temperature in field experiment with three replicates by using randomize complete block design. Seeds of this germplasm were obtained from Agricultural Technology Utilization and Transfer Project, Agricultural Research Center, Dokki, Egypt. The highest resistant cultivars to low temperature, *i.e.*, Paulista, Oxyra and Bronco were selected. Moreover, the highest susceptible cultivars, *i.e.*, Primera, Samantha and Giza-6 were selected. Crosses were made in summer season of 2001 between the selected cultivars to obtain the following F_1 hybrids:

Paulista × Primera, Paulista × Samantha, Oxyra × Giza-6 and Bronco × Giza-6.

Seeds of the parental cultivars and F_1populations of the previous mentioned crosses were planted in the field in the summer season of 2002. Plants of F_1 populations were selfed to obtain seeds of F_2 populations and crossed to both parental cultivars to obtain seeds of backcross populations. In addition, the previous mentioned crosses between the parental cultivars were repeated to obtain enough seeds of F_1 populations.

On October 11, 2002 seeds of parental cultivars, F_1, F_2, Bc_1 and Bc_2 populations were planted in the open field on one side of ridges spaced 70 cm. wide with three seeds per hill 25 cm. apart, using a randomized complete block design with three replicates. Each replicate contained one ridge for each of the parental cultivars and the F_1 plants, four ridges for each F_2 plants and two ridges for each backcross plants. This planting date was selected to record the performance of the plants of the different populations under the relatively cold weather conditions which was expected. All other agricultural practices, *i.e.*, irrigation, fertilization, weed control…etc., were done as followed in the district.

Data recorded:-

The following characters were recorded for the individual plants of the different populations of the different crosses:-

Cold tolerance (percentage of healthy leaves to total number of plant leaves), Earliness (number of days from planting date to the first flower bud anthesis), number of branches/plant, number of pods/plant, fruit set percentage, pod length and diameter (cm) and total green pod yield/plant.

Reducing, non-reducing and total sugars were assayed calorimetrically in plant leaves using the method described by Flood and Priestly (1973). Moreover, photosynthetic pigments and carotenoides were determined in fresh leaves as described in AOAC (1975).

Pollen Grain fertility:-

Pollen fertility was estimated by the germination of pollen grains on a cultural media (Shahine, 1961). Germination of pollen grains took place on slides surrounded by water (to control humidity) at low temperature (about 5±2°C) in Petri dishes in the laboratory on the media mentioned by Darlington and La-Cour (1960). The culture media was made up of 100ml-distilled water, (6g. Cane sugar, 2g. Agar and 2g. Gelatin). Inspection and counts of germinated and non-germinated pollen grains were carried out after 48 hours to calculate the percentage of pollen germination.

Statistical analysis:-

The nature of dominance was determined by calculating the potence ratio (P) using the equation given by Smith (1952).

$$\text{Potence ratio (P)} = \frac{F1 - M.P.}{1/2(P2 - P1)}$$

Where:

F_1 = F_1 mean, P_1 = The smaller parent mean, P_2 = The larger parent mean, M.P. = Mid parent value = ½(P_2 + P_1).

Broad sense heritability (BSH) was estimated by the following method which was described by Allard (1960).

$$\text{BSH} = \frac{VF2 - (VF1 + VP1 + VP2)/3}{VF2} \times 100$$

Narrow sense heritability (NSH) was estimated after Mather and Jinkes (1971).

$$\text{NSH} = \frac{2VF2 - (VBc1 + VBc2)}{VF2} \times 100$$

Where:

VF_1 = Variance of the first generation, VF_2 = Variance of the second generation, VP_1 = Variance of the first parent, VP_2 = Variance of the second parent, VBc_1 = Variance of the first backcross, and VBc_2 = Variance of the second backcross.

The minimum number of the gene pairs differentiating the two parents was estimated using the method given by Castle and Wright (1921)

$$\text{N} = \frac{D^2}{8(VF2 - VF1)}$$

Where:

N = minimum number of gene pairs by which the parental differ, D = Mean of larger parent – Mean of smaller parent, VF_2 = Variance of F_2 population, and VF_1 = Variance of F_1 population.

Estimates of the mean and its standard deviation, total variance and type of inheritance of the studied characters for all populations were calculated using the methods described by Briggs and Knowles (1977).

Coefficients of correlation between different characters in F_2 populations and multiple regression analysis were performed using the methods described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Cold tolerance:

Using percentage of unaffected leaves per plant as a measure for tolerance to low temperature, it was found that cultivar Paulista had the highest degree of tolerance comparing to the other parental snap bean cultivars (Table, 1). The average percentage of tolerance was 90.23%, 37.57%, 44.18%, 89.50%, 35.67% and 78.83% for Paulista, Primera, Samantha, Oxyra, Giza-6 and Bronco, respectively. The results indicated that cvs. Paulista, Oxyra and Bronco were more tolerance to low temperature, the differences between them was not significant, than the other cultivars. These results corroborate those of Hardwick and Andrews (1981), Klein (1981), Farlow (1983), Drijfhout (1984), Hennig and Dube (1988), Santos *et al.* (1990), Chalyk (1991), Santos *et al.* (1993), Zaiter *et al.* (1994), Melo *et al.* (1997) and Ferrao *et al.* (2002) who mentioned that there were genetic differences in cold tolerance between snap bean cultivars or lines.

