Dirasat, Agricultural Sciences, Volume **33**, No. **1**, 2006

Response of Chickpea (*Cicer arietinum* L.) to Soil Moisture Levels in a Semiarid Environment

Million E. Woldeamanuel, Ahmad M. Abu-Awwad and Nasri I. Haddad *

ABSTRACT

Chickpea (*Cicer arietinum* L.) is an important food legume which is grown in most geographical regions. Chickpea can experience two types of drought: intermittent drought stress caused by breaks in winter rainfall; and terminal drought stress, resulting from receding soil moisture at the late stage of the crop growth. One way of improving the low productivity of chickpea in drought environment is to develop varieties, which can withstand moisture stress and produce high yield under such environment. A two year field experiment was carried out at the University of Jordan Research Station in the Jordan Valley. Six genotypes of chickpea; four Kabuli type and two desi type were evaluated. A line source sprinkler system was used to obtain the desired pattern of water application. Measurement on yield and yield components and other agronomic traits was made. Drought Susceptibility Index (DSI) and Water Use Efficiency (WUE) were also measured for the studied characters. Genotypes behaved differently in response to water levels for their seed yield and other characters. FLIP-98-107 gave the highest seed yield at the intermediate water level (W3) and the seed yield decreased as water level increased to W4 and W5 or decreased to W2 and W1. Results further indicated that the WUE of high yielding and/or early genotypes was better than that of the low yielding and late maturing genotypes at the lowest two water level treatments (W1 and W2). The most important traits that contribute to the ability of these genotypes to tolerate moisture stress conditions are: high harvest index, earliness, high number of pods and number of seeds per plant.

KEYWORDS: Breeding for drought conditions, line source irrigation system, moisture stress.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important food legume which is grown in most geographical regions; the tropical, sub-tropical and temperate regions. Two main types of chickpeas, desi and Kabuli, are cultivated in the world.

Chickpea can experience two types of drought: intermittent drought stress caused by breaks in winter rainfall; and terminal drought stress, resulting from receding soil moisture at the late stage of the crop growth. Significant chickpea yield losses due to inadequate soil moisture availability were reported, and up to a 50% increase in chickpea production was achieved when moisture stress was alleviated (Saxena et al., 1993; Subbaro et al., 1995).

Results from a study carried out under field conditions in Syria revealed that supplemental irrigation significantly increased grain yield of different chickpea genotypes, although there was less increase in grain yield in the wet seasons than in the dry seasons (Zhang, et al., 2000).

Genotypic differences in drought resistance levels has great practical relevance. In this regard, Saxena (1987) and Saxena et al. (1993), reported genotypic differences in drought tolerance levels in chickpea. Brown et al. (1989) reported lower yield in later maturing variety tested together with early varieties under field conditions in Syria where moisture stress was a limiting factor. Likewise, Silim and Saxena (1993) found that cultivars varied significantly in grain yield response and yield components as related to moisture supply. This was attributed to early phenology differences, high harvest index and a deep root system.

One way of improving the low productivity of chickpea in drought environments is to develop varieties,

* Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia; and Faculty of Agriculture, University of Jordan.
Received on 8/11/2004 and Accepted for Publication on /10/2005.

Table1. Amount of applied water and rainfall received at the Jordan valley experimental site on the different irrigation gradients during 2001 /2002 and 2002/2003 growing seasons.

Variable	Water levels				
	W1	**W2**	**W3**	**W4**	**W5**
Seasonal amount of water received (mm)					
2001/2002 Season					
a.) Irrigation (15*)	119.4	199.5	280.5	313.5	331.5
b) Rainfall	181.5	181.5	181.5	181.5	181.5
c) Total	300.9	381.0	462.0	495.0	513.0
2002/2003 Season					
a) Irrigation (4*)	39.8	66.5	93.6	104.5	110.5
b) Rainfall	267.8	267.8	267.8	267.8	267.8
c) Total	307.6	334.3	361.4	372.3	378.3

* Figures in parenthesis refer to number of irrigations.

which can withstand moisture stress and produce high yield under such environment. The line-source sprinkler technique has been successfully used to create moisture gradients suitable for comparing moisture response of different genotypes (Hanks et al., 1976; Johansen et al., 1994). Therefore, this study was undertaken to:

- study the response of genotypes to soil moisture gradient and its effect on yield and yield components;
- identify the traits that are most sensitive to moisture stress; and
- suggest criteria to improve crop stability under moisture stress conditions.

MATERIALS AND METHODS

Experimental Site

Field experiments were carried out for two years from the end of November to early June (2001/2002) and late December to early April (2002/2003) at the University of Jordan Research Station in the Jordan Valley. The station is located at - 240 meters below sea level. The soil in the 0-40 cm layer is sandy clay loam, and at the 40-100 cm depth is clay loam. The climate of the Jordan Valley is characterized by a moderate winter and hot summer.

Treatments

Six chickpea genotypes, four Kabuli and two desi, were evaluated. The Kabuli genotypes were: FLIP-97-241, FLIP-98- 107, FLIP-93-55, and FLIP-97-99 received from the International Center for Agricultural Research in the Dry Areas (ICARDA). The desi genotypes were: DZ-10-92 and DZ-10-11 received from the Ethiopian National Program.

Five water level gradients (W1 to W5) were created. W1 was the lowest and most stressed, while W5 was the highest. A line source sprinkler system was used to obtain the desired triangular pattern of water application as described by Hanks et al. (1976). The system used was with Rain bird 30 B sprinklers on 6 meter spacings. The highest soil moisture level (W5) was sustained at 30-50 centi bar in 2001/2002 and 50-75 centi bar in 2002/2003. Tensiometers were installed at the 15, 30, and 60 cm soil depth. Irrigation was applied in the early morning when wind speeds were very low.

