

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

By

**Badr, L.A.A.\*; Khedr, Z. A. \*\*and Refaat, M.H. \*\*\***

\*Department of Horticulture

\*\*Department of Agric. Botany

\*\*\*Department of Genetics

Fac. of Agric. Moshtohor, Zagazig University, Benha Branch, Egypt.

## 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 22<sup>nd</sup>, 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<sub>1</sub>'s were harvested separately and kept for the next season.

On March 17<sup>th</sup>, 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<sub>1</sub> plants were selfed to obtain F<sub>2</sub> seeds. Backcrosses populations were obtained by crossing each F<sub>1</sub> hybrid with its respective parents.

### ***I. Pots experiment:***

On March 16, 2004, seeds of the different parental cultivars in addition to their F<sub>1</sub> 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 16<sup>th</sup>, 2004, seeds of the parental genotypes, F<sub>1</sub>, F<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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<sub>1</sub> plants and four ridges for the F<sub>2</sub> 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<sup>2</sup> (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<sub>1</sub>, F<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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<sub>1</sub> 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 X Giza-6	P1	14.40	0.764	0.200	19.57	0.593	0.183	35.90	22.38	9.29
	P2	10.17	0.593	0.089	11.60	0.345	0.070	14.06	41.82	21.35
	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 X Emy	P1	14.40	0.764	0.200	19.57	0.593	0.183	35.90	22.38	9.29
	P2	8.67	0.458	0.076	9.30	0.237	0.054	7.27	48.25	28.95
	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 X Giza-6	P1	16.07	1.133	0.210	23.27	0.628	0.195	44.80	44.57	7.14
	P2	10.17	0.593	0.089	11.60	0.345	0.070	14.06	41.82	21.35
	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 X Sigme	P1	16.07	1.133	0.210	23.27	0.628	0.195	44.80	44.57	7.14
	P2	11.27	0.682	0.155	12.10	0.405	0.090	7.36	40.62	41.94
	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 potence 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<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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 give clear and dependable information about the inheritance of drought tolerance. The average drought tolerance for the plants of F<sub>1</sub> was much higher than

Table (3): Frequency distributions for plant reaction to drought tolerance in parents, F<sub>1</sub>, F<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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 Giza-6	P <sub>1</sub>	-	-	-	-	-	-	-	13	6	11	30	78.60±2.49	186.62
	Bc <sub>1</sub> (F <sub>1</sub> XP <sub>1</sub> )	-	-	-	12	15	7	7	8	11	-	60	57.00±2.76	457.96
	F <sub>1</sub>	-	-	-	-	-	-	12	18	-	-	30	70.37±2.69	217.91
	F <sub>2</sub>	4	5	7	9	14	16	22	23	17	3	120	56.21±2.25	608.95
	Bc <sub>2</sub> (F <sub>1</sub> XP <sub>2</sub> )	-	9	8	8	8	7	8	12	-	-	60	52.00±2.99	536.85
	P <sub>2</sub>	-	-	15	15	-	-	-	-	-	-	30	30.73±2.56	197.12
L.S.D.	0.05											29.63		
	0.01											44.88		
Tema X Emy	P <sub>1</sub>	-	-	-	-	-	-	-	13	6	11	30	78.60±2.49	186.62
	Bc <sub>1</sub> (F <sub>1</sub> XP <sub>1</sub> )	-	-	-	21	6	8	13	12	-	-	60	53.68±2.92	512.57
	F <sub>1</sub>	-	-	-	-	-	-	7	23	-	-	30	73.83±1.75	91.97
	F <sub>2</sub>	4	6	6	6	6	19	29	24	14	6	120	58.38±2.04	499.08
	Bc <sub>2</sub> (F <sub>1</sub> XP <sub>2</sub> )	-	-	-	14	15	15	16	-	-	-	60	49.00±2.55	389.06
	P <sub>2</sub>	-	8	8	14	-	-	-	-	-	-	30	29.60±2.68	214.92
L.S.D.	0.05											26.96		
	0.01											40.84		
Oxyra X Giza-6	P <sub>1</sub>	-	-	-	-	-	-	-	-	18	12	30	88.70±0.58	9.99
	Bc <sub>1</sub> (F <sub>1</sub> XP <sub>1</sub> )	-	-	-	-	-	-	5	28	27	-	60	78.12±2.05	251.98
	F <sub>1</sub>	-	-	-	-	-	-	18	12	-	-	30	69.67±2.92	256.75
	F <sub>2</sub>	-	3	10	12	16	10	21	19	13	10	120	56.22±1.74	363.11
	Bc <sub>2</sub> (F <sub>1</sub> XP <sub>2</sub> )	-	-	-	20	12	9	12	7	-	-	60	57.17±2.25	304.50
	P <sub>2</sub>	-	-	15	15	-	-	-	-	-	-	30	30.73±2.56	197.12
L.S.D.	0.05											24.64		
	0.01											37.33		
Oxyra X Sigme	P <sub>1</sub>	-	-	-	-	-	-	-	-	18	12	30	88.70±0.58	9.99
	Bc <sub>1</sub> (F <sub>1</sub> XP <sub>1</sub> )	-	-	-	-	-	-	25	12	15	8	60	73.57±2.46	362.82
	F <sub>1</sub>	-	-	-	-	-	-	-	22	8	-	30	75.03±1.14	38.94
	F <sub>2</sub>	-	-	-	2	11	18	25	33	18	13	120	64.60±1.95	456.68
	Bc <sub>2</sub> (F <sub>1</sub> XP <sub>2</sub> )	-	-	-	-	7	29	15	9	-	-	60	58.75±2.31	321.00
	P <sub>2</sub>	-	-	-	-	10	20	-	-	-	-	30	54.53±1.21	43.69
L.S.D.	0.05											21.32		
	0.01											32.30		

