ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor, Vol. 42 (3): 1271-1292, (2004).

INHERITANCE AND NATURE OF DROUGHT TOLERANCE IN COMMON BEAN (*Phaseolus vulgaris*, L)

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ABSTRACT

Crosses were made between the cultivars Tema and Oxyra, which are tolerant to drought, as well as cv. Giza-6, Emy and Sigme, which are susceptible to drought, to study the inheritance and nature of drought tolerance and some related characteristics which may have direct or indirect effects on drought tolerance. There were highly significant differences between the previously mentioned parental cultivars concerning root characters, i.e. root length, fresh and dry weight under normal irrigation and drought conditions in pot experiment. There were highly significant increase percentages in root length in P_1, P_2 and F_1 for each cross under water stress conditions compared with this percentage under normal irrigation. On the other hand, there were highly significant decrease percentages in root fresh and dry weight under water conditions. There were slight partial dominance for high root length and fresh and dry weight.

Drought tolerance, leaf water loss ratio, total yield/plant and leaf proline content were inherited quantitatively. Partial dominance was detected for high level of drought tolerance, total yield/plant and leaf proline content over low levels. Whereas, partial dominance were found for low level of leaf water loss ratio over high leaf water loss ratio. Broad sense heritability for drought tolerance, leaf water loss ratio, and total dry seed yield/plant and leaf proline content ranged from intermediate to high. Meanwhile, narrow sense heritability for the same characters ranged from low to above intermediate. Number of major genes controlling drought tolerance, leaf water loss ratio, total dry seed yield/plant and leaf proline content ranged from 1 to 4, 1 to 3, 1 to 4 and 3 gene pairs, respectively.

Drought tolerance was positively correlated with each of number of branches/plant, number of pods/plant, fruit set percentage, as well as with number of seeds/pod, 100 seed weight and total dry seed yield/plant. On the other hand, drought tolerance was negatively correlated with each of number of days from sowing date to the first flower bud anthesis, leaf water loss ratio and leaf area Free proline content of plant leaves was positively correlated with each of drought tolerance, number of branches/plant, number of seeds/pod, 100 seed weight and total dry seed yield/plant. On the contrary, there was highly significant negative correlation between free proline content of leaves and each of number of days passed from sowing date to the first flower bud anthesis, leaf water loss ratio and leaf area. There were highly significant regression between drought tolerance and each of number of days required from sowing date to the first flower bud anthesis, number of branches/plant, fruit set percentage, 100 seed weight, total dry seed yield/plant, leaf water loss ratio and leaf area.

INTRODUCTION

Environmental stresses manifest their effects in many forms, yet the most prevalent impact of stresses is their common effect on plant water status. The availability of water to perform its biological functions as solvent and transport medium, as electron donor in the Hill reaction of photosynthesis, and as evaporative coolant, is often impaired by environmental stress conditions. Although all plant species express sensitivity and response to the decrease in water potential caused by drought, low temperature or high salinity, they have different levels of capabilities for stress perception, signaling and response Bohnert *et al.* (1995).

Availability and use of high-yielding drought-tolerant of common bean (*Phaseolus vulgaris*) cultivars would reduce dependence on irrigation water and hence production costs, stabilize yield in drought-prone environments, and potentially increase profit margins for growers. Among various selection criteria, seed yield has been found to be the most effective one to improve drought tolerance in common bean. Many investigators working on drought tolerance in common bean plants, i.e. Pimentel and Cruz (2000), Moreno *et al.*(2000), Boutraa and Sanders (2001), Teran and Singh(2002) and Mejia *et al.*(2003) found that there were highly differences among common bean genotypes with regard to drought resistance. Moreover, EL-Tohamy *et al.* (1999a), Perez *et al.* (1999), Pimentel and Cruz (2000), Aguirre *et al.*(2002), Kohashi *et al.*(2002) and Mayek *et al.*(2002a) mentioned that there were genetic differences between common bean cultivars concerning leaf water loss ratio. In this respect, Thomas (1983) mentioned that seed weight was controlled by a large number of genes, with both additive and dominance effects. Ramirez and Kelly (1998) showed that the heritability estimates for seed yield were higher.

EL-Tohamy *et al.* (1999b) indicated a high linear relationship between yield and water stress levels. Mayek *et al.* (2002b) illustrated that drought stress decreased transpiration rate and leaf area. Also, Teran and Singh (2002) mentioned that 100-seed weight was slightly reduced in drought- stressed versus non-stressed environments. Solanki *et al.* (2003) found that days to flowering and maturity had significant positive correlation with each other while these traits had significant negative correlation with grain yield. In addition, they found that number of Pods/plant, pod length and seeds/pod had significant positive correlation with yield. Maiti *et al.* (2000) showed that in all stress situations there is an increase in the accumulation of free proline in bean plants. Moreover, Mejia *et al.* (2003) showed that proline increased under drought conditions in common bean plants.

The objectives of the present work were to study the inheritance and nature of drought tolerance in common bean plants and to obtain the genetic parameters required to design a successful breeding programs for high tolerance to water-stress in common bean plants. Introduction of tolerant varieties may be useful in cultivation in new area.

MATERIAL AND METHODS

This research was conducted at the Agricultural Experimental Station of the Horticulture Department, Faculty of Agriculture. Moshtohor, Zagazig University, Benha Branch, during four summer seasons of 2001 to 2004.

A randomized complete block design with four replicates was adopted in this experiment to evaluate 30 cultivars of common bean to drought tolerance in 2001- summer season. Seeds of this cultivars were obtained from the Agricultural Technology Utilization and Transfer Project, Agricultural research center, Dokki, Egypt. The cultivars Tema and Oxyra, which were found to be tolerant to drought and the cultivars Giza-6, Emy and Sigme, which expressed susceptibility to drought, were selected to study the inheritance and nature of drought tolerance in common bean plants.

On March 22nd, 2002, seeds of all selected cultivars were sown in the field. The following crosses were made between the parental genotypes: (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme). Seeds of the F_1's were harvested separately and kept for the next season.

On March 17th, 2003, hybrid seeds of each cross and seeds of the parental genotypes were planted in the field. Crosses between the parental genotypes were repeated and F_1 plants were selfed to obtain F_2 seeds. Backcrosses populations were obtained by crossing each F_1 hybrid with its respective parents.

I. Pots experiment:

On March 16, 2004, seeds of the different parental cultivars in addition to their F1 seeds were planted separately in pots, 30 cm in diameter, containing sandy clay soil 1:1(*v:v*). Five seeds were planted in each pot. Ten pots were planted for each population. When the plants reached the two true leaves stage, the pots were divided into two groups; each group consisted of five pots for each population. The first group was irrigated regularly, while the second group was not irrigated. Then, the pots were arranged according to the randomized complete block design with five replicates. After four weeks, when the non-tolerant plants started to wilt and die, all pots were taken and the roots of the plants were washed with running water and left to dry. Then root lengths (cm), root fresh and dry weight (g) of individual plants were recorded. Representative soil samples were taken from each pot, directly after taking the sample plants for evaluation. Moisture of soil in the pot was determined as field capacity percentage.