The average irrigation treatments (about two hours time) were:

W1 = 8 mm/irrigation, W2 = 13 mm/irrigation, W3 = 19 mm/irrigation,W4 = 21 mm/irrigation, W5 = 22 mm/irrigation.

Thirty treatment combinations were used in the experiment. Data on date, depth and frequency of irrigation were recorded for each treatment. Water application rates and depths were measured using pressure gauge and catch cans. The amount of water applied to each plot was measured for each irrigation, by placing plastic catch cans in the peripheries of the four replications. A total of fifteen irrigations during the 2001/2002 cropping season and four irrigations during the 2002/2003 season were applied on the basis of the treatment requirement, which was determined by tensiometer reading. The amount of water applied and rainfall received during the 2001/2002 and 2002/2003 growing season are shown in Table (1).

Table 2: significance of mean square of treatments and their interaction in the line source study during 2001/2002 and 2002/2003 seasons.

Source of variation 2001/2002	**Grain yield**	**Harvest index**	**Pods/plant**	**Seeds/plant**	**Seeds/pod**	**100 seed weight**	**Primary branches/ plant**
Water levels	**	**	**	**	*	**	**
Genotypes	**	**	**	**	**	**	**
Genotypes X water level	**	**	*	**	ns	ns	*
	Secondary branches/plant	Days to flower	Days to maturity	Plant height	Leaf area index	Water use efficiency	
Water levels	**	ns	**	**	**	*	
Genotypes	**	**	**	**	**	**	
Genotypes X water level	ns	**	**	ns	ns	**	
2002/2003	Grain yield	Harvest index	Pods/plant	Seeds/plant	Seeds/pod	100 seed weight	Primary branches/ plant
Water levels	ns	ns	ns	ns	ns	ns	ns
Genotypes	**	**	**	**	ns	**	**
Genotypes X water level	ns	ns	ns	ns	ns	ns	ns
	Secondary branches/plant	Days to flower	Days to maturity	Plant height	Leaf area index	Water use efficiency	
Water levels	ns	ns	ns	ns	ns	ns	
Genotypes	**	**	**	**	ns	**	
Genotypes X water level	ns	ns	ns	ns	ns	ns	

**, *, ns= mean square significant at 5%, I% and non significant respectively

Experimental Design and Agronomic Practice

The experimental design was a split-plot with water level treatments as the main plots and genotypes as sub plots. However, as the nature of the line source did not allow for randomizing the main plot (Hanks et al., 1976), only the sub-plot treatments were randomized. The size of the experimental plot was 3.8 m^2 (1.8 m x 2.1 m). Seeds were planted in rows with spacing of 30 cm between rows and 10 cm between plants, which maintained a plant population of 33 plants $m^{2\ -1}$ (Haddad, 1983). Row direction was established parallel to the line source sprinkler to avoid runoff.

Fertilizer was applied at the rate of 20 Kg N ha^{-1} and 40 Kg P_20_5 ha^{-1} before planting in the form of Di Ammonium Phosphate (DAP), 18% N and 46% P_2O_5. During the growing season 2002/2003, the crop was sprayed eight times with the fungicide Zeneb, as the incidence of ascochyta blight disease was high during the season.

Soil Moisture Measurements

To monitor soil moisture, aluminum access tubes 58 mm in diameter and 1.2 m long were placed in the center of each experimental plot in two replicates. Measurement was made, before each irrigation, with a neutron moisture meter (NMM), hydroprobe model 503 DR Matinez. CA. USA. The NMM was calibrated in situ against gravimeterically determined soil water at the beginning and conclusion of the experiment.

Water Budget

The amount of water depleted (evapotranspiration, ET) by the crop was calculated from applied irrigation water, rainfall, and the change in stored soil moisture, following the water balance method:

$ET = I + P - R - dD + \Delta SM$. Where ET = Evapotranspiration , I = Irrigation, P = Rainfall, R = Runoff , dD = Deep percolation and Δ SM = Change in soil water content.

The drainage water was estimated for each irrigation event, as used by Abu-Awwad (2001).

Data Collection

The following observations were taken on a plot basis: Days to flowering, days to maturity, seed yield (Kg ha^{-1}), Harvest Index (HI), water use efficiency (Kg ha^{-1} mm^{-1}). The following measurements were taken from ten random plants at maturity, and converted to per plant: number of primary branches, number of secondary branches, plant height (cm), number of pods per plant, number of seeds per plant, number of seeds per pod and 100-seed weight

Drought Susceptibility Index (DSI)

The index of Fischer and Maure (1978), was used to calculate the drought susceptibility index of seed yield and yield components grown under the most water stressed (W1) and optimum (W3) water regime treatments.

Statistical Analysis:

All the above data were analyzed statistically using the analysis of variance (ANOVA) technique by MSTAT-C program.

RESULTS

Water Budget

Soil moisture content (measured before irrigation) varied considerably among the water level treatments. During the 2001/2002 season, the highest soil moisture was recorded at the highest water level (W5) and the lowest at the lowest water level treatment (W1) (figure1a). The results further indicate that the highest cumulative amount of applied water (Irrigation and Rainfall) was recorded during the months of March and April and the lowest in December (early growing stage of the crop) at each water level treatment (figure 1b).

In the 2002/2003 growing season, the soil moisture content was uniform and high for all water levels treatment during planting (17/12/2003) to early pod setting stage (15/03/2003) of the crop. The plants did not suffer from moisture deficiency at all water levels. Therefore, only the results of the agronomic traits will be presented for this growing season for comparison purpose.

Effect of Soil Moisture Levels and Genotype on Yield and Yield Components

The effects of genotypes, water levels and their interactions during the two growing seasons are presented in table (2). In the first growing season, the main treatments' effects were significant for all the studied characters. However, the interaction effect was significant for 9 out of 13 characters. In the second growing season, only the genotype effect was significant, whereas the water levels and the interaction were not significant for all studied characters.