The frequency distribution for tolerance to low temperature in P_1, P_2, F_1, F_2, Bc_1 and Bc_2 populations for all crosses under this study indicated the quantitative inheritance pattern for this character (Table, 1).Same pattern of inheritance was detected by Dickson and Petzoldt (1987) who mentioned that cold tolerance at different stages was inherited quantitatively and independently. In addition, Badr (2003), working on tomato, found that the inheritance of cold tolerance was in quantitative pattern.

The F_1 values estimates were intermediate between the two parental cultivars for each cross (Table, 1). This has bean also observed by Klein (1981) who working on snap bean and Badr (2003) who working on tomato.

The potence ratios (P) were 0.69, 0.34, 0.26 and 0.95 for the crosses Paulista × Primera, Paulista × Samantha, Oxyra × Giza-6 and Bronco × Giza-6, respectively. This indicated the partial dominance for high tolerance over low level of tolerance. Obtained results were supported by those of Klein (1981) who mentioned that cold tolerance at the seedling stage tended to be inherited as a dominant character.

Table (1): Frequency distribution and segregation for plant reaction to cold tolerance in parents, F_1, F_2, Bc_1 and Bc_2 generations in some snap bean crosses.

Generations	Frequency distribution and segregation for plant reaction (%)										Total No of plants	Mean±SE	Variance
	10	20	30	40	50	60	70	80	90	100			
Paulista (P_1)	-	-	-	-	-	-	-	-	19	11	30	90.23±3.77	122.32
Primera (P_2)	-	-	-	18	12	-	-	-	-	-	30	37.57±3.77	133.17
F_1	-	-	-	-	-	-	-	14	16	-	30	82.17±3.77	104.65
F_2	4	5	7	7	8	33	26	18	7	5	120	67.94±1.89	684.87
Bc_1 (F_1XP_1)	-	-	-	-	-	-	-	25	35	-	60	82.08±2.67	428.33
Bc_2 (F_1XP_2)	-	-	-	27	12	21	-	-	-	-	60	46.00±2.67	560.96
L.S.D. 0.05 0.01												29.21 44.25	
Paulista (P_1)	-	-	-	-	-	-	-	-	19	11	30	90.23±4.53	122.32
Samantha(P_2)	-	-	-	-	21	9	-	-	-	-	30	44.10±4.53	416.03
F_1	-	-	-	-	-	-	17	13	-	-	30	75.00±4.53	712.12
F_2	6	9	10	12	13	14	18	21	12	5	120	65.32±2.26	795.24
Bc_1 (F_1XP_1)	-	-	-	-	-	-	-	29	31	-	60	77.42±3.20	610.76
Bc_2 (F_1XP_2)	-	-	-	-	-	36	24	-	-	-	60	58.92±3.20	655.36
L.S.D. 0.05 0.01												35.05 53.09	
Oxyra (P_1)	-	-	-	-	-	-	-	-	17	13	30	89.50±4.05	97.22
Giza-6 (P_2)	-	-	-	8	22	-	-	-	-	-	30	35.67±4.05	106.50
F_1	-	-	-	-	-	-	16	14	-	-	30	69.67±4.05	541.49
F_2	4	2	6	12	15	16	27	19	17	2	120	60.55±2.03	767.29
Bc_1 (F_1XP_1)	-	-	-	-	-	-	-	-	25	35	60	88.42±2.86	581.90
Bc_2 (F_1XP_2)	-	-	-	-	-	36	24	-	-	-	60	59.00±2.86	507.60
L.S.D. 0.05 0.01												31.34 47.48	
Bronco (P_1)	-	-	-	-	-	-	-	18	12	-	30	78.83±3.43	371.73
Giza-6 (P_2)	-	-	-	8	22	-	-	-	-	-	30	35.67±3.43	206.50
F_1	-	-	-	-	-	-	-	6	24	-	30	77.83±3.43	92.16
F_2	-	3	8	13	16	23	22	13	12	10	120	62.08±1.71	513.48
Bc_1 (F_1XP_1)	-	-	-	-	-	18	13	29	-	-	60	68.83±2.42	494.47
Bc_2 (F_1XP_2)	-	-	-	-	15	20	25	-	-	-	60	57.67±2.42	329.96
L.S.D. 0.05 0.01												26.54 40.20	

The broad sense heritability estimates for tolerance to low temperature ranged from 47.59% to 82.47% (Table, 2). Whereas, narrow sense heritability estimates ranged from 39.44% to 58.01%. Based on these estimates, which ranged from intermediate to above intermediate, it is advisable to select for cold tolerance using percentage of healthy leaves per plant as a criteria based on family mean basis in replicated experiments to remove, as much as possible, the environmental effects.