II. Field experiment

On March 16th, 2004, seeds of the parental genotypes, F_1, F_2, Bc_1 and Bc_2 populations of the different crosses were planted in the field for the purpose of evaluating the individual plants for resistance to drought. The experimental design used in conducting this study was randomized complete block design with three replicates. Each replicate contained one ridge for each of the parental genotypes and their F_1 plants and four ridges for the F_2 plants, meanwhile, two ridges for each backcross population. Ten seeds were planted on one side of ridges 60 cm. width, with one seed per hill 30 cm apart. Plants of all populations were irrigated two times after sowing irrigation; the first irrigation was after 10 days from sowing date while the second irrigation was performed at the full blooming stage. All other agriculture practices, *i.e.* fertilization, weed control, *etc.*, were followed as commonly used in the district.

Data recorded:

The following measurements for drought tolerance and its components were recorded on the individual plants of the different populations under water stress conditions in the field experiment:

Drought resistance (the percentage for healthy leaves compared with total leaves/plant), earliness (number of days from sowing time to the first flower bud anthesis), number of branches/plant, number of pod/plant, fruit set percentage, number of seeds/pod, 100 seed weight (g), total dry seed yield/plant, leaf water loss ratio (by weighting the fifth fully expanded leaf ,from the top of the plant, in the laboratory every two hours and calculate the ratio of water loss using the method described by Pimentel and Cruz, (2000) and leaf area cm^2 (It was determined by the leaf area and weight relationship using leaf disks obtained by a cork borer)using the method described by Wallace and Munger(1965).

In dry plant leaves, free proline was estimated colorimetrically using the method described by Bates *et al.* (1973). Samples were taken from the third and fourth fully expanded leaf (from the top of the plant).

Statistical Genetic analysis:

Estimates of the mean and its standard error and total variance of the different quantitative characteristics in all populations were calculated using the methods described by Briggs and Knowles (1977).

Type of inheritance was determined from the frequency distribution of the different quantitative characteristics in the parental genotypes, F_1, F_2, Bc_1 and Bc_2 of each cross based on the method described by Briggs and Knowles (1977).

Mid and better parent heterosis percentages were calculated using the equation described by Bhatt (1971).

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

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

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

The minimum number of the gene pairs differentiating the two parental genotypes was estimated using the method which was described by Castle and Wright (1921).

Coefficients of correlation between the different studied quantitative characters and resistance measurements were calculated and multiple regression analysis was performed using the method described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

I. Pots experiment

Highly significant differences were observed between the parental cultivars Tema, Giza-6, Emy, Oxyra and Sigme concerning root characters Table (1). Oxyra gave the highest values for root characters, i.e. root length, fresh and dry weight under normal irrigation, i.e. 16.07 cm, 1.133 g and 0.210 g, respectively and under drought conditions, i.e. 19.27 cm, 0.628 g and 0.195 g, respectively. However, the other parental genotypes Tema, Sigme, Giza-6 and Emy gave 14.40 cm, 0.764 g and 0.200 g; 11.27 cm, 0.682 g and 0.155 g; 10.17 cm, 0.593 g and 0.089 g; and 8.67 cm, 0.458 g and 0.076 g, respectively under normal irrigation,while under drought conditions, the values were 15.57 cm, 0.593 g and 0.183 g; 15.10 cm, 0.405 g and 0.090 g; 14.60 cm, 0.345 g and 0.070 g, and 12.30 cm, 0.237 g and 0.054 g, respectively. These results indicated that the parental cultivars Oxyra and Tema were the most tolerant genotypes to water stress as explained by its relatively high increase percentage of root length under water stress conditions Table(1). These results were supported by the results of Sponchiado *et al.* (1989) and Hadidi (1999) who found highly significant differences between common bean cultivars with regard to shoot and root fresh and dry weight, root length and number of secondary roots, under water stress conditions. The F_1 values were intermediate between the two parents for each cross under study.

Under water stress, there was highly significant increase in root length percentage in P_1, P_2 and F_1 for each cross under water stress compared with root length under normal irrigation conditions (Table- 1).

The cultivar Oxyra gave the highest increase percentage in root length (44.80%) followed by cv. Tema (35.90%), cv. Giza-6 (14.06%), cv. Sigme (7.36%) and cv. Emy (7.27%). The increase in percentage of F_1 root length values was intermediate between the two parents for each cross under this study. On the other hand, there were highly significant decrease percentage in the root fresh and dry weight between P_1, P_2 and F_1 populations for each cross under drought conditions in pot experiment compared with normal irrigation conditions. The cultivar Emy gave the highest decrease in root fresh weight, followed by cv. Oxyra, cv. Giza-6, cv. Sigme, and cv. Tema. Meanwhile, the cultivar Sigme gave the highest decrease in root dry weight, followed by cv. Emy, cv. Giza-6, cv. Tema and cv. Oxyra, respectively. The decrease in percentage of F_1 root fresh and dry weight values was intermediate between the two parents of each cross in all cross under study, Table: (1). In this respect, Hadidi (1999) mentioned that shoot and root fresh and dry weights and lengths and number of secondary roots, had significantly decreased with increasing of water stress.

Table (1): Mean of some root characteristics and percentages of increase or decrease in these characteristics for the plants of different common bean parents and their F_1 hybrids, evaluated under normal irrigation and water stress conditions in pots experiment.

Cross	Popula.	Normal			Stress			Root length increase (%)	Decrease (%)	
		Root length (cm)	Root F. W. (g)	Root D.W. (g)	Root length (cm)	Root F.W. (g)	Root D.W. (g)		Root F.W.	Root D.W.
Tema	P1	14.40	0.764	0.200	19.57	0.593	0.183	35.90	22.38	9.29
X	P2	10.17	0.593	0.089	11.60	0.345	0.070	14.06	41.82	21.35
Giza-6	F1	13.10	0.684	0.159	16.20	0.499	0.139	23.66	27.05	12.58
L.S.D.	0.05	1.37	0.12	0.09	0.09	0.14	0.06	14.59	12.50	12.32
	0.01	2.00	0.18	0.13	0.15	0.20	0.09	21.08	18.07	17.81
Tema	P1	14.4o	0.764	0.200	19.57	0.593	0.183	35.90	22.38	9.29
X	P2	8.67	0.458	0.076	9.30	0.237	0.054	7.27	48.25	28.95
Emy	F1	13.00	0.665	0.169	15.07	0.418	0.140	15.92	37.14	17.16
L.S.D.	0.05	1.37	0.17	0.12	1.47	0.06	0.06	17.36	17.45	13.36
	0.01	2.00	0.25	0.18	2.15	0.09	0.09	25.09	25.22	19.31
Oxyra	P1	16.07	1.133	0.210	23.27	0.628	0.195	44.80	44.57	7.14
X	P2	10.17	0.593	0.089	11.60	0.345	0.070	14.06	41.82	21.35
Giza-6	F1	14.67	0.896	0.150	17.66	0.499	0.135	20.38	44.31	10.00
L.S.D.	0.05	1.10	0.28	0.06	2.30	0.18	0.12	13.93	6.12	9.67
	0.01	1.60	0.41	0.09	3.34	0.26	0.17	20.13	8.84	13.97
Oxyra	P1	16.07	1.133	0.210	23.27	0.628	0.195	44.80	44.57	7.14
X	P2	11.27	0.682	0.155	12.10	0.405	0.090	7.36	40.62	41.94
Sigme	F1	14.67	0.930	0.187	17.83	0.550	0.163	21.54	40.86	12.83
L.S.D.	0.05	1.63	0.40	0.08	2.70	0.15	0.06	9.85	6.02	14.16
	0.01	2.36	0.58	0.12	3.95	0.21	0.09	14.23	8.70	20.46
Field capacity %		79.42			22.40					