Yield and Yield Component and Other Agronomic Characters

Under this section, we will present first the characters which showed a significant interaction, then we will present the main effect for the characters which did not have such interaction.

Results of the 2001/2002 Growing Season

Grain Yield and Harvest Index: At the lowest water level treatment (W1), DZ-10-11 gave the highest yield which was 17% higher than the second yielder FLIP-98-107 and FLIP-93-255 gave the lowest yield (Table 3). The yield was reduced significantly as the water level was increased from the intermediate water level treatment (W3) to the wettest (W5). The reduction was in the range of 14% to 33.2%.

The highest value of harvest index (40%) was obtained from DZ-10-11 at W4 water level (Table 3). The same genotype had the highest harvest index at W1. On the other hand, and at W3, the maximum harvest index (38%) was produced by FLIP-98-107 and the lowest (32.8%) by DZ-10-92. Also, most of the tested genotypes had their highest harvest index at W3, and further deviation from this level resulted in appreciable reduction in harvest index for all of the tested genotypes, except for DZ-10-11.

Number of Pods and Seeds Per Plant: At W1, DZ-10-11 produced the highest number of pods (37.9) and seeds (40.1) per plant among the tested genotypes. Furthermore, as the soil moisture increases beyond W3 the number of pods and seeds per plant starts to decrease. It is clear that the desi type gave higher number of pods and seeds per plant than the Kabuli.(table 4).

Days to flowering and days to maturity: The days to 50% flowering was hastened, in the desi types by 5 days at the lowest water level treatments (W1 and W2), in contrast to that, flowering time for Kabuli types was delayed with the decrease in soil moisture, although the difference among each group was not high (Table 5). The number of days to maturity for most of the tested

Table 3. Mean grain yield (Kg ha^{-1}) and harvest index (%)of chickpea genotypes as affected by different water levels grown at the Jordan Valley, during the 2001/2002 growing season.

	Genotypes						
Water levels	**FLIP 97-241**	**FLIP 93-255**	**DZ 10-11**	**FLIP 97-99**	**FLIP 98-107**	**DZ 10-92**	**Means**
				Grain Yield (Kg ha^{-1})			
W1	1052 k-m	500 n	1476 e-j	908 lm	1225 i-l	953 l-m	**1018 C**
W2	1506 e-j	745 m-n	1631 c-g	1376 g-k	1817 b-e	1400 g-k	**1412 B**
W3	1747 b-g	1413 f-k	1958 a-d	2055 ab	2281 a	1816 b-e	**1879 A**
W4	1777 b-f	1242 h-l	1687 c-g	1996 a-c	1578 e-j	1611 d-h	**1648 AB**
W5	1494 e-j	1100 kl	1401 g-k	1594 d-i	1718 b-g	1212 j-l	**1420 B**
Means	**1515 BC**	**1000 D**	**1631 AB**	**1584 AB**	**1724 A**	**1398 C**	
				Harvest Index (%)			
W1	24.2 h-j	14.7 l	31.1c-g	22.2 i-j	29.9 i-h	25.5 g-i	**24.6 C**
W2	29.6 d-h	17.4 k-l	35.6 a-d	31.0 c-h	31.4 b-g	31.6 b-g	**29.4 BC**
W3	32.9 b-f	34.1 a-e	37.3 a-c	34.2 a-e	38.0 ab	32.8 b-f	**35.0 A**
W4	28.8 d-i	31.0 c-h	40.0 a	28.7 e-i	26.0 f-i	27.0 f-i	**30.3 AB**
W5	26.6 f-i	25.8 g-i	28.3 e-i	27.5 e-i	27.3 e-i	19.1 j-l	**25.8 BC**
Means	**28.4 BC**	**24.6 D**	**34.5 A**	**28.7 BC**	**30.5 B**	**27.2 C**	

* For each character, means within water levels, genotypes, and their interactions followed by the same letter (s) are not significantly different at the 5% probability level according to DMRT.

Table 4. Mean number of pods and seeds per plant of chickpea genotypes as affected by different water levels grown at the Jordan Valley, during the 2001/2002 growing season.

	Genotypes						
Water levels	**FLIP 97-241**	**FLIP 93-255**	**DZ 10-11**	**FLIP 97-99**	**FLIP 98 -107**	**DZ 10-92**	**Means**
				Pods per plant			
W1	21.9 h-m	6.1 m	37.9 b-d	6.9 lm	25.4 f-k	25.2 f-k	**23.8 B**
W2	24.6 f-l	18.3 k-m	39.2 bc	20.3 i-m	28.8 e-h	30.7 d-g	**27.0 B**
W3	27.8 e-j	33.0 ef	49.1 a	27.6 e-j	32.4 e-f	43.7 ab	**35.6 A**
W4	29.1 e-h	20.9 h-m	37.3 b-d	26.5 f-k	23.5 g-m	37.1 b-d	**29.1 B**
W5	27.9 e-i	19.4 j-m	35.8 b-e	22.7 g-m	27.0 f-j	23.6 g-m	**26.1 B**
Means	**26.3 C**	**21.5 D**	**39.9 A**	**22.8 D**	**27.4 C**	**32.0 B**	
				Seeds per plant			
W1	22.2 j-m	15.8 m	40.1 cd	16.7 lm	23.7 h-l	26.6 g-k	**24.2 C**
W2	27.4 gh	16.4 lm	51.4 ab	21.8 j-m	32.0 e-g	36.8 de	**31.0 B**
W3	31.2 e-h	28.8 f-j	57.7 a	32.7 k-g	35.6 d-f	49.5 b	**39.3 A**
W4	30.2 e-i	19.4 k-m	46.7 bc	27.6 g-j	22.7 i-m	40.8 cd	**31.2 B**
W5	28.3 f-j	19.4 k-m	40.6 cd	22.1 j-m	26.2 g-k	27.5 g-j	**27.4 BC**
Means	**27.9 C**	**20.0 E**	**47.3 A**	**24.2 D**	**28.0 C**	**36.3 B**	

* For each character, means within water levels, genotypes, and their interactions followed by the same letter (s) are not significantly different at the 5% probability level according to DMRT.