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).

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.

<i>Cross</i>	<b>Character parameter</b>	<b>Drought tolerance</b>	<b>Leaf water loss ratio</b>	<b>Total yield/plant</b>	<b>Leaf proline content</b>
<b>Tema X Giza-6</b>	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
<b>Tema X Emy</b>	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
<b>Oxyra X Giza-6</b>	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
<b>Oxyra X Sigme</b>	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*

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).

## 2. Leaf water loss ratio:

The results presented in Fig., 1 indicated that there were highly significant differences between parents, F<sub>1</sub>, F<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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<sub>1</sub> 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 F<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> populations of all crosses under study showed quantitative inheritance pattern (Table, 5).

Significant differences were found between leaf water loss ratio of F<sub>1</sub> 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<sub>1</sub>'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<sub>1</sub> plants had the lowest values of leaf water loss ratio compared with the plants of Bc<sub>2</sub> 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.

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 $\pm$ SE	Variance
		35	40	45	50	55	60	65			
<b>Tema X Giza-6</b>	<b>P<sub>1</sub></b>	-	30	-	-	-	-	-	30	38.57 $\pm$ 0.12	0.40
	<b>Bc<sub>1</sub>(F<sub>1</sub>XP<sub>1</sub>)</b>	-	-	26	34	-	-	-	60	44.42 $\pm$ 0.67	27.02
	<b>F<sub>1</sub></b>	-	-	15	15	-	-	-	30	44.92 $\pm$ 0.87	22.56
	<b>F<sub>2</sub></b>	16	16	46	23	7	5	7	120	42.61 $\pm$ 0.65	50.84
	<b>Bc<sub>2</sub>(F<sub>1</sub>XP<sub>2</sub>)</b>	-	-	14	19	9	18	-	60	50.23 $\pm$ 0.90	48.72
	<b>P<sub>2</sub></b>	-	-	-	-	-	-	30	30	61.99 $\pm$ 0.12	0.44
<i>L.S.D.</i>	<i>0.05</i> <i>0.01</i>									7.86 11.90	
<b>Tema X Emy</b>	<b>P<sub>1</sub></b>	-	30	-	-	-	-	-	30	38.57 $\pm$ 0.12	0.40
	<b>Bc<sub>1</sub>(F<sub>1</sub>XP<sub>1</sub>)</b>	-	8	27	25	-	-	-	60	43.97 $\pm$ 0.87	45.05
	<b>F<sub>1</sub></b>	-	15	15	-	-	-	-	30	44.61 $\pm$ 0.38	4.28
	<b>F<sub>2</sub></b>	14	22	40	19	7	6	12	120	41.40 $\pm$ 0.72	62.57
	<b>Bc<sub>2</sub>(F<sub>1</sub>XP<sub>2</sub>)</b>	-	-	-	30	16	14	-	60	51.47 $\pm$ 0.86	44.82
	<b>P<sub>2</sub></b>	-	-	-	-	12	18	-	30	55.72 $\pm$ 0.62	11.36
<i>L.S.D.</i>	<i>0.05</i> <i>0.01</i>									7.72 11.69	
<b>Oxyra X Giza-6</b>	<b>P<sub>1</sub></b>	30	-	-	-	-	-	-	30	32.87 $\pm$ 0.10	0.32
	<b>Bc<sub>1</sub>(F<sub>1</sub>XP<sub>1</sub>)</b>	-	26	13	15	6	-	-	60	43.62 $\pm$ 1.07	68.94
	<b>F<sub>1</sub></b>	-	9	18	3	-	-	-	30	46.71 $\pm$ 0.49	7.29
	<b>F<sub>2</sub></b>	9	17	19	30	24	10	11	120	42.60 $\pm$ 0.84	85.19
	<b>Bc<sub>2</sub>(F<sub>1</sub>XP<sub>2</sub>)</b>	-	-	-	21	39	-	-	60	54.65 $\pm$ 0.87	45.84
	<b>P<sub>2</sub></b>	-	-	-	-	-	-	30	30	61.99 $\pm$ 0.12	0.44
<i>L.S.D.</i>	<i>0.05</i> <i>0.01</i>									9.16 13.87	
<b>Oxyra X Sigme</b>	<b>P<sub>1</sub></b>	30	-	-	-	-	-	-	30	32.87 $\pm$ 0.10	0.32
	<b>Bc<sub>1</sub>(F<sub>1</sub>XP<sub>1</sub>)</b>	-	-	50	10	-	-	-	60	42.72 $\pm$ 1.10	72.92
	<b>F<sub>1</sub></b>	-	-	-	30	-	-	-	30	46.38 $\pm$ 0.13	0.53