With respect to potence ratio, data in Table (2) obviously show that the potence ratio (p) calculated for root length, fresh and dry weight under drought conditions in pot experiment showed slightly partial dominance for high parent values in all crosses under this study. Meanwhile, the potence ratio calculated for root length increases and root fresh and dry weight decreases under the same conditions showed slight partial dominance for low parent values in all crosses under this study except that for the decrease percentages of root fresh weight in the crosses (Tema x Emy) and (Oxyra x Giza-6) where the potance ratio showed slight partial dominance for high parent values.

Concerning better- parent heterosis, the same data in Table (2) showed that there were negative better-parent heterosis vigor for root length, fresh and dry weight as well as the percentage of root length increases whereas, there were positive better-parent heterosis for the percentages of root fresh and dry weight decreases in all crosses under study. The highest value estimated for better-parent heterosis for root length (-17.22%) was obtained from the cross (Tema X Giza-6). Whereas, the highest values of better-parent heterosis for root fresh and dry weight (-12.42% and -16.41%, respectively) were obtained from the cross (Oxyra X Sigme).

On the other hand, the lowest values for root length and dry weight (-24.11% and -30.77%, respectively) were obtained from the plants of the cross (Oxyra X Giza-6), whereas, the lowest value for root fresh weight (-29.51%) was obtained from the plants of the cross (Tema X Emy) in Table (2). Also, the highest value estimated of better-parent heterosis for the percentages of root length increases (-34.09%) was obtained from the cross (Tema x Giza-6). Meanwhile, the highest values of better-parent heterosis for the percentages of root fresh and dry weight decreases (65.95% and 84.71%, respectively) were obtained from the cross (Tema x Emy).

Table (2): Potance ratio and Better parent Heterosis of some root characteristics for the plants of different common bean crosses evaluated under water stress condition in pots experiment

Cross	Parameter	Root characters					
		Root length (cm)	Root F.W. (g)	Root D.W. (g)	Root length Increase %	Root F.W. Decrease %	Root D.W. Decrease %
Tema X Giza-6	P. ratio	0.16	0.24	0.22	-0.12	-0.52	-0.45
	Heterosis% (BP)	-17.22	-15.85	-24.05	-34.09	20.87	35.41
Team X Emy	P. ratio	0.12	0.02	0.33	-0.40	0.14	-0.20
	Heterosis% (BP)	-22.99	-29.51	-23.50	-55.65	65..95	84.71
Oxyra X Giza-6	P. ratio	0.04	0.09	0.05	-0.59	0.81	-0.60
	Heterosis% (BP)	-24.11	-20.54	-30.77	-54.51	5.95	40.06
Oxyra X Sigme	P. ratio	0.03	0.27	0.40	-0.24	-0.88	-0.67
	Heterosis% (BP)	-23.38	-12.42	-16.41	-51.92	0.59	79.69

II. Field experiment

1. Drought tolerance:

Significant differences were observed between common bean cultivars, Tema, Oxyra, Giza-6, Emy, and Sigme in their tolerance to drought, Table 3. The cultivar Oxyra had the highest drought tolerance measured by percentage of healthy leaves under stress conditions (88.70%), while the plants of the cultivar Emy had the lowest value (29.60%), this indicates that the cultivar Oxyra can be considered as a good source for genes controlling high tolerance to drought. With regard to varietal differences, many investigators, i.e. Moreno *et al.* (2000), Pimentel and Cruz (2000), Boutraa and Sanders (2001), Molina *et al.* (2001) Teran and Singh (2002) and Mejia *et al.* (2003) observed differences among common bean genotypes with regard to level of drought resistance.

The frequency distribution for drought tolerance in the F_2, Bc_1 and Bc_2 populations of the crosses (Tema X Giza-6), (Tema X Emy), (Ozyra X Giza-6) and (Oxyra X Sigme), Table(3), indicated that this character was inherited quantitatively.

The results obtained from the crosses between the involved parents showed relative large differences between their degree of drought tolerance, i.e., (Tema X Emy), (Tema X Giza-6), (Oxyra X Giza-6) and (Oxyra X Sigme). This may gave clear and dependable information about the inheritance of drought tolerance. The average drought tolerance for the plants of F_1 was much higher than that of the low tolerance-parental cultivars in all crosses under study. These results may indicate the possibility of improving the drought tolerance of the local common bean cultivars by using Oxyra or Tema cultivars as source of genes controlling the high drought tolerance of common bean plants. The potence ratio values were 0.66, 0.81, 0.34 and 0.20 in the crosses (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme) respectively, which may indicate that the high level of drought tolerance was partially dominant over the low level of drought tolerance (Table, 4).

Positive values for mid-parent (MP) heterosis % were estimated for drought tolerance, i.e. 36.47%, 28.74%, 16.66% and 4.34% while the values of the better-parent (BP) heterosis were negative, i.e. -6.07%, -10.47%, -21.45% and -15.41% for the crosses (Tema X Emy), (Tema X Giza-6), (Oxyra X Giza-6) and (Oxyra X Sigme), respectively (Table, 4). The heterosis over the mid-parent indicated the possibility of improving drought tolerance.

The broad sense heritability estimates for drought tolerance ranged from intermediate (47.86%) to high (93.24%) in the different crosses (Table, 4).

Meanwhile, the narrow sense heritability values ranged from 19.34% to 50.26%. These results indicate the possibility of achieving success in selecting for high level of drought tolerance in the segregating generations of the common bean crosses.

The minimum number of effective genes controlling drought tolerance of the common bean plants ranged from 1 to 4 gene pairs (Table, 4).

Table (3): Frequency distributions for plant reaction to drought tolerance in parents, F_1, F_2, Bc_1 and Bc_2 segregations derived from some Common bean crosses.