The minimum number of effective gene pairs controlling cold tolerance ranged from 1 to 4 gene pairs. In this respect, Chalyk (1991) mentioned that differences in resistance in the varieties studied were conditioned by 2 genes that differed in dominance depending on the cross.

Table (2): Potence ratio, broad (BSH) and narrow sense heritability (NSH) and minimum number of effective gene pairs estimates for some snap bean crosses.

aracters	Cold tolerance				Earliness (days)				Total yield/plant			
Crosses	P. ratio	BSH	NSH	No of gene pairs	P. ratio	BSH	NSH	No of gene pairs	P. ratio	BSH	NSH	No of gene pairs
Paulista × Primera	0.69	82.47	55.55	1	0.58	51.52	34.54	2	0.58	66.51	39.50	1
Paulista × Samantha	0.34	47.59	40.79	4	0.80	63.46	38.05	1	0.76	65.68	40.27	2
Oxyra × Giza-6	0.26	67.63	58.01	2	0.57	47.00	9.73	4	0.77	58.67	25.74	5
Bronco × Giza-6	0.95	56.49	39.44	1	0.38	53.47	23.02	2	0.92	66.95	24.90	1

Pollen grain fertility

The pollen grain of the cultivar Paulista had the highest percentage of germination (57.32%) when measured at full blooming stage, followed cv. Oxyra (53.98%), cv. Bronco (46.87%), cv. Samantha (30.33%), cv. Primera (28.67%) and Giza-6 (28.33%), (Table, 3). These results agree with those of plant foliage cold tolerance (Table, 1), where these results indicate that cvs. Paulista and Oxyra can be considered as a good sources for high pollen grain germination under cold conditions, which is one of the most important determinations for cold tolerance cultivars. In this respect, Abd El-Rahman (1994) found that there were highly differences between common bean cultivars for pollen grain fertility.

The F_1 and F_2 hybrids of the cross Paulista × Samantha had the highest values of pollen grain germination which were 50.10% and 44.17%, whereas, plants of the F_1 and F_2 of the cross Bronco × Giza-6 had the lowest values (44.69% and 38.08%, respectively) (Table, 3). Backcrosses of F_1 plants of all crosses under study with the highest parent for germination gave the highest germination values compared with crosses of F_1 plants with the lowest parent (Table, 3). Bc_1 and Bc_2 of the cross Paulista × Samantha gave the highest values for pollen grain germination compared with the Bc_1 and Bc_2 plants of the other crosses under this study (Table, 3).

Earliness of flowering

Under the conditions of planting date, the cultivar Primera had the shortest periods from planting date to the first flower bud anthesis (45.10 days), followed by the cultivar Giza-6 (46.00 days). On the other hand, cultivar Paulista had the longest period from planting date to the first flower bud anthesis (65.33 days), while cultivar Oxyra had significant short period (63.33 days), (Table, 4). It is worth mentioning here that the relatively extreme short period from planting date to the first flower bud anthesis observed with cultivar Primera could be due to high sensitivity of this cultivar to low temperature which may result in unperfected green pod and dry seed maturity. Based on these results, it can be suggested that cultivar Primera has genes for early flowering under the conditions of low temperature. Obtained results were supported by those of Melo *et al* (1997) who mentioned that parents differed in flowering period and grain yield under low temperature conditions at the adult phase.

Table (3): Pollen grain germination (%) in parents, F_1, F_2, Bc_1 and Bc_2 generations under cold conditions for some snap bean crosses.

Bronco × Giza-6	Oxyra × Giza-6	Paulista × Samantha	Paulista × Primera	Crosses / Populations
46.87	53.98	57.32	57.32	P_1
28.33	28.33	30.33	28.67	P_2
44.69	47.68	50.10	49.13	F_1
38.08	39.96	44.17	42.55	F_2
45.89	52.73	55.89	56.22	Bc_1
40.42	43.83	47.24	45.33	Bc_2
9.46	11.59	12.51	12.91	L.S.D. 0.05
14.33	17.56	18.95	19.56	0.01

The relative potence of gene set (P) for the period from planting date to first flower bud anthesis indicate the partial dominance of late flowering under the conditions of low temperature in all crosses (Table, 2). The number of days from planting date to the first flower bud anthesis for plants was intermediate between the two parents for each cross. The frequency distribution for earliness in the F_1, F_2, Bc_1 and Bc_2 populations of different crosses indicate quantitative inheritance for this character (Table, 4).

The broad sense heritability estimates for the period from sowing date to the first flower bud anthesis were 51.52%, 63.46%, 47.00% and 53.47% in the crosses Paulista × Primera, Paulista × Samantha, Oxyra × Giza-6 and Bronco × Giza-6, respectively (Table, 2). On the other hand, the narrow sense heritability were 34.54%, 38.05%, 9.73% and 23.02% in the same crosses respectively (Table, 2). These results indicate high influence of non-additive type of gene actions on the inheritance of this character, which should be considered when selecting for earliness of flowering under the conditions of low temperature. In this respect, Dickson and Petzoldt (1987) mentioned that narrow sense heritability for germination (at 5°C), seedling vigour and days to flowering (all at 16°C) were 28, 56 and 45, respectively. In addition, Otubo *et al.* (1996) and Melo *et al.* (1997) found that additive effects of the genes were observed for the flowering period.