	<b>F<sub>2</sub></b>	3	24	38	26	20	2	7	120	44.24 $\pm$ 1.01	123.21
	<b>Bc<sub>2</sub>(F<sub>1</sub>XP<sub>2</sub>)</b>	-	-	-	24	36	-	-	60	50.64 $\pm$ 1.12	74.80
	<b>P<sub>2</sub></b>	-	-	-	-	-	-	30	30	61.27 $\pm$ 0.18	1.00
<i>L.S.D.</i>	<i>0.05</i> <i>0.01</i>									9.67 14.65	

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).

### **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<sub>2</sub>, Bc<sub>1</sub> and Bc<sub>2</sub> 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<sub>1</sub> 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<sub>1</sub> 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 0.07% 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.

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

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<sub>1</sub> 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.

The mode of inheritance of leaf proline content was found to be quantitative based on the frequency distribution of the F<sub>2</sub> 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<sub>1</sub> population was higher than that of BC<sub>2</sub> population in the same cross (Table, 7).

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 <sub>1</sub>	-	-	-	-	18	20	30	34.81±0.83	1.18
	P <sub>2</sub>	-	21	9	-	-	-	30	20.29±0.83	1.06
	F <sub>1</sub>	-	-	-	22	8	-	30	29.10±0.83	12.54
	F <sub>2</sub>	9	10	16	40	23	22	120	27.49±0.42	25.02
	BC <sub>1</sub> (F <sub>1</sub> X P <sub>1</sub> )	-	-	-	20	40	-	60	32.43±0.59	16.61
	BC <sub>2</sub> (F <sub>1</sub> X P <sub>2</sub> )	-	-	41	19	-	-	60	25.48±0.59	15.13

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.

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<sub>2</sub> 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.

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.

Table (8): Correlation coefficients between some characteristics of the F<sub>2</sub> 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**	na
	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**	
	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**	
Tema X Emy	Leaf water loss ratio									0.901**	
	Drought tolerance	-0.245**	0.658**	0.940**	0.762**	0.555**	0.855**	0.826**	-0.974**	-0.930**	na
	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**	
	Seed No./pod						0.802**	0.846**	-0.498**	-0.595**	
100 seed weight							0.922**	-0.796**	-0.858**		
Oxyra X Giza-6	Total yield/plant								-0.768**	-0.840**	
	Leaf water loss ratio									0.882**	
	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
Oxyra X Sigme	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**
	Drought resistance	-0.310**	0.787**	0.761**	0.553**	0.783**	0.659**	0.752**	-0.980**	-0.983**	na
	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**		
Seed No./pod						0.775**	0.905**	-0.746**	-0.770**		
100 seed weight							0.913**	-0.644**	-0.665**		
Oxyra X Sigme	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

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 F<sub>2</sub> 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<sub>2</sub> populations were significant. The results presented in Table, 9 show highly significant positive correlation between drought tolerance

Table (9): Multiple correlation coefficients between drought tolerance and some characteristics in the F<sub>2</sub> plants of some common bean crosses exposed to drought.