Cross	Population	Upper class limit (% of healthy leaves/plant under water stress)										Total No.of plants	Mean±SE	Variance
		10	20	30	40	50	60	70	80	90	100			
Tema X iza-	P_1	-	-	-	-	-	-	-	13	6	11	30	78.60 2.49	186.62
	$Bc_1(F_1XP_1)$	-	-	-	2	15	7	7	8	11	-	60	57.00±2.76	457.96
	F_1	-	-	-	-	-	-	12	18	-	-	30	70.37±2.69	217.91
	F_2	4	5	7	9	14	16	22	23	17	3	120	56.21±2.25	608.95
	$Bc_2(F_1XP_2)$	-	9	8	8	8	7	8	12	-	-	60	52.00±2.99	536.85
	P_2	-	-	15	15	-	-	-	-	-	-	30	30.73±2.56	197.12
L.S.D.	0.05												29.63	
	0.01												44.88	
Tema X Emy	P_1	-	-	-	-	-	-	-	13	6	11	30	78.60±2.49	186.62
	$Bc_1(F_1XP_1)$	-	-	-	21	6	8	13	12	-	-	60	53.68±2.92	512.57
	F_1	-	-	-	-	-	-	7	23	-	-	30	73.83±1.75	91.97
	F_2	4	6	6	6	6	19	29	24	14	6	120	58.38±2.04	499.08
	$Bc_2(F_1XP_2)$	-	-	-	14	15	15	16	-	-	-	60	49.00±2.55	389.06
	P_2	-	8	8	14	-	-	-	-	-	-	30	29.60±2.68	214.92
L.S.D.	0.05												26.96	
	0.01												40.84	
Oxyra X iza-	P_1	-	-	-	-	-	-	-	-	18	12	30	88.70±0.58	9.99
	$Bc_1(F_1XP_1)$	-	-	-	-	-	-	5	28	27	-	60	78.12±2.05	251.98
	F_1	-	-	-	-	-	-	18	12	-	-	30	69.67±2.92	256.75
	F_2	-	3	10	12	16	10	21	19	13	10	120	56.22±1.74	363.11
	$Bc_2(F_1XP_2)$	-	-	-	20	12	9	12	7	-	-	60	57.17±2.25	304.50
	P_2	-	-	15	15	-	-	-	-	-	-	30	30.73±2.56	197.12
L.S.D.	0.05												24.64	
	0.01												37.33	
Oxyra X Sigme	P_1	-	-	-	-	-	-	-	-	18	12	30	88.70±0.58	9.99
	$Bc_1(F_1XP_1)$	-	-	-	-	-	-	25	12	15	8	60	73.57±2.46	362.82
	F_1	-	-	-	-	-	-	-	22	8	-	30	75.03±1.14	38.94
	F_2	-	-	-	2	11	18	25	33	18	13	120	64.60±1.95	456.68
	$Bc_2(F_1XP_2)$	-	-	-	-	7	29	15	9	-	-	60	58.75±2.31	321.00
	P_2	-	-	-	-	10	20	-	-	-	-	30	54.53±1.21	43.69
L.S.D.	0.05												21.32	
	0.01												32.30	

Table (4): Potance ratio, mid and better parent heterosis, broad and narrow sense heritability and minimum number of effective gene pairs estimates for the studied characteristics in some common bean crosses.

Cross	Character parameter	Drought tolerance	Leaf water loss ratio	Total yield/plant	Leaf proline content
Tema X Giza-6	P. ratio	0.66	-0.46	0.01	K
	Heterosis% (MP)	28.74	-10.66	0.26	K
	Heterosis%(BP)	-10.47	16.46	27.66	K
	BSH%	67.07	84.66	43.37	K
	NSH%	36.64	51.02	36.54	K
	No. of genes	1.0	3.0	1.0	K
Tema X Emy	P. ratio	0.81	-0.31	0.37	K
	Heterosis% (MP)	36.47	-5.60	15.14	K
	Heterosis%(BP)	-6.07	15.40	-18.01	K
	BSH%	47.86	91.45	71.45	K
	NSH%	19.34	56.37	25.84	K
	No. of genes	1.0	1.0	1.0	K
Oxyra X Giza-6	P. ratio	0.34	-0.05	0.01	0.21
	Heterosis%(MP)	16.66	-1.15	0.07	5.63
	Heterosis%(BP)	-21.45	42.11	-15.28	-16.40
	BSH%	66.60	96.85	63.68	80.30
	NSH%	46.75	65.27	57.86	73.14
	No. of genes	4.0	2.0	1.0	3.0
Oxyra X *Sigme*	P. ratio	0.20	-0.05	0.29	K
	Heterosis%(MP)	4.34	-1.53	13.54	K
	Heterosis%(BP)	-15.41	41.10	-22.38	K
	BSH%	93.24	99.50	54.26	K
	NSH%	50.26	80.11	31.10	K
	No. of genes	1.0	1.0	4.0	K

K = not available

2. Leaf water loss ratio:

The results presented in Fig., 1 indicated that there were highly significant differences between parents, F_1, F_2, Bc_1 and Bc_2 populations in all crosses under this study concerning leaf water loss ratio at different times after leaf cutting from the plants of the different populations. The parental cultivar Tema had the lowest leaf water loss ratios (12.20%, 7.84%, 7.03%, 5.61% and 5.39%) followed by cv. Oxyra (14.22%, 10.11%, 9.86%, 7.35% and 7.03%) meanwhile, the parental cultivar Giza-6 had the highest leaf water loss ratios(20.30%, 14.46%, 13.05%, 10.95% and 9-93%), after two, four, six, eight and ten hours from leaf cutting from the plant, respectively. Whereas, leaf water loss ratio of the F_1 plants was intermediate between the two parental cultivars for each cross under study (Fig., 1). These findings corroborate that of Perez *et al.*

(1999), Aguirre *et al.*(2002) and Mayek *et al.*(2002a)who found highly differences between common bean genotypes with regard to leaf water loss ratio.

The leaf of the parental cultivar Oxyra had a total water loss ratio equal to 32.87% which was significantly lower than that of the parental cultivars Tema (38.57%), Emy (55.72%), Sigme (61.27%) and Giza-6 (61.99%), (Table, 5). These results indicated the value of Oxyra as a source for genes controlling low water loss of leaves under drought conditions. These results agreed with those of El-Tohamy *et al.* (1999a), Pimentel and Cruz (2000) and Kohashi *et al.* (2002) who mentioned that there were genetic differences between common bean cultivars concerning leaf water loss ratio.

The frequency distribution for leaf water loss ratio in the F2, Bc_1 and Bc_2 populations of all crosses under study showed quantitative inheritance pattern (Table, 5).

Significant differences were found between leaf water loss ratio of F_1 plants of all crosses under study and that of the two parental cultivars of each cross. The values of water loss ratio of leaf for F_1's were intermediate between the two parental cultivars of each cross (Table, 5). Furthermore, partial dominance for low water loss ratio of leaf was observed in all crosses as indicated by the potance ratio , i.e. -0.46, -0.31, -0.05 and - 0.05 for the crosses (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme), respectively (Table, 4). Concerning backcross, leaves of Bc_1 plants had the lowest values of leaf water loss ratio compared with the plants of Bc_2 in the crosses(Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme) under laboratory condition in different times in Fig.(1).

The estimated values of mid-parent (MP) heterosis percentage for leaf water loss ratio after used drought stress were negative, i.e. -10.66, -5.60%, -1.51%, and -1.53% while those of the better- parent (BP) were positive, i.e. 16.46%, 15.40%, 42.11% and 41.10% for the crosses (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme), respectively(Table, 4). The better parent heterosis indicated the possibility of improving drought tolerance by decreasing leaf water loss under water stress conditions.