Table (4): Frequency distribution for earliness in different populations of some snap bean crosses.

Variance	Mean±SE	otal No of plants	Upper class limits (days)								Populations
			80	75	70	65	60	55	50	45	
39.59	65.33±1.22	30	-	-	18	12	-	-	-	-	Paulista (P_1)
22.25	45.10±1.22	30	-	-	-	-	-	-	14	16	Primera (P_2)
53.10	61.10±1.22	30	-	-	-	15	15	-	-	-	F_1
79.03	61.42±0.61	120	12	15	15	31	32	8	4	3	F_2
67.14	55.47±0.87	60	-	-	-	10	13	37	-	-	Bc_1 (F_1X P_1)
63.62	52.40±0.87	60	-	-	-	-	11	33	16	-	Bc_2 (F_1X P_2)
	9.47 14.35										L.S.D. 0.05 0.01
29.59	65.33±1.39	30	-	-	18	12	-	-	-	-	Paulista (P_1)
30.03	53.77±1.39	30	-	-	-	-	17	13	-	-	Samantha (P_2)
45.02	64.17±1.39	30	-	-	8	22	-	-	-	-	F_1
95.45	62.42±0.70	120	4	12	25	36	18	14	11	-	F_2
79.06	63.33±0.98	60	-	-	22	16	22	-	-	-	Bc_1 (F_1X P_1)
75.52	59.90±0.98	60	-	-	-	21	27	12	-	-	Bc_2 (F_1X P_2)
	10.76 16.30										L.S.D. 0.05 0.01
18.52	63.23±1.20	30	-	-	8	22	-	-	-	-	Oxyra (P_1)
21.47	46.00±1.20	30	-	-	-	-	-	-	23	7	Giza-6 (P_2)
39.71	59.50±1.20	30	-	-	-	13	17	-	-	-	F_1
50.13	55.73±0.60	120	3	3	4	11	33	42	15	9	F_2
49.00	57.92±0.85	60	-	-	-	16	14	30	-	-	Bc_1 (F_1X P_1)
46.38	51.73±0.85	60	-	-	-	-	-	32	28	-	Bc_2 (F_1X P_2)
	9.26 14.02										L.S.D. 0.05 0.01
36.55	64.40±1.16	30	-	-	9	21	-	-	-	-	Bronco (P_1)
31.47	46.00±1.16	30	-	-	-	-	-	-	23	7	Giza-6 (P_2)
50.91	58.73±1.16	30	-	-	-	10	10	10	-	-	F_1
85.20	57.32±0.58	120	1	4	14	13	26	46	12	4	F_2
69.54	54.82±0.82	60	-	-	-	-	22	38	-	-	Bc_1 (F_1X P_1)
81.25	52.50±0.82	60	-	-	-	-	-	40	20	-	Bc_2 (F_1X P_2)
	8.95 13.56										L.S.D. 0.05 0.01

Number of major genes controlling earliness of flowering ranged from 1 to 4 gene pairs (Table, 2).

Total green pod yield per plant

The results presented in Table, 5 indicate that the parental cultivar Oxyra had the highest total green pod yield per plant (87.00 g.) followed, in descending order, by Paulista (69.84 g.), Bronco (65.25 g.), Giza-6 (56.00 g.), Samantha (39.65 g.) and Primera (36.65 g.). These results indicated that cultivar Oxyra can be a source for genes controlling high total green pod yield per plant. Similar findings were obtained by Melo *et al.* (1997) who mentioned that the parents differed in flowering period and grain yield under low temperature conditions at the adult phase.

The total green pod yield per plant of the F_1 plants of the cross Oxyra X Giza-6 (83.48 g.) was significantly higher than those of the other crosses under study. The potence ratio of gene set (P) calculated in all crosses under study indicated partial dominance for high total green pod yield/plant over low total yield/plant (Table, 2). The frequency distribution for total green pod yield/plant in the F_2, Bc_1 and Bc_2 populations of all crosses under this study indicate quantitative inheritance pattern for this character (Table, 5). This has been also observed by Badr (2003) who working on tomato and found that the inheritance of total yield/plant was in quantitative pattern.

The broad sense heritability estimates for total green pod yield/plant were 66.51%, 65.68%, 58.67% and 66.95% in the crosses Paulista × Primera, Paulista × Samantha, Oxyra × Giza-6 and Bronco × Giza-6, respectively (Table, 2). On the other hand, the narrow sense heritability estimates ranged from 24.90% to 40.27%. These results indicate that the effects of environment and non-additive type of gene actions had a great influence on the variation observed for this character. Based on these results, selection for high total green pod yield/plant in the segregating generations should be performed in replicated experiments, on family means basis.

The number of effective gene pairs controlling total green pod yield per plant ranged from 1 to 5 gene pairs (Table, 2). This has been also observed in tomato by Badr (2003) who mentioned that the minimum number of effective gene pairs controlling total yield/plant under low temperature conditions were 1 to 4 gene pairs.