Table 5. Mean number of days to flowering and to maturity of chickpea as affected by different water levels and genotypes grown at the Jordan Valley, during the 2001/ 2002 growing season.

	Genotypes						
Water levels	**FLIP 97-241**	**FLIP 93-255**	**DZ 10-11**	**FLIP 97-99**	**FLIP 98-107**	**DZ 10-92**	**Means**
				Days to flowering			
W1	93 bc	108 a	61 i-j	90 c-e	89 c-e	60 j	**84 A**
W2	95 b	108 a	60 j	90 c-e	91 b-d	61 i-j	**84 A**
W3	90 c-e	105 a	66 g-i	86 d-f	85 e-f	64 h-j	**83 A**
W4	90 c-e	105 a	64 h-j	85 e-f	84 f	69 g	**83 A**
W5	90 c-e	105 a	64 h-j	85 e-f	84 f	68 g-h	**83 A**
Means	**92 B**	**106 A**	**63 D**	**87 C**	**86 C**	**65 D**	
				Days to maturity			
W1	137 i-j	152 a-c	118 m	135 j-k	134 jk	126 l	**134 D**
W2	141 f-i	152 bc	129 kl	143 e-h	137 ij	134 jk	**140 C**
W3	146 d-f	154 ab	133 jk	142 e-i	144 d-g	139 g-j	**143 BC**
W4	148 c-e	155 ab	138 hj	150 b-d	147 c-f	138 hj	**146 AB**
W5	152 bc	158 a	144 e-h	145 d-g	146 d-f	142 e-i	**148 A**
Means	**145 B**	**154 A**	**132 E**	**143 BC**	**142 C**	**136 D**	

* For each character, means within water levels, genotypes, and their interaction followed by the same letter (s) are not significantly different at the 5% probability level according to DMRT.

Table 6: main effect for several characters under first season.

LAI	Plant height (cm)	Secondary branches/plant	Primary branches/plant	100 seed weight (gm)	Seed/pod	Treatment
						Genotypes
3.2 b	79.3 a	7.53 b	2.46 a	25.9 b	1.059 bc	Flip-97-241
2.7 c	63.0 cd	9.81 a	2.45 a	20.8 b	0.993 c	Flip-93-255
3.4 ab	62.4 d	7.15 b	2.11 b	11.4 e	1.197 a	DZ-10-11
3.3 b	67.0 c	8.00 b	2.25 ab	28.5 a	1.025 bc	Flip-97-99
3.3 b	74.9 b	10.11 a	2.35 a	25.5 b	1.014 c	Flip-98-107
3.7 a	55.9 e	7.70 b	2.37 a	13.5 d	1.121 b	DZ-10-92
0.13	2.2	0.311	0.064	0.28	0.03	SE
						Water level
2.3 b	51.0 d	5.90 c	2.13 b	20.1 c	1.013 b	W1
2.7 b	60.0 c	6.70 c	2.20 b	20.8 b	1.114 ab	W2
3.6 a	67.8 b	8.70 b	2.29 b	21.7	1.135 a	W3
3.8 a	76.0 a	9.55 ab	2.35 b	21.7 a	1.054 a-c	W4
3.9 a	81.0 a	11 a	2.70 a	21.5 a	1.046 a-c	W5
0.17	1.5	0.54	0.08	0.15	0.03	SE
17	10	17	12	6.0	11	CV (%)

**, *, ns= mean square significant at 5%, I% and non significant respectively.

genotypes was extended as the water level was increased from the lowest (W1) to the highest (W5). The earliest (129 days) and the latest maturity (158 days) was recorded for DZ-10-11 and FLIP-93-255, respectively, at W2 and W5.

Seeds Per Pod and Hundred Seed Weight: Number of seeds per pod under the most stressed plot (W1) was lower by 107% than under W3 treatment (Table 6). The highest seed weight was obtained from FLIP-97-99 followed by FLIP-98-107 which gave seeds two folds heavier as compared to DZ-10-11 and DZ-10-92.

Table 7. Mean water use efficiency (Kg ha^{-1} mm^{-1}) for seed yield of chickpea genotypes as affected by different water levels grown at the Jordan Valley, during the 2001/2002 growing season.

	Genotypes						
Water levels	**FLIP 97-241**	**FLIP 93-255**	**DZ 10-11**	**FLIP 97-99**	**FLIP 98-107**	**DZ 10-92**	**Means**
W1	3.5 e-h	1.6 m	5.2 a	3.0 h-k	4.1 b-f	3.3 f-i	**3.4 AB**
W2	3.9 c-g	1.9 lm	4.6 a-c	3.6 d-h	4.8 ab	3.9 c-g	**3.8 AB**
W3	3.8 c-h	3.1 g-k	4.6 a-c	4.4 a-d	4.9 ab	4.3 b-e	**4.2 A**
W4	3.7 d-h	2.4 j-l	3.6 d-h	4.2 b-e	3.2 g-j	3.6 d-h	**3.5 AB**
W5	3.1 g-k	2.3 k-m	3.1 g-k	3.3 f-i	3.6 d-h	2.6 i-l	**3.0 B**
Means	**3.6 B**	**2.3 C**	**4.2 A**	**3.7 B**	**4.1 A**	**3.5 B**	

* Means within water levels, genotypes, and their interactions followed by the same letter (s) are not significantly different at the 5% probability level according to DMRT.