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

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<sup>2</sup> 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.

## REFERENCES

- Aguirre, M. J. F., Acosta, G. J. A., Ruiz, P. L. M., Shibata, J. K. and Trejo, L.C. (2002): Morphological differences on the leaf epidermis of common bean and their relationship to drought tolerance. *Agric. Tecnica en Mexico*, 28(1):53-64. (Database of Agricola- Internet).
- Allard, R. W. (1960): Principles of plant Breeding. John Wiley and Sons, New York, U. S. A.
- Bates, L. S., Waldren, R. P. and Teare, I. D. (1973): Rapid determination of free proline for water-stress studies. *Plant Soil*, 939:205-207.
- Bhatt, G. M. (1971): Heterotic performance and combining ability in a diallel cross among spring wheat's (*T. aestivum* L.). *Austr. J. of Agric. Res.*, 22:359-369. (Database of Agricola- Internet).
- Bohnert, H.J., Nelson, D.E. and Jensen, R.G. (1995): Adaptation to environmental stresses. *Plant Cell*, 7:1099-1111.
- Boutraa, T. and Sanders, F.E. (2001): Influence of water stress on grain yield and vegetative growth of two cultivars of bean (*Phaseolus vulgaris* L.). *J. of Agronomy and Crop Sci.*, 187(4):251-257.
- Briggs, N. F. and Knowles, P.E. (1977): Introduction to Plant Breeding. Reinhold Publishing Corporation, USA.
- Castle, W. E. and Wright, S. (1921): An improved method of estimating the number of genetic factors concerned in cases of blending. *Inheritance Science*, 54: 223.
- Camacho, B.M. and Gonzalez, M.E. (1998): Comparative study of enzymes related to proline metabolism in tepary bean (*Phaseolus acutifolius*) and common bean (*Phaseolus vulgaris*) under drought and irrigation conditions, and various urea concentrations. *Plant foods for Human Nutrition*, 52 (2): 119 -132.
- EL-Tohamy, W., Schnitzler, W. H., EL-Behairy, U. and Abou-Hadid, A. F. (1999a): Evaluation of drought and heat tolerance of common bean (*Phaseolus vulgaris* L.). *Angewandte Botanik*, 73(5/6):169-172. (Database of Agricola- Internet).
- EL-Tohamy, W., Schnitzler, W. H., EL-Behairy, U. and Singer, S. M. (1999b): Effect of long-term drought stress on growth and yield of bean plants (*Phaseolus vulgaris* L.). *Angewandte Botanik*, 73(5-6):173-177. (Database of Agricola- Internet).
- Gomez, K. A. and Gomez, A.A. (1984): Statistical procedures for agricultural research. 2<sup>nd</sup> ed John Wiley & Sons, New York.
- Hadidi, N. A. (1999): Germination and early growth of two common bean cultivars as affected by water stress and seed size. *Dirasat Agric. Sci.*, 26 (1):23-35. (Database of Agricola- Internet).
- Kohashi, S.J., Galvan, T.M., Garcia, E.A., Yanez, J.P., Martinez, V.E. and Ruiz, P.L. (2002). Water stress effect on the growth of phytomers in common bean (*Phaseolus vulgaris* L.). *Agricu. Tecnica en Mexico* 28 (1): 65-75. (Database of Agricola- Internet).
- Maiti, R. K., Nunez, G. A., Wesche, E. P., Moreno, L. S. L., Cardenas, A. M. L. and Hernandez, p. j. L. (2000): Proline and protein profile as indicators of resistance to biotic and a biotic stresses in bean (*Phaseolus vulgaris* L.)-a review. *Agric. Reviews*, 21(4): 231-237.
- Mather, K. and Jinks, J. L. (1971): Biometrical genetics. The study of continuous variations. Cornell Univ. press, Ithaca, N. Y.