Relatively high estimates of broad and narrow sense heritability were calculated for leaf water loss ratio, in the different crosses, (Table, 4). The broad sense heritability estimates for leaf water loss ratio were 84.66%, 91.45%, 96.85% and 99.50%, meanwhile, the values of narrow sense heritability were 51.02%, 56.37%, 65.27% and 80.11% for the crosses (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme), respectively. Such estimates indicate the possibility of making progress in selecting for low leaf water loss ratio under water stress conditions in breeding programs for drought tolerance of common bean.

The minimum number of gene pairs controlling the leaf water loss ratio ranged from 1 to 3 gene pairs (Table, 4).

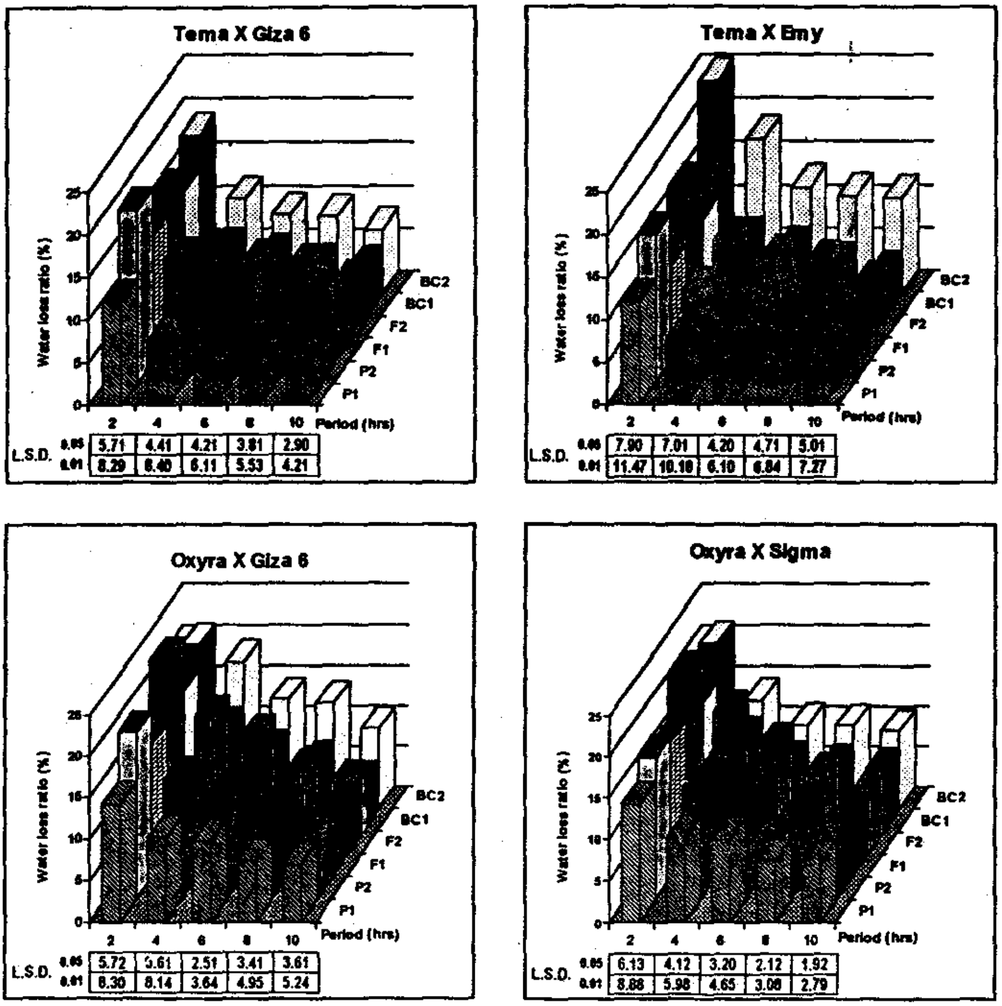

Fig. (1): Leaf water loss ratio in parents, F_1, F_2, Bc_1 and Bc_2 segregation derived from some common bean crosses under water stress in laboratory conditions.

Table (5): Frequency distributions of leaf water loss ratio in different populations for some Common bean crosses.

Cross	Population	Range of leaf water loss (%)							Total No.of plants	Mean ± SE	Variance
		35	40	45	50	55	60	65			
Tema X Giza-6	P_1	-	30	-	-	-	-	-	30	38.57±0.12	0.40
	$Bc_1(F_1XP_1)$	-	-	26	34	-	-	-	60	44.42±0.67	27.02
	F_1	-	-	15	15	-	-	-	30	44.92±0.87	22.56
	F_2	16	16	46	23	7	5	7	120	42.61±0.65	50.84
	$Bc_2(F_1XP_2)$	-	-	14	19	9	18	-	60	50.23±0.90	48.72
	P_2	-	-	-	-	-	-	30	30	61.99±0.12	0.44
L.S.D. 0.05										7.86	
0.01										11.90	
Tema X Emy	P_1	-	30	-	-	-	-	-	30	38.57±0.12	0.40
	$Bc_1(F_1XP_1)$	-	8	27	25	-	-	-	60	43.97±0.87	45.05
	F_1	-	15	15	-	-	-	-	30	44.61±0.38	4.28
	F_2	14	22	40	19	7	6	12	120	41.40±0.72	62.57
	$Bc_2(F_1XP_2)$	-	-	-	30	16	14	-	60	51.47±0.86	44.82
	P_2	-	-	-	-	12	18	-	30	55.72±0.62	11.36
L.S.D. 0.05										7.72	
0.01										11.69	
Oxyra X Giza-6	P_1	30	-	-	-	-	-	-	30	32.87±0.10	0.32
	$Bc_1(F_1XP_1)$	-	26	13	15	6	-	-	60	43.62±1.07	68.94
	F_1	-	9	18	3	-	-	-	30	46.71±0.49	7.29
	F_2	9	17	19	30	24	10	11	120	42.60±0.84	85.19
	$Bc_2(F_1XP_2)$	-	-	-	21	39	-	-	60	54.65±0.87	45.84
	P_2	-	-	-	-	-	-	30	30	61.99±0.12	0.44
L.S.D. 0.05										9.16	
0.01										13.87	
Oxyra X Sigme	P_1	30	-	-	-	-	-	-	30	32.87±0.10	0.32
	$Bc_1(F_1XP_1)$	-	-	50	10	-	-	-	60	42.72±1.10	72.92
	F_1	-	-	-	30	-	-	-	30	46.38±0.13	0.53
	F_2	3	24	38	26	20	2	7	120	44.24±1.01	123.21
	$Bc_2(F_1XP_2)$	-	-	-	24	36	-	-	60	50.64±1.12	74.80
	P_2	-	-	-	-	-	-	30	30	61.27±0.18	1.00
L.S.D. 0.05										9.67	
0.01										14.65	

3. Total yield per plant:

The parental cultivar Tema had the highest total dry seed yield/plant (56.76 g), while the parental cultivar Sigme had a relatively very low of total dry seed yield/plant (19.44 g) Table (6). Whereas, the cultivars Oxyra, Giza-6 and Emy had a relatively intermediate total dry seed yield/plant (52.95, 36.70 and 24.07 g, respectively). These results indicated that the parental cultivar Tema was the best source for genes controlling high total dry seed yield/plant under water stress conditions. In this respect, El-Tohamy *et al.* (1999b) and Molina *et al.* (2001) illustrated that there were genetic differences between common bean germplasm with regard to total yield/plant under drought condition.