Table 8. Mean susceptibility index values for some characters of the tested genotypes grown at the Jordan Valley, during the 2001/2002 season.

		Number of			
Genotype	**Seed yield**	**Pods per plant**	**Seeds per plant**	**Seeds per pod**	**Hundred seed weight**
FLIP-97-241	0.868	0.648	0.750	0.828	0.890
FLIP-93-255	1.411	1.561	1.176	1.040	1.034
DZ-10-11	0.538	0.696	0.797	0.823	0.835
FLIP-97-99	1.228	1.183	1.269	1.469	1.269
FLIP-98-107	1.010	0.652	0.867	1.232	0.898
DZ-10-92	1.040	1.290	1.210	0.622	0.925
Mean	1.016	1.005	1.011	1.002	0.973
DII*	0.458	0.329	0.384	0.107	0.074

* DII = Drought intensity index

Table 9: The mean values for several characters for three chickpeas genotypes grown under the Jordan Valley Conditions during the 2002/2003 growing season

Genotypes	**Characters**										
	Grain Yield Kg/ha	**Harvest index %**	**pods per plant**	**Seeds per plant**	**Hundred seed wt. (g)**	**Primary branchs**	**Secon-dary branchs**	**Days to flower.**	**Days to matur.**	**Plant height**	**WUE**
FLIP-97-241	1448 b	29.0 b	27.8 b	24.9 b	31.1 a	2.7 a	7.1 a	81 a	130 a	81 a	4.3 b
FLIP-97-99	1384 b	29.3 b	17.7 c	19.0 c	29.2 b	2.4 b	5.7 b	80 a	129 a	69 c	4.0 b
FLIP-98-107	1807 a	34.2 a	28.3 a	30.9 a	29.6 b	2.8 a	7.5 a	72 b	122 b	77 b	5.2 a
SE	53.5	1.13	0.9	1.1	0.42	0.1	0.34	1.6	0.45	1.6	0.15
C.V. (%)	15.3	16	17.5	19.1	6.25	15	23.8	9.1	1.6	9.3	15

*For each character, means followed by the same letter (s) are not significantly different at the 5% probability level according to DMRT.

Primary and Secondary Branches: The highest values for these parameters, respectively, (2.7 and 11) were obtained at W5 and the lowest (2.13 and 5.9) at W1 (Table 6). The highest number of primary and secondary branches was produced by FLIP-98-107 and the lowest by DZ-10-11. The number of branches among the other genotypes was observed to be comparable.

Plant Height: Plant height was markedly decreased from 81 cm to 51 cm, as the water level was decreased from W5 to W1 (Table 6). The shortest plant height (55.9 cm) was produced by DZ-10-92 and the tallest (79.3 cm) by FLIP-97-241. In general, Kabuli types were taller than the desi type.

Leaf Area Index (LAI): Relative to the mean leaf area index of the wettest plot (W5) the reductions were 31% and 41% for the second W2 and first W1 water levels, respectively. The highest LAI value (3.7) was obtained from DZ-10-92 genotype followed by DZ-10-11 (3.4). The lowest (2.7), on the other hand, was produced by FLIP- 93-255.

Water Use Efficiency (WUE): Results in table (7) shows that water use efficiency of the tested genotypes vary at the different water level treatments. At the intermediate level (W3), FLIP-98-107 was superior in efficient utilization of water and production of high seed yield per unit of water consumed (4.9 Kg ha^{-1} mm^{-1}) and FLIP-93-255 genotype was the least efficient in water utilization. At the driest water level treatment (W1), however, the highest WUE value (5.2 Kg ha^{-1} mm^{-1}) was obtained from DZ-10-11 and the lowest (1.6 Kg ha^{-1} mm^{-1}). WUE value for FLIP-98-107 and DZ-10-11 was significantly higher than that of the other genotype.

Drought Susceptibility Index (DSI): Lowest DSI was reported with DZ- 10-11 with a value of 0. 538 followed by FLIP-97-241, FLIP-98-107 with index values of 0.868 and 1.01, respectively (Table 8). Whereas the highest value of the DSI (1.411) was obtained by FLIP-93-255 followed by FLIP-97-99 (1.228).

Drought intensity index for seed yield (0.458), number of seeds per plant (0.384) and pod per plant (0.329) were higher than those of seed per pod (0.107) and hundred seed weight (0.0743).

Results of the 2002/2003 Growing Season

As we indicated earlier, the experiment in the second growing season received high amounts of rainfall, which did not allow creation of soil moisture gradient specially at the low moisture levels. Furthermore, the genotypes were severely affected by the ascochyta blight disease which resulted in killing three of the tested genotypes which were found to be highly susceptible, these genotypes are the two desi and FLIP-93-255, DZ-10-11 and DZ-10-92. On the other hand, the other three genotypes were found to be highly resistance to the disease. This is an important finding for chickpea breeders, when they breed for resistance of the disease.

Similar to the results of the 2001/2002 season, FLIP-98-107 gave the highest yield (1807.8 Kg Ha^{-1}) and the highest harvest index (34.23%). This genotype was highly resistant to the ascochyta blight race prevailing in this area. FLIP-98-107 also gave the highest pods and seeds per plant. This genotype was earlier in flowering by about 9 days and in maturity by 3 days as compared to the other two genotypes. In confirmation to this, FLIP-98-107 gave the highest water use efficiency (5.2 Kg ha^{-1} mm^{-1}) (table 9). FLIP-97-242 gave the tallest plants (81 cm) which exceeded significantly FLIP-97-99 by 12 cm and FLIP-98-107 by 4 cm. FLIP-98-107 and FLIP-97-241 gave the highest primary (2.8) and secondary branches (7.3).