Leaves chemical composition

The results presented in Table, 6 show that there were highly significant differences between P_1, P_2, F_1, F_2, Bc_1 and Bc_2 populations of the crosses Paulista × Samantha and Oxyra × Giza-6 in photosynthetic pigments (chlorophyll a and b as well as total carotenoides) and sugars content (reducing, non-reducing and total). The parental cultivar Oxyra had the highest photosynthetic pigments content, *i.e.* chlorophyll a, b and total carotenoides (54.45, 43.16 and 100.41 mg/100 g.f.w., respectively, and sugars, *i.e.* reducing, non-reducing and total (6.64, 15.24 and 21.88 mg/100g f.w., respectively), followed by cv. Paulista where the photosynthetic pigments were 44.47, 42.95 and 62.53 mg/100g f.w. for chlorophyll a and b and total carotenoides as well as sugars values which were 6.76, 12.31 and 19.07 mg/100g f.w. for reducing, non-reducing and total, respectively. On the other hand, leaves of Giza-6 cultivar was contained lower amounts of photosynthetic pigments and sugars. These results are in accordance with those reported by Siebeneichler *et al.* (2000) who showed that the non-reducing sugar levels had a higher *increase* in cv. Vermelho, an evidence of its greater cold tolerance, than other cultivar. The F_1values estimates were intermediate between two parents in each cross for photosynthetic pigments and sugars content (Table, 6). Moreover, Bc_1 values were higher than Bc_2 values in each cross for all chemical composition characters mentioned above. In this regard, Narikawa and Muira (1974) showed that the reduction of photosynthetic efficiency by low temperature was due to a reduction in leaf chlorophyll content. Wu (1978) showed that the area, dry weight and chlorophyll concentration of leaves of 15 cultivars grown at low temperature in the field were lower than in control plants grown at normal temperature in the greenhouse. In addition, Badr (2003) on tomato, mentioned that highly significant positive correlations between foliage cold tolerance and chemical composition of plant foliage, *i.e.* chlorophyll a and b and total carotenoides as well as reducing, non-reducing and total sugars were detected.

Table (5): Frequency distribution for total green pod yield per plant in different populations for some snap bean crosses.

Variance	Mean±SE	Total No of plants	Upper class limits (g)										Populations
			110	100	90	80	70	60	50	40	30	20	
263.74	69.84±2.30	30	-	-	-	13	17	-	-	-	-	-	Paulista (P_1)
109.20	36.65±2.30	30	-	-	-	-	-	-	12	18	-	-	Primera (P_2)
109.20	62.90±2.30	30	-	-	-	-	14	16	-	-	-	-	F_1
479.83	56.00±1.15	120	-	2	1	4	9	60	24	17	3	-	F_2
391.82	58.84±1.62	60	-	-	-	-	26	34	-	-	-	-	Bc_1 (F_1X P_1)
378.32	49.63±1.62	60	-	-	-	-	-	22	18	20	-	-	Bc_2 (F_1X P_2)
	17.78 26.93												L.S.D. 0.05 0.01
63.74	69.84±3.96	30	-	-	-	13	17	-	-	-	-	-	Paulista (P_1)
64.32	39.65±3.96	30	-	-	-	-	-	-	14	16	-	-	Samantha (P_2)
567.87	66.21±3.96	30	-	-	-	15	15	-	-	-	-	-	F_1
676.00	59.08±1.98	120	4	5	3	10	12	13	33	23	12	5	F_2
442.74	68.88±2.80	60	-	-	-	19	16	25	-	-	-	-	Bc_1 (F_1X P_1)
637.06	61,25±2.80	60	-	-	-	-	36	24	-	-	-	-	Bc_2 (F_1X P_2)
	29.65 44.92												L.S.D. 0.05 0.01
77.50	87.00±3.66	30	-	12	18	-	-	-	-	-	-	-	Oxyra (P_1)
62.57	56.00±3.66	30	-	-	-	-	-	22	8	-	-	-	Giza-6 (P_2)
457.90	83.48±3.66	30	-	-	19	11	-	-	-	-	-	-	F_1
482.24	69.55±1.83	120	2	2	8	9	27	21	16	16	11	8	F_2
350.68	70.74±2.58	60	-	-	-	30	13	17	-	-	-	-	Bc_1 (F_1X P_1)
489.68	65.09±2.58	60	-	-	-	-	30	14	16	-	-	-	Bc_2 (F_1X P_2)
	21.02 31.85												L.S.D. 0.05 0.01
196.56	65.25±3.15	30	-	-	-	6	24	-	-	-	-	-	Bronco (P_1)
112.57	56.00±3.15	30	-	-	-	-	-	22	8	-	-	-	Giza-6 (P_2)
141.61	64.90±3.15	30	-	-	-	-	20	10	-	-	-	-	F_1
454.54	59.53±1,57	120	2	3	5	14	18	21	20	17	10	10	F_2
377.52	59.20±2.23	60	-	-	-	-	28	15	17	-	-	-	Bc_1 (F_1X P_1)
418.37	54.25±2.23	60	-	-	-	-	-	19	23	18	-	-	Bc_2 (F_1X P_2)
	8.37 12.68												L.S.D. 0.05 0.01