Quantitative inheritance pattern for total dry seed yield/plant under water stress was detected from the frequency distribution of this character in the F_2, Bc_1 and Bc_2 populations of the crosses (Tema X Giza-6), (Tema X Emy), (Oxyra X Giza-6) and (Oxyra X Sigme), (Table, 6). These results are in conformity with those reported by Thomas (1983) who found that seed weight was controlled by a large number of genes, with both additive and dominance effects.

The potence ratio values were 0.01, 0.37, 0.01 and 0.29 which indicated slight partial dominance for high total dry seed yield/plant under drought conditions, (Table, 4). The F_1 hybrid of the cross (Tema X Giza-6) can be considered the best hybrid because it had the highest total dry seed yield/plant (46.85 g) comparing to the means of the other F_1 hybrids presented in Table, 6, *i.e.* Tema X Emy (46.54 g), Oxyra X Giza-6 (44.86 g) and Oxyra X Sigme (41.10 g).

The estimated values of mid-parent (MP) heterosis percentages for dry seed yield/plant under water stress were 15.14%, 13.54%, 0.26% and o.o7% and that of the better parent (BP) heterosis percentages were -18.01%, -22.38%, -27.66% and -15.28% for the crosses (Tema X Emy), (Tema X Giza-6), (Oxyra X Giza-6) and (Oxyra X Sigme), respectively (Table, 4).

The values of the broad sense heritability (BSH) for total dry seed yield/plant were 43.37%, 71.45%, 63.68% and 54.26%, while the narrow sense heritability were 36.54%, 25.84%, 57.86% and 31.10% for all crosses under study in Table (4). The observed low to intermediate estimate values of (NSH) indicated that total dry seed yield/plant was highly affected by the environmental conditions. Because of the relatively low (NSH) observed in most crosses, the additive part of the genetic variance for this character is expected to be either low or very low. Based on these results, selection for high total dry seed yield/plant in the segregating generations should be based on family mean basis and not on individual plant basis. In this respect, Ramirez and Kelly (1998) showed that the heritability estimates for seed yield under water stress were higher.

Number of major genes controlling total dry seed yield/plant ranged from 1 to 4 gene pairs (Table, 4). These results are in conformity with those obtained by Thomas (1983) who found that seed weight was controlled by a large number of genes, with both additive and dominance effects.

4. Leaf proline content

The two parental cultivars Oxyra and Giza-6 showed highly significant differences in leaf proline content (Table, 7). Leaf proline content of cultivar Oxyra was 34.81 mg/100 g dry weight while that of the cultivar Giza-6 was 20.29 mg/100g dry weight. The value of F_1 leaf proline content was intermediate between the two parents in the cross (Oxyra X Giza-6). These results agree with those reported by Camacho and Gonzalez (1998), Maiti *et al.* (2000) and Mejia *et al.* (2003) who found that there were significant differences between common bean germplasm with regard to leaf proline accumulation under drought conditions.

Table (6): Frequency distributions for total dry seed yield/plant in different populations for some Common bean crosses.

Cross	Population	Range of total yield/plant (g) 10	20	30	40	50	60	70	80	90	Total No.of plants	Mean± SE	Variance
Tema X Giza-6	P_1	-	-	-	-	-	19	11	-	-	30	56.76±2.74	225.00
	$Bc_1(F_1XP_1)$	-	-	-	23	12	12	11	-	-	60	46.67±1.94	225.60
	F_1	-	-	-	-	13	17	-	-	-	30	46.85±1.03	31.58
	F_2	-	20	31	32	21	7	2	5	2	120	45.07±1.41	237.47
	$Bc_2(F_1XP_2)$	-	-	13	18	16	13	-	-	-	60	40.65±1.65	162.56
	P_2	-	-	12	18	-	-	-	-	-	30	36.70±2.21	146.89
L.S.D.	0.05											12.62	
	0.01											19.12	
Tema X Emy	P_1	-	-	-	-	-	19	11	-	-	30	56.76±2.74	225.00
	$Bc_1(F_1XP_1)$	-	-	12	15	20	13	-	-	-	60	49.14±3.05	556.96
	F_1	-	-	-	-	17	13	-	-	-	30	46.54±1.17	40.83
	F_2	15	15	23	31	18	8	5	1	4	120	36.27±1.83	399.20
	$Bc_2(F_1XP_2)$	-	-	8	18	24	10	-	-	-	60	42.04±1.52	138.30
	P_2	-	13	17	-	-	-	-	-	-	30	24.07±1.59	76.04
L.S.D.	0.05											16.63	
	0.01											25.19	
Oxyra X Giza-6	P_1	-	-	-	-	18	12	-	-	-	30	52.95±1.74	90.42
	$Bc_1(F_1XP_1)$	-	-	-	22	28	10	-	-	-	60	44.29±1.61	156.17
	F_1	-	-	-	14	16	-	-	-	-	30	44.86±2.04	74.32
	F_2	-	5	24	35	29	12	11	4	-	120	39.95±1.55	286.05
	$Bc_2(F_1XP_2)$	-	-	18	26	16	-	-	-	-	60	39.37±2.17	281.81
	P_2	-	-	12	18	-	-	-	-	-	30	36.70±2.21	146.89
L.S.D.	0.05											10.39	
	0.01											15.74	
Oxyra X Sigme	P_1	-	-	-	-	18	12	-	-	-	30	52.95±1.74	90.42
	$Bc_1(F_1XP_1)$	-	-	11	12	26	11	-	-	-	60	42.67±2.31	320.78
	F_1	-	-	-	21	9	-	-	-	-	30	41.10±3.12	291.82
	F_2	10	19	26	41	14	4	4	2	-	120	38.91±1.66	331.56
	$Bc_2(F_1XP_2)$	-	32	14	14	-	-	-	-	-	60	33.55±1.99	239.24
	P_2	4	17	9	-	-	-	-	-	-	30	19.44±1.56	72.77
L.S.D.	0.05											16.50	
	0.01											25.00	

The mode of inheritance of leaf proline content was found to be quantitative based on the frequency distribution of the F_2 plants in the cross (Oxyra X Giza-6), (Table, 7).

In the cross Oxyra X Giza-6, the value of potence ratio (P) was 0.21 (Table, 4). These results indicate a slight partial dominance for high leaf proline content under drought conditions. These results were supported by results of backcrosses where leaf proline content of BC_1 population was higher than that of BC_2 population in the same cross (Table, 7).

The estimated value of mid-parent (MP) heterosis percentages for leaf proline content was 5.63%while these of the better-parent (BP)was negative(-16.40%) for the cross(Oxyra X Giza-6), (Table, 4). The mid-parent heterosis indicated the possibility of improving drought tolerance by selection for high leaf proline content under water stress conditions.

Table (7): Frequency distribution for leaf Proline content mg/100g dry weight (DW) in different populations of the cross (Oxyra X Giza-6).