DISCUSSION

Breeders are trying hard to increase seed yield of chickpea either by direct selection for seed yield or through the selection for yields' contributing characters. However, under arid and semi arid environments, where moisture is limited for achieving the crop yield potential, selecting genotypes for wide adaptation and high stability across variable environments is a useful strategy, which ensures the production of an economic yield under variable soil moisture conditions. This is even more important for subsistence farming, where farmers grow the crop mainly for their family consumption.

Genotypes behaved differently in response to water levels for their seed yield and other characters. FLIP-98-107 gave the highest seed yield at the intermediate water level (W3) and the seed yield decreased as water level increased to W4 and W5 or decreased to W2 and W1. All genotypes behaved similarly in response to the increased water levels, especially at the highest water level W5. This can be attributed to excessive moisture, which resulted in excessive vegetative growth, causing poor flower setting and yield reduction. This was reflected in the reduction of the harvest index values as well as on smaller pods and seeds produced when soil moisture increased behind W3. These results are is in agreement with the findings of Saxena and Yadav (1976), and Saxena (1984). According to those researchers, irrigation tends to cause excessive growth which leads to lodging and yield reduction.

The results are further confirmed by the Water Use Efficiency (WUE) data, where the highest WUE values were recorded under W3 and then the values start to decline as water levels (soil moisture) increase. The genotype FLIP-98-107 was found to be more efficient in utilizing water at this level. This result indicates that the optimum water level for optimum or maximum seed yield is the intermediate water level treatment (W3) and not the maximum (W5). This result is especially important when chickpea is grown under full or supplemental irrigation; an excess of irrigation water will result in yield reduction, and therefore, careful irrigation management is needed for optimum yield.

The result also revealed that further decline of the water level from the optimum (W3) to the driest water level treatment (W1) resulted in marked reduction in seed yield, harvest index, and seed yield components of the tested genotypes. DZ-10-11 and FLIP-98-107 were superior, as compared to the other tested genotypes, for most of the yield related traits, they are also found to be early in flowering and in maturity under the low soil moisture levels W1 and W2, which indicate their tolerance to moisture stress conditions under this study. Saxena et al. (1997) in support of this idea also reported that early flowering and podding restrict vegetative growth in indeterminate crop like chickpea. However, relatively higher temperatures faced by the late-maturing crop will also reduce seed yield. Siddique et al. (2001) reported that the major traits of adaptation for chickpea producing large yields in the short season environment are early flowering, pod and seed set before the onset of terminal drought. Brown et al. (1989) who worked under field condition in a Mediterranean environment, found significant differences in harvest index among genotypes, where late maturing genotypes gave lower harvest index. Therefore, in formers' situations a compromise is necessary between the reduced seed yield potential of short-duration cultivars and the losses caused by the end of season drought.

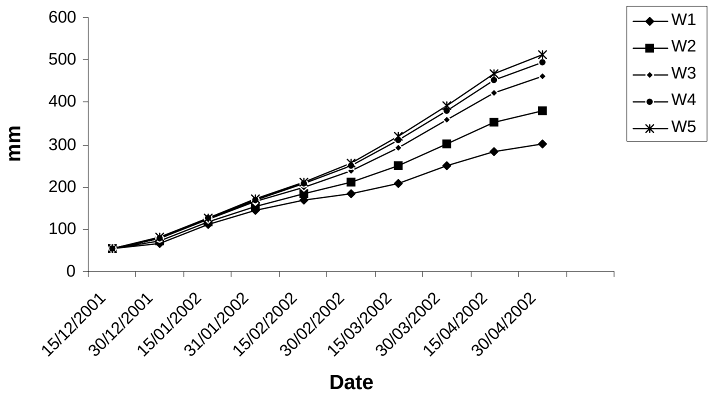
Results further indicated that the WUE of high yielding and/or early genotypes was better than that of the low yielding and late maturing genotypes at the lowest two water level treatments (W1 and W2). This is in agreement with the results of other similar studies on chickpea by Saxena (1987); EL-Waraky and EL-Kolley (2001); and on beans by Boutraa and Sanders (2001).

It should be noted that DZ-10-11 gave the highest seed yield under the lowest water level (W1) which was 27.6% more than the yield of FLIP-98-107 which ranked second. It has also the lowest Drought Susceptibility Index (DSI) (0.538) for seed yield which indicates its adaptability to low moisture growing environments. The second genotype which had such behavior is FLIP-98-107; it has the second low DSI value (1.01). However, FLIP-98-107 has a wide adaptation as it continues to perform well under increasing moisture level, where it gave the highest yield among the tested genotypes at the highest water level. FLIP-98-107, was also found superior in seed yield and its components, harvest index and WUE in the second growing season over the other two tested genotypes. These two genotypes are potential genotypes that have drought tolerance ability and wider adaptation to the variable soil moisture content. Similar to these findings, Singh et al. (1986) identified genotypes with high mean yield and stability in changing environment using DIS. However, and in contrast to that, Singh and Bejiga (1990) reported that their stable lines were average yielder whereas the unstable lines were high yielding.

Similarly, the higher harvest index at the most stressed water level (W1) was obtained from the highest yielding genotypes, DZ-10-11 and FLIP-98-107, compared with the low yielding genotypes, FLIP-93-255 and FLIP-97-99. This is rather expected, because more grain as compared to straw yield is produced by high yielding genotypes under the water-limited environments and therefore, higher harvest index will be achieved. According to Boyer (1996), crop genotypes which are successful under water limiting environment display higher harvest index as compared to the poorer performance. Therefore, harvest index is a good selection criteria and need to be considered in developing a strategy for crop improvement under moisture stress.

Days to 50% flowering was hastened by 5 days for the desi genotypes DZ-10-11 and DZ-10-92 at the two lowest water level treatments (W1 and W2), in contrast to that, flowering time for Kabuli genotypes was delayed with increasing moisture stress, although the difference among each group was not large. This indicates that the two groups of chickpeas (desi and Kabuli) respond differently to moisture stress for this character.