- Mayek, P. N., Acosta, G. J. A. and Lopez, C. C. (2002a): Relationship between early vigor of common bean (*Phaseolus vulgaris* L.) and resistance to water stress and to *Macrophomina phaseolina* (Tassi) Goidanich. *Revista Mexicana de Fitopatologia*, 20(2):133-140. (Database of Agricola- Internet).
- Mayek, P. N., Garcia, E. R., Lopez, C. C., Acosta, G. J. A. and Simpson, J. (2002b): Water relations, histopathology and growth of common bean (*Phaseolus vulgaris* L.) during pathogenesis of *Macrophomina phaseolina* under drought stress. *Physio. and Molecular Plant Patho.*, 60(4):185-195.
- Mejia, E. G., Martinez, R. V., Castano, T. E. and Lparca, P. G.(2003): Effect of drought on polyamine metabolism, yield, protein content and in vitro proteine digestibility in tepary (*Phaseolus acutifolius*) and common bean (*Phaseolus vulgaris*) bean seeds. *J. Sci. of food and Agric.*, 83 (10): 1022-1030.
- Mencuccini, M. and Comstock, J. (1999): Variability in hydraulic architecture and gas exchange of common bean (*Phaseolus vulgaris*) cultivars under well-watered conditions: interactions with leaf size. *Australian J. of Plant Physio.*, 26(2):115-124. (Database of Agricola- Internet).
- Molina, J. C., Moda, C. V., Fonseca, J. N. S., Faria, R. T. and Destro, D. (2001): Response of common bean cultivars and lines to water stress. *Crop Breeding and Applied Biotechnology*, 1 (4): 363-372.
- Moreno, L. S., Maiti, R. K. and Nunez, G.A. (2000): Differential responses of two bean cultivars (*Phaseolus vulgaris* L.) resistant and susceptible to water stress in seedling growth and mineral uptake. *Research on Crops*, 1(1) 20-24. (Database of Agricola- Internet).
- Navea, C., Terrazas, T., Delgado, S. A. and Ramirez, V. P. (2002): Foliar response of wild and domesticated *Phaseolus vulgaris* L. to water stress. *Genetic Resources and Crop Evolution*, 49(2):125-132.
- Perez, H. P., Acosta, D. E., Padilla, R. S. and Acosta, G.J.A. (1999): Effect of drought stress on seed quality of common bean (*Phaseolus vulgaris* L.). *Agric. Tecnica en Mexico*, 25(2):107-114. (Database of Agricola- Internet).
- Pimentel, C. and Cruz, P.A.J. (2000): Establishment of parameters for water stress tolerance evaluation on bean genotypes. *Pesquisa Agropecuaria Brasileira*, 35(1):31-39. (Database of Agricola- Internet).
- Ramirez, V. P. and Kelly, J. D. (1998): Traits related to drought resistance in common bean. *Euphytica*, 99 (2): 127-136.
- Smith, H. H.(1952): Fixing transgressive vigor in *Nicotiana rustica* in Heterosis, Iowa state college press. Ames Iowa, USA.
- Solanki, S. D., Chauhan, R. M. and Tikkas, S. B. S. (2003): Character associations over environments in moth bean. *Advances in arid legumes research*, pp. 112-114. (Database of Agricola- Internet).
- Sponchiado, B.N.; White, J.W.; Castillo, J.A. and Jones, P.G. (1989): Root growth of four common bean cultivars in relation to drought tolerance in environments with contrasting soil types. *Experimental Agric.*, 25 (2): 249-257.
- Teran, H. and Singh, S. P. (2002): Selection for drought resistance in early generations of common bean populations. *Canadian J. of plant Science*, 82 (3):491-497. (Database of Agricola- Internet).
- Thomas, C. V.(1983): Genetic, morphological and physiological studies of drought and heat resistance in tepary bean (*Phaseolus acutifolius* A. Gray) and common bean (*P. vulgaris* L.). *Dissertation Abstracts International*, B, 44 (2) P. 410B. (Database of Agricola- Internet).

- Turner, N.C. and Kramer, P.J. (1980): Adaptation of plants to water and high temperature stress. John Wiley & Sons. New York. *P.482.*
- Wallace, D. H. and Munger, H.M. (1965): Studies of the physiological basis for yield differences. I: Growth analysis of six dry bean varieties. *Crop Sci.5:343-348.*