Cross	Population	Upper class limits mg/100g DW.						Total No. of plants	Mean±SE	Variance
		15	20	25	30	35	40			
Oxyra X Giza-6	P_1	-	-	-	-	18	20	30	34.81±0.83	1.18
	P_2	-	21	9	-	-	-	30	20.29±0.83	1.06
	F_1	-	-	-	22	8	-	30	29.10±0.83	12.54
	F_2	9	10	16	40	23	22	120	27.49±0.42	25.02
	$BC_1(F_1 X P_1)$	-	-	-	20	40	-	60	32.43±0.59	16.61
	$BC_2(F_1 X P_2)$	-	-	41	19	-	-	60	25.48±0.59	15.13

A relatively high broad and narrow sense heritability estimates were calculated for this character in the previously mentioned cross (Table, 7). The broad sense heritability estimate was 80.30% and the narrow sense heritability was 73.14%. Based on these result, selection for high leaf proline content under drought conditions in the segregating generations should be based on individual plant basis. The relatively high broad and narrow sense heritability indicated that selection for this possible component of resistance to drought can be made with relatively high chance Turner and Kramer (1980).

Number of major genes controlling leaf proline content under drought conditions was 3 gene pairs (Table, 4).

5. Simple correlation:

Drought tolerance measured by percentage of healthy leaves on individual plants which exposed to drought, was positively correlated with each of number of branches/plant, fruit set percentage, number of pods/plant, number of seeds/pod, 100 seed weight and total dry seed yield/plant in the F_2 of all crosses under study (Table, 8). On the other hand, drought tolerance was negatively correlated with each of number of days from sowing date to the first flower anthesis, leaf water loss ratio and leaf area in the crosses Tema X Giza-6, Tema X Emy, Oxyra X Giza-6 and Oxyra X Sigme. These results are in accordance with those reported by Perez *et al.* (1999) who mentioned that water stress significantly reduced the seed weight. Teran and Singh (2002) mentioned that 100-seed weight of common bean was slightly reduced in drought-stressed versus non-stressed environments. In addition, they found Non-stressed environment seed yields were positively correlated with drought-stressed yields.

Significant positive correlations were observed between total dry seed yield/plant and each of drought tolerance, number of branches/plant, number of pods/plant, fruit set percentage, number of seeds/pod and 100 seed weight. Whereas, there were negatively correlation between total dry seed yield/plant and number of days from sowing date to the first flower anthesis. These results are also in agreement with those of EL-Tohamy *et al.* (1999b) who recorded high linear

relationship between yield and water stress levels. Also, Boutraa and Sanders (2001) found that water stress reduced yield and its components. The affected components were seed weight, number of seeds per plant and number of pods per plant. Time to maturity was slightly prolonged. Water stress reduced number of main branches. Solanki *et al*. (2003) found that days to flower and maturity had significant positive correlation with each other while these traits had significant negative correlation with grain yield. Also they found number of Pods/plant, pod length and seeds/pod had significant positive correlation with yield.

Table (8): Correlation coefficients between some characteristics of the F_2 plants of some common bean crosses exposed to drought stress.

Cross	Characters	Earliness	No. of branches	Pod No./ plant	Fruit set (%)	Seed No./ pod	100 seed weight	Total yield/ plant	Leaf water loss ratio	Leaf area	Proline content
Tema X Giza-6	Drought tolerance	-0.303**	0.424**	0.400**	0.523**	0.196*	0.184*	0.330**	-0.974**	-0.934**	
	No. of branches			0.676**	0.395**	0.284**	0.205*	0.595**	-0.350**	-0.318**	
	Pod No./plant				0.391**	0.233**	0.283**	0.771**	-0.402**	-0.309**	
	Fruit set percentage					-0.006	0.057	0.273**	-0.541**	-0.435**	na
	Seed No./pod						0.153	0.589**	-0.189*	-0.199*	
	100 seed weight							0.669**	-0.184*	-0.185*	
	Total yield/plant								-0.308**	-0.243**	
	Leaf water loss ratio									0.901**	
Tema X Emy	Drought tolerance	-0.245**	0.658**	0.940**	0.762**	0.555**	0.855**	0.826**	-0.974**	-0.930**	
	Earliness		0.198*	0.265**	0.367**	0.242**	0.209*	-0.260**	0.271**	0.229*	
	No. of branches			0.685**	0.676**	0.818**	0.849**	0.869**	-0.575**	-0.682**	
	Pod No./plant				0.793**	0.549**	0.806**	0.867**	-0.908**	-0.900**	
	Fruit set percentage					0.578**	0.744**	0.780**	-0.712**	-0.760**	na
	Seed No./pod						0.802**	0.846**	-0.498**	-0.595**	
	100 seed weight							0.922**	-0.796**	-0.858**	
	Total yield/plant								-0.768**	-0.840**	
	Leaf water loss ratio									0.882**	
Oxyra X Giza-6	Drought resistance	-0.224**	0.685**	0.443**	0.415**	0.758**	0.753**	0.708**	-0.960**	-0.977**	0.982**
	Earliness		0.044	-0.032	0.223**	-0.311**	-0.276**	-0.271**	0.174*	0.255**	-0.256**
	No. of branches			0.162	-0.016	0.496**	0.453**	0.518**	-0.718**	-0.600**	0.596**
	Pod No./plant				0.610**	0.026	0.234**	0.657**	-0.180*	-0.188*	0.119
	Fruit set percentage					-0.004	0.088	0.347**	-0.181*	-0.181*	-0.002
	Seed No./pod						0.642**	0.712**	-0.736**	-0.730**	0.740**
	100 seed weight							0.767**	-0.696**	-0.751**	0.774**
	Total yield/plant								-0.676**	-0.674**	0.684**
	Leaf water loss ratio									0.919**	-0.933**
	Leaf area										-0.991**
Oxyra X Sigme	Drought resistance	-0.310**	0.787**	0.761**	0.553**	0.783**	0.659**	0.752**	-0.980**	-0.983**	
	Earliness		-0.338**	-0.315**	-0.209*	-0.430**	-0.214*	-0.333**	0.316**	0.273**	
	No. of branches			0.940**	0.733**	0.820**	0.900**	0.927**	-0.764**	-0.781**	
	Pod No./plant				0.751**	0.394**	0.927**	0.970**	-0.740**	-0.758**	
	Fruit set percentage					0.660**	0.693**	0.729**	-0.545**	-0.572**	na
	Seed No./pod						0.775**	0.905**	-0.746**	-0.770**	
	100 seed weight							0.913**	-0.644**	-0.665**	
	Total yield/plant								-0.709**	-0.753**	
	Leaf water loss ratio									0.956**	

* =Significant at 5%, level of significance

** =Significant at 1% level of significance

na = not available

Leaf water loss ratio and leaf area was negatively correlated with each of drought tolerance, number of branches/plant, number of pods/plant, fruit set percentage, number of seeds/pod, 100 seed weight and total dry seed yield/plant. Whereas, there were highly positively correlation between leaf water loss ratio and leaf area and number of days from sowing date to the first flower anthesis in all crosses under study (Table, 8). This has been also observed by Mencuccini and Comstock (1999) who found that cultivars bred for cultivation in hot and dry regions had significantly smaller leaves but higher transpiration rates per unit of leaf area. Pimentel and Cruz (2000) found that leaf area and shoot dry weight were the morphological variables more sensitive to water stress. Mayek *et al.* (2002b) showed that drought stress decreased transpiration rate and leaf area. Also, Navea *et al.* (2002) mentioned that leaf area being bigger in genotypes from warm and humid lands than those from dry and temperate ones.