Figure 1 b: Cumulative amount of water applied (Irrigation and Rainfall), during 2001/2002 growing season.



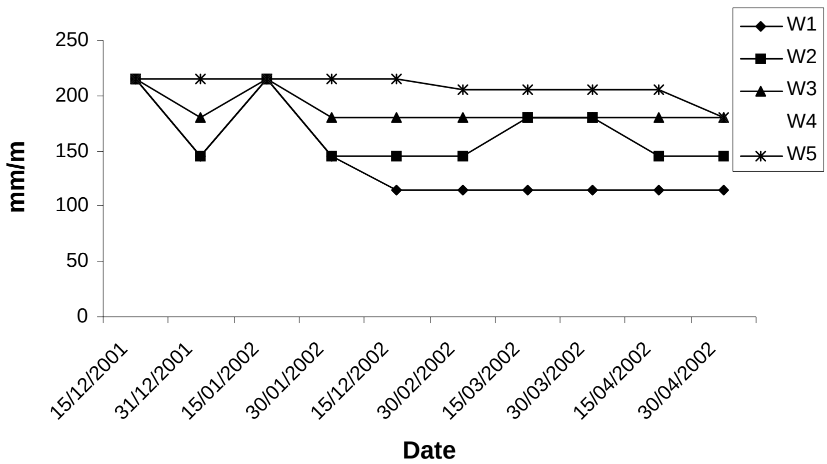


Figure 1a : Change in soil moisture (as measured by neutron probe), during 2001/2002 growing season.

On the other hand, maturity time for most of the tested genotypes was reduced as the water level was declined from wettest (W5) to the driest (W1). This could be interpreted as a shortening of their vegetative period to escape the drought conditions. Thus, their transformation into the reproductive phase assures their seed production (survival) under the existing low soil moisture condition which has similar effect in the final yield of the crop, as it is in genotype like DZ-10-11. The above findings are in agreement with that reported by Weaver et al. (1983) and Ramirez-Vallejo and Kelly (1998).

Primary branches are important characters because they determine to some extent the potential of the plant to produce straw and possibly grain if all other factors are optimum. Whereas the importance of studying the secondary branches is because the majority of pods and leaves are carried on them. These parameters as well as plant height and leaf area index of chickpea were substantially reduced with a decline in the water level treatments. Several researchers indicated lower number of primary and secondary branches (Rahman and Uddin, 2000; El-Waraky and El-Koliey, 2001) and reduced plant height (Rahman et al., 2000) with an increase in soil moisture stress level which also differed among the genotypes of chickpea.

In conclusion, chickpea genotypes differ in their response to soil moisture levels. Two genotypes, FLIP-98-107 and DZ-10-11, showed high performance under low moisture situations, and had wide adaptability over the moisture gradient. The most important traits that contribute to the ability of these genotypes to stand moisture stress conditions are: high harvest index, earliness, high number of pods and number of seeds per plant. These traits need to be considered by breeder for the improvement of chickpea germplasms for drought condition.

REFERENCES

Abu-Awwad, A.M. 2001. Influence of Different Water Quantities and Qualities on Lemon Trees and Soil Salt Distribution at the Jordan Valley. *Agricultural Water Management,* 52: 53-71.

Brown, S.C., Gregory, P.J., Cooper, P.J.M., and Keatinge, J.D.J. 1989. Root and Shoot Growth and Water Use of Chickpea (*Cicer arietinum* L) Grown in Dryland Conditions: Effects of Sowing Date and Genotype. *Journal Of Agricultural Science,* 13 (1): 41-50.

Boutraa, A., and Sander, F.E. 2001. Influence of Water Stress on Grain Yield and Vegetative Growth of Two Cultivars of Bean (*Phaseolus vulgaris* L.). *Journal of Agronomy and Crop Science,* 187 (4): 251.

Boyer, J.S. 1996. Advances in Drought Tolerance in Plants. Advances in Agronomy, 56: 187-218.

El-Waraky M. K., and El-Koliey, M.M. 2001. Response of Two Chickpea Genotypes to Irrigation at Different Physiological Stages of Growth. *Assiut Journal of Agricultural Science,* 31: 137-149.

Fischer, R.A., and Maurer, R. 1978. Drought Resistance in Spring Wheat Cultivars I. Grain Yields Responses. *Australian Journal of Agricultural Research*, 29:897-912.

Haddad, N. 1983. Effect of Date of Planting and Plant Population on the Yield of Chickpea (*Cicer arietinum* L.) in Jordan. *Dirasat,* 10 (1): 117-128.

Hanks, R.J., Keller, J., Rasmusssen, V.P., and Wilson, G.D. 1976. Line Source Sprinkler for Continues Variable Irrigation-crop Production Studies. *Soil Sci. Soc. Amer. J.* 40: 426-429.

Johansen, C., Krishnamurthy, L., Saxena, N.P., and Sethi, S.C. 1994. Genotypic Variation in Moisture Response of Chickpea Grown Under Line-source Sprinklers in Semi-arid Tropical Environment. *Field Crops Research*, 37: 103-112.

Rahman, S.M.L., and Uddin, A.S.M. 2000. Ecological Adaptation of Chickpea (*Cicer arietinum* L.) to Water Stress. Grain Yield, Harvest Index, Flowering and Maturity Studies. *Legume Research,* 23 (1): 1-8.

Rahman, S.M.L., Nawata, E., Sauratani, T., and Uddin, A.S.M. 2000. Ecological Adaptation of Chickpea (*Cicer arietinum* L.) to Water Stress- 1. Effect of Water Stress on Leaf Area Development, Growth, Biomass Accumulation and Stress Period of Chickpea Varieties Collected from Different Agro Ecological Regions. *Legume Research*, 23 (3): 141-145.