Simple correlation

Cold tolerance was positively correlated with each of number of days from sowing date to the first flower bud anthesis, number of branches/plant, number of pods/plant, fruit set percentage and total green pod yield/plant in the F_2 population of all crosses under study, and with each of reducing, non-reducing and total sugars, chlorophyll a, b and total carotenoides in the F_2 population of the crosses Paulista × Sàmantha and Oxyra × Giza-6 (Table, 7). Based on these results, it can be used the above mentioned characters for selecting to cold tolerance in snap bean plants. Positive correlation was reported by Badr (2003) on tomato, who showed that there were highly significant positive correlation between foliage cold tolerance and chemical composition of plant foliage, *i.e.*, chlorophyll a and b and total carotenoides as well as reducing, non-reducing and total sugars.

Table (6): Leaf chemical composition of parents, F_1, F_2, $Bc_1$and Bc_2 populations derived from the crosses Paulista × Samantha and Oxyra × Giza-6 as affected by low temperature (mg/100g.f.w.)

Sugars (mg/100g. fresh weight)			Photosynthetic pigments (mg/100g. fresh weight)			Characters / Populations
Total	Non - reducing	Reducing	Carotenoides	Chlorophyll b	Chlorophyll a	
19.07	12.31	6.76	62.53	42.95	44.47	Paulista (P_1
9.33	4.01	5.32	36.34	15.86	17.49	Samantha (P_2)
14.65	9.90	4.75	67.57	34.63	38.93	F_1
19.60	12.54	7.06	55.47	38.22	38.50	F_2
18.88	12.14	6.74	71.58	38.47	39.32	Bc_1 (F_1× P_1)
13.64	8.52	5.12	51.91	31.94	33.08	Bc_2 (F_1× P_2)
6.85	5.94	1.20	19.29	14.15	14.19	L.S.D. 0.0
10.37	9.00	1.82	29.23	21.44	21.49	0.0
21.88	15.24	6.64	100.41	43.16	54.45	Oxyra (P_1)
10.59	6.19	4.40	29.33	13.38	12.99	Giza-6 (P_2)
16.61	13.06	3.55	54.21	30.05	32.40	F_1
18.02	13.25	4.77	64.47	34.32	38.25	F_2
22.03	16.70	5.33	92.64	39.71	48.23	Bc_1 (F_1× P_1)
13.94	9.36	4.58	45.53	22.71	22.00	Bc_2 (F_1× P_2)
9.08	7.85	1.45	28.66	13.35	17.12	L.S.D. 0.0
13.76	11.89	2.19	43.41	20.23	25.94	0.01

Significant positive correlations were observed between fruit set percentage and total green pod yield/plant in the F_2 population of all crosses under study, and with each of reducing, non-reducing and total sugars, chlorophyll a and b as well as total carotenoides in the crosses Paulista × Samantha and Oxyra × Giza-6. On the other hand, highly significant negative correlation was detected between fruit set percentage and pod diameter in all crosses.

Total green pod yield/plant was positively correlated with each of cold tolerance, number of branches/plant, number of pods/plant and fruit set percentage in all crosses under study, and with chemical composition of plant leaves, *i.e.* reducing, non-reducing and total sugars as well as chlorophyll a, b and total carotenoides in the crosses Paulista × Samantha and Oxyra × Giza-6. On the other hand, significant negative correlation was detected between total green pod yield/plant and number of days from sowing date to the first flower bud anthesis in the F_2 populations of all crosses. These results are in accordance with those reported by Wu (1978) who found that seed yield was positively correlated with the chlorophyll concentration of leaves. Whereas, Ferrao *et al.* (2002) showed that grain yield and number of pods per plot were less important characteristics influencing genetic diversity. However, as they showed low genotypic correlation with other characteristics.

Table (7): Correlation coefficient values (r) of different characters for some snap bean crosses.