Free proline content of plant leaves was negatively correlated with each of number of days from sowing date to the first flower anthesis, leaf water loss ratio and leaf area. On the other hand, there were highly significant positive correlations between proline content and each of drought tolerance, number of branches/plant, number of seeds/pod, 100 seed weight and total dry seed yield/plant in the F2 plants of the cross Oxyra X Giza-6. That was in accordance with the findings of Maiti *et al.* (2000) who showed that in all stress situation, there was an increase in the accumulation of proline in common bean plants (*P. vulgaris*). Moreover, Mejia *et al.* (2003) mentioned that proline increased under drought conditions.

6. Multiple correlation:

The multiple correlation coefficients calculated for drought tolerance and some characters from data of F_2 populations were significant. The results presented in Table, 9 show highly significant positive correlation between drought tolerance and each of number of days required from sowing date to the first flower bud anthesis, number of branches/plant, fruit set percentage, 100 seed weight, total dry seed yield/plant, leaf water loss ratio and leaf area. Such R^2 values indicated that the proportion of the variance in the tolerance which can be explained by all the studied characters was high .Therefore, based on the results of the multiple regression analysis presented in Table, 9, the number of days from sowing date to the first flower anthesis, number of branches/plant, fruit set percentage, 100 seed weight, total dry seed yield/plant, leaf water loss ratio and leaf area should be considered together when selecting for tolerance of common bean plants to drought tolerance.

Table (9): Multiple correlation coefficients between drought tolerance and some characteristics in the F_2 plants of some common bean crosses exposed to drought.

Cross	Involved indepent variables	R-square	Multiple-R	Significance
Tema X Giza-6	Earliness			
	No. of branches			
	Fruit set percentage			
	100 seed weight	0.977	0.988	**
	Total yield/plant			
	Leaf water loss ratio			
	Leaf area			
Tema X Emy	Earliness			
	No. of branches			
	Fruit set percentage			
	100 seed weight	0.977	0.988	**
	Total yield/plant			
	Leaf water loss ratio			
	Leaf area			
Oxyra X Giza-6	Earliness			
	No. of branches			
	Fruit set percentage			
	100 seed weight	0.984	0.992	**
	Total yield/plant			
	Leaf water loss ratio			
	Leaf area			
Oxyra X Sigme	Earliness			
	No. of branches			
	Fruit set percentage			
	100 seed weight	0.989	0.994	**
	Total yield/plant			
	Leaf water loss ratio			
	Leaf area			

** Significant at 1% level of significance

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توريث وطبيعة المقاومة لتحمل الجفاف في الفاصوليا

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تم التهجين بين الأصناف تيما و اوجزيرا (وهى أصناف تتحمل الجفاف) وكذلك أيضا الأصناف جيره٦ وامي و سيجما (وهى أصناف حساسة للجفاف) وذلك لدراسة توريث وطبيعة المقاومة لتحمل الجفاف وبعض الصفات المرتبطة بالجفاف التي يعتقد أن لها تأثير مباشر أو غير مباشر على تحمل الجفاف . وجد أن هناك اختلافات عالية المعنوية بين الأصناف السابقة الذكر في صفات الجذور التي درست مثل طول الجذر والوزن الطازج والجاف له تحت ظروف الري المنتظم وظروف الجفاف في تجربة الأصص. كما وجد أن هناك زيادة معنوية في النسبة المئوية لطول الجذر في الأب الأول والأب الثاني والجيل الأول في كل الهجن تحت ظروف الجفاف مقارنة بطول الجذر تحت ظروف الري المنتظم . وعلى العكس من ذلك وجد أن هناك انخفاضا معنويا في النسبة المئوية لنقص الوزن الطازج والجاف للجذر. هناك سيادة جزئيه قليلة للآباء العالية في طول الجذر والوزن الطازج والجاف له .

وجد أن صفات التحمل للجفاف و معدل فقد الورقة للماء و محصول النبات الكلي من البذور الجافة ومحتوى أوراق النبات من الحامض الاميني برولين تورث كميا٠ووجد أن هناك سيادة جزئيه للمستوى العالي من تحمل الجفاف ومحصول النبات الكلي من البذور الجافة ومحتوى أوراق النبات من الحامض الاميني برولين على المستوى المنخفض٠ بينما وجدت سيادة جزئيه للمستوى المنخفض من معدل فقد الورقة للماء على المعدل العالي لفقد الورقة للماء٠ وقدرت القدرة على التوريث بمعناها الواسع لصفات تحمل الجفاف و معدل فقد الورقة للماء و محصول النبات الكلي من البذور الجافة ومحتوى أوراق النبات من الحامض الاميني برولين فتراوحت مابين المتوسطه إلى العالية- بينما القدرة على التوريث بمعناها الضيق لنفس الصفات السابقة تراوحت ما بين قليلة إلى فوق المتوسطه٠ وقدرعدد أزواج العوامل الوراثيه التي تتحكم في توريث صفات تحمل الجفاف و معدل فقد الورقة للماء ومحصول النبات الكلي من البذور الجافة ومحتوي أوراق النبات من الحامض الاميني برولين تراوحت ما بين ١-٤و ١-٣و ١-٤ و٣ أزواج من العوامل الوراثيه على التوالي.

تحمل الجفاف ارتبط ارتباطا معنويا موجبا مع كل من عدد أفرع النبات وعدد قرون النبات والنسبة المئوية لعقد الثمار وعدد البذور بالقرن ووزن ١٠٠ بذره و محصول النبات الكلي من البذور الجافه٠ وعلى العكس من ذلك وجد أن تحمل الجفاف ارتبط ارتباطا سالبا مع كل من عدد الأيام من الزراعة حتى تفتح أول زهره على النبات ومعدل فقد الورقة للماء ومساحة الورقة. وجد أن محتوى أوراق النبات من الحامض الاميني برولين ارتبط ارتباطا موجبا مع كل من تحمل الجفاف وعدد أفرع النبات وعدد البذور بالقرن ووزن ١٠٠ بذره ومحصول النبات الكلي من البذور الجافة. وعلى العكس من ذلك وجد أن هناك علاقة سالبه عالية المعنوية مابين محتوى أوراق النبات من الحامض الاميني برولين وكل من عدد الأيام من تاريخ الزراعة حتى تفتح أول زهره على النبات ومعدل فقد الورقة للماء و مساحة الورقة. وجد أن هناك انحدارا معنويا بين تحمل النبات للجفاف وكل من عدد الأيام من تاريخ الزراعة حتى تفتح أول زهره على النبات وعدد أفرع النبات والنسبة المئوية لعقد الثمار ووزن ١٠٠ بذره ومحصول النبات الكلي من البذور الجافة ومعدل فقد الورقة للماء ومساحة الورقة.