Ramirez-Vallejo, P. and Kelly, J.M. 1998. Traits Related Drought Resistance in Common Beans. *Euphytica*, 99: 127-136.

Saxena, M.C. 1984. Agronomic Studies on Winter Chickpeas. 123-137. In Saxena, M.C. and Singh, K.B. (eds), Ascochyta Blight and Winter Sowings of Chickpea. ICARDA, Aleppo, Syria.

Saxena M.C. 1987. Agronomy of chickpea. In: The Chickpea. 207-232. Saxena, M. C. and Singh K.B. (Eds). Commonwealth Agricultural Bureax International, Walingford. CAB International, UK.

Saxena, N.P., Saxena, M.C., and Johnson, C. 1997. Chickpea Ideotypes for Low-and High Input Conditions. In: A.N. Asthana and M. Ali (eds.), Recent Advances in pulse Research, 217-231. Indian Society of Pulses Research and Development, Indian Institute of Pulses Research (IIPR). Kanpur, India.

Saxena, M.C. and Yadav, D.S. 1976. Some Agronomic Consideration of Pigeonpeas and Chickpeas. In Proceeding of the International Workshop on Grain Legumes. ICRISAT, Hyderabad, India, 31-62.

Saxena, N.P., Johnsen, C., Saxena, M.C., and Silm, S.N. 1993. Selection for Drought and Salinity Tolerance in Cool Season Legumes. 245-270. In Singh, K. B. and Saxena M.C. (eds.), Breeding for Stress Tolerance in Cool-Season Food Legumes. John Wiley and Sons, a Co-publication with the International Center for Agricultural Research in the Dry Areas (ICARDA) and Sayce Publishing: United Kingdom.

Siddique, K.H.M., Regan, K.L., Tennant, D., and Thomson, B.D. 2001. Water use and Water Use Efficiency of Cool Season Grain Legumes in Low Rainfall Mediterranean-Type Environments. *European Journal of Agronomy,* 15 (4): 267-280.

Silim, S.N., and Saxena, M.C. 1993. Adaptation of spring-sown chickpea to the Mediterranean Basin I. Response to Moisture Supply. *Field Crop Research,* 34 (2): 121-136.

Singh K.B. and Bejiga G. 1990. Analysis of stability for some characters in Kabuli

chickpea. *Euphytica*, 49: 223-227.

Singh R. Yadav, H.S., and Singh, P. 1986. Stability Analysis for Grain Yield in Gram (*Cicer arietinum* L,), *Science and Culture,* 52: 204-205.

Subbaro, G.V., Johnson, C. Slinkard, A.E. Nagaeswara, R.C., Saxena, N.P. and Chauhan, Y.S. 1995. Strategies for Improving Drought Resistance in grain Legumes. *Plant Science,* 14 (6): 469-523.

Weaver, D.B., Thurlow, D.L., and Patterson, R.M. 1983. Stability Parameters of Soybean Cultivars in Maturity Groups VI, VII, and VIII. *Crop Science*, 23: 569-571.

Zhang, H., Pala, M., Oweeis, T., and Harris, H. 2000. Water uSe and Water-use Efficiency of Chickpea and Lentil in a Mediterranean Environment. *Australian Journal of Agricultural Research,* 51 (2): 295-304.

إستجابه سلالات الحمص لمستويات رطوبة ألتربه تحت ظروف البيئة شبه الجافة

مليون أ. وولدامانيول، أحمد م. أبوعواد ونصري أ. حداد*

ملخص

الحمص محصول بقولي هام يزرع في معظم المناطق في العالم. يتعرض الحمص إلى نوعين من الجفاف: الأول ناتج عن توقف الأمطار خلال فصل الشتاء والثاني نتيجة انقطاعها في نهاية الموسم. ومن طرق تحسين إنتاجية المحصول تحت ظروف البيئة الجافة تطوير أصناف تستطيع تحمل الجفاف وإنتاج غله عالية تحت البيئة الجافة. تم تنفيذ تجربه لموسمين زراعيين في محطة أبحاث ألجامعه الأردنية في غور الأردن. اختبرت ست سلالات من الحمص أربع من النوع الكابلي (Kabuli) واثنتان من النوع الديزي (Desi). أستعمل خط المرشات للحصول على كميات متدرجة من المياه المضافة. تم قياس محصول البذور ومكوناته وعدد من الصفات المحصولية الأخرى، كذلك تم حساب كفاءة استعمال المياه ومؤشر الحساسية للجفاف. اختلفت استجابة السلالات لمستويات الرطوبة، إذ أعطت السلالة Flip 98-107 أعلى انتاج من البذور تحت الرطوبة المتوسطة، وانخفضت إنتاجيتها عندما ارتفعت أو انخفضت الرطوبة عن المستوي المتوسط. أشارت النتائج الى ان كفاءة استخدام الماء كان الأفضل للسلالات عالية الإنتاجيه والسلالات المبكرة عن المتدنية الإنتاجية والمتأخرة في النضج، وذلك تحت مستويات الرطوبة المنخفضة. ووجد أن أهم الصفات التي تساعد السلالات في قدرة تحملها للشد الرطوبي هي: دليل الحصاد المرتفع، التبكير في النضج، عدد القرون وعدد البذور في النبات. كما وجد أن استجابة سلالات الحمص لرطوبة التربة ليست خطية، لذلك يجب أن يؤخذ ذلك بعين الاعتبار في ادارة ري هذا المحصول.

الكلمات الدالة: الجفاف، الشد الرطوبي، نظام الري بالرشاشات، تحسين الحمص لمقاومة الجفاف.

---

* كلية الزراعة، الجامعة الأردنية. تاريخ استلام البحث 2004/11/8، وتاريخ قبوله /2005/10.