Crosses	Characters	Earliness	No. of branches	No. of pods/plant	Fruit set percentage	Pod length	Pod diameter	Total yield/plant	Reducing sugar	Non-reducing sugar	Total sugar	Chlorophyll a	Chlorophyll b	Total carotenoids
Paulista × Primera	**Cold tolerance**	** 0.397	** 0.550	* 0.233	** 0.280	** 0.404	-0.050	** 0.522						
	Earliness		-0.088	** -0.262	** 0.284	** 0.364	** -0.263	** -0.475						
	No. of branches			** 0.534	* 0.188	0.122	0.067	** 0.646						
	No. of pods/plant				** 0.488	-0.112	-0.106	** 0.904						
	Fruit set percentage					0.075	** -0.298	** 0.533						
	Pod length						0.108	0.079						
	Pod diameter							-0.033						
Paulista × Samantha	**Cold tolerance**	** 0.332	** 0.846	** 0.812	** 0.746	-0.006	0.067	** 0.691	** 0.940	** 0.980	** 0.986	** 0.982	** 0.930	** 0.951
	Earliness		* -0.232	** -0.559	-0.141	-0.142	* -0.180	** -0.577	** -0.396	** -0.319	** -0.332	** -0.334	** -0.356	** -0.322
	No. of branches			** 0.829	** 0.720	-0.071	0.086	** 0.756	** 0.738	** 0.808	** 0.809	** 0.788	** 0.749	** 0.760
	No. of pods/plant				** 0.735	0.079	** 0.237	** 0.953	** 0.781	** 0.772	** 0.782	** 0.773	** 0.727	** 0.758
	Fruit set percentage					-0.030	** -0.420	** 0.649	** 0.717	** 0.700	** 0.710	** 0.709	** 0.651	** 0.673
	Pod length						** 0.533	0.069	0.026	0.022	0.022	0.036	0.030	0.042
	Pod diameter							0.169	0.085	0.050	0.055	0.057	0.062	0.084
	Total yield/plant								** 0.696	** 0.648	** 0.661	** 0.654	** 0.628	** 0.643
	Reducing sugar									** 0.899	** 0.921	** 0.933	** 0.917	** 0.901
	Non-reducing sugar										** 0.999	** 0.991	** 0.910	** 0.975
	Total sugar											** 0.995	** 0.921	** 0.977
	Chlorophyll a												** 0.929	** 0.971
	Chlorophyll b													** 0.866

Table (7): Continued

Crosses	Characters	Earliness	No. of branches	No. of pods/plant	Fruit set percentage	Pod length	Pod diameter	Total yield/plant	Reducing sugar	Non-reducing sugar	Total sugar	Chlorophyll a	Chlorophyll b	Total carotenoids
Oxyra × Giza-6	Cold tolerance	0.289**	0.723**	0.764**	0.808**	-0.017	0.065	0.832**	0.960**	0.812**	0.909**	0.976**	0.921**	0.887**
	Earliness		-0.185*	-0.291**	0.006	-0.207*	-0.039	-0.272**	-0.147	-0.040	-0.129	-0.153	-0.138	-0.143
	No. of branches			0.639**	0.475**	0.096	0.080	0.757**	0.746**	0.700**	0.751**	0.720**	0.746**	0.618**
	No. of pods/plant				0.792**	0.078	-0.003	0.955**	0.792**	0.775**	0.817**	0.750**	0.772**	0.610**
	Fruit set percentage					0.026	-0.643**	0.722**	0.648**	0.604**	0.655**	0.605**	0.604**	0.498**
	Pod length						0.611**	0.109	-0.054	-0.007	-0.005	-0.019	-0.048	-0.004
	Pod diameter							0.023	-0.073	-0.017	-0.030	-0.052	-0.059	-0.063
	Total yield/plant								0.856**	0.832**	0.878**	0.821**	0.845**	0.875**
	Reducing sugar									0.860**	0.946**	0.965**	0.961**	0.851**
	Non-reducing sugar										0.948**	0.810**	0.870**	0.651**
	Total sugar											0.902**	0.940**	0.750**
	Chlorophyll a												0.932**	0.915**
	Chlorophyll b													0.771**
Bronco × Giza-6	Cold tolerance	0.272**	0.441**	0.299**	0.529**	0.095	-0.120	0.380**						
	Earliness		-0.306**	-0.236**	0.198**	-0.045	0.041	-0.387**						
	No. of branches			0.427**	0.261**	0.021	0.062	0.659**						
	No. of pods/plant				0.336**	-0.140	-0.032	0.483**						
	Fruit set percentage					0.064	-0.288**	0.633**						
	Pod length						0.228*	0.092						
	Pod diameter							-0.286**						

Compound correlation

In the crosses Paulista × Primera and Bronco × Giza-6, number of days from planting date to the first flower bud anthesis, number of branches/plant, number of pods/plant, fruit set percentage and total green pod yield/plant were found to have a significant combined effect on cold tolerance (Table, 8). The multiple correlation coefficient (R-Square) were 0.680 and 0.483 and the multiple-R were 0.824 and 0.695, respectively. These results indicate that 68.0% and 48.3% of the variation in cold tolerance can be attributed to variation in earliness, number of branches/plant, number of pods/plant, fruit set percentage and total green pod yield/plant. Based on this, the previously mentioned characters should be considered during selection under low temperature conditions to obtain plants with high productivity under such conditions.

Table (8): Multiple regression coefficients between cold tolerance and some characters in some snap bean crosses.

Significance	Multiple R	R-square	Involved indepent variables	Crosses
**	0.824	0.680	Earliness No. of branches/plant No. of pods/plant Fruit set percentage Total yield/plant	Paulista × Primera
**	0.991	0.982	Earliness No. of branches/plant No. of pods/plant Fruit set percentage Total yield/plant Total sugars Chlorophyll-a	Paulista × Samantha
**	0.979	0.958	Earliness No. of branches/plant No. of pods/plant Fruit set percentage Total yield/plant Total sugars Chlorophyll-a	Oxyra × Giza-6
**	0.695	0.483	Earliness No. of branches/plant No. of pods/plant Fruit set percentage Total yield/plant	Bronco × Giza-6

** Significant at 1% level of significance

In the crosses Paulista × Samantha and Oxyra× Giza-6, the combined effect of number of days from planting date to the first flower bud anthesis, number of branches/plant, number of pods/plant, fruit set percentage, total green pod yield/plant, total sugars and chlorophyll a was significantly correlated with cold tolerance. The multiple correlation coefficient were 0.991 and 0.979 and R-square were 0.982 and 0.958, respectively (Table, 8). These results indicated the importance of the previously mentioned characters when selecting for cold tolerance in the segregating generations under low temperature conditions.

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دراسات وراثية على تحمل البرودة في الفاصوليا

لطفي عبد الفتاح عبد الرحمن بدر
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تم إجراء التهجين بين أصناف الفاصوليا الخضراء وهى بوليستا واكزيرا وبرونكو (وهى أصناف تتحمل البرودة) وبريميرا وساماننا وجيزة-٦ (وهى أصناف حساسة للبرودة) وذلك لدراسة توريث وطبيعة تحمل البرودة وبعض الصفات المكونة لها. وجد ان صفات تحمل البرودة والتبكير في الإزهار ومحصول النبات الكلى من القرون الخضراء تورث كميا. وجد أن هناك سيادة جزئيه للمستوى العالي من تحمل البرودة والعدد الأكثر من الأيام اللازمة من تاريخ الزراعة حتى تفتح أول برعم زهري ومحصول النبات العالي من القرون الخضراء على المستوى المنخفض من هذه الصفات. قدر معامل التوريث بمعناه الواسع وكان يتراوح بين ٥٩و٤٧ % – ٤٧و٨٢ % ومن ٠٠و٤٧% -٤٦و٦٣ % ومن ٦٧و٥٨% – ٩٥و٦٠% – بينما معامل التوريث بمعناه الضيق تراوح بين ٤٤و٣٩% – ٠١و٥٨% ومن ٧٣و٩% – ٥٠و٣٨% ومن ٩٠و٢٤% -٢٧و٤٠% وذلك لصفات تحمل البرودة والتبكير في الإزهار ومحصول النبات الكلى من القرون الخضراء-وذلك بنفس الترتيب.اقل عدد من أزواج العوامل الوراثيه التي تتحكم في صفات تحمل البرودة والتبكير في الإزهار ومحصول النبات الكلى من القرون الخضراء تراوح بين ١-٤، ١-٤ ، ١-٥ زوج من العوامل الوراثيه – بنفس الترتيب السابق. وجد أن هناك اختلافات عالية المعنوية بين الآباء ونباتات الجيل الأول والجيل الثاني والتهجين الرجعى لنباتات الجيل الأول مع الأب الأول والتهجين الرجعى لنباتات الجيل الأول مع الأب الثاني وذلك في الهجن بوليستا x ساماننا واوكزيرا x جيزة -٦ وذلك في صفات صبغات التمثيل الضوئي (كلوروفيل ا و ب والكاروتينات الكلية) والمحتوى من السكريات (المختزلة والغير مختزله والكلية). وجد أن الصنف اوكزيرا الذي يتميز بتحمل درجات الحرارة المنخفضة كان يحتوى على أعلى كميه من صبغات التمثيل الضوئي والسكريات – بينما الصنف جيزة-٦ والذي يتميز بالحساسية لدرجات الحرارة المنخفضة كان يحتوى على اقل كميه. تحمل النباتات للبرودة كان مرتبط ارتباط موجب مع كل من عدد الأيام من تاريخ الزراعة حتى تفتح أول برعم زهري وعدد أفرع النبات وعدد قرون النبات والنسبة المئوية لعقد القرون ومحصول النبات الكلى من القرون الخضراء وذلك في نباتات الجيل الثاني في كل الهجن تحت الدراسة – وكانت ترتبط مع كل من السكريات المختزلة والغير مختزله والكلية وكلوروفيل ا و ب والكاروتينات الكلية وذلك في نباتات الجيل الثاني في الهجن بوليستا x ساماننا واوكزيرا x جيزة-٦.

وجد في الهجن بوليستا x بريميرا و برونكو x جيزة-٦ أن عدد الأيام من تاريخ الزراعة حتى تفتح أول برعم زهري وعدد أفرع النبات وعدد قرون النبات والنسبة المئوية لعقد القرون ومحصول النبات الكلى من القرون الخضراء وجد أن لها تأثير مشترك معنوي على تحمل النباتات للبرودة. أما في الهجن بوليستا x ساماننا واوكزيرا x جيزة-٦ وجد أن هناك تأثير مشترك لصفات عدد الأيام من تاريخ الزراعة حتى تفتح أول برعم زهري وعدد أفرع النبات وعدد قرون النبات والنسبة المئوية لعقد قرون النبات ومحصول النبات الكلى من القرون الخضراء و السكريات الكلية وكلوروفيل ا على تحمل النباتات للبرودة.