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Yield and Yield Components of Chickpea (*Cicer arietinum* L.) as Influenced by Supplemental Irrigation under Semi-arid Region of Tunisia

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Abstract A field experiment was conducted at the research station of Higher Agriculture School of Kef located in a semi-arid region of Tunisia to study the effect of supplemental irrigation on yield and yield components of four Tunisian chickpea genotypes (Béja 1, Bouchra, Neyer and Kasseb). Two supplemental irrigations were applied at the flowering and pod formation stages. Results showed a significant effect of supplemental irrigation on biological yield (BY/P), seed number per plant (SN/P), grain yield per plant (GY/P), 100-seed weight (100 SW), grain yield per m^2 (GY/m^2), harvest index (HI) and number of days to maturity (NDM). Grain yields under supplemental irrigation varied from 62.3 to 140.4 g/m^2, and varied from 28.1 to 94.3 g/ m^2 under the drought condition. The average 100-seeds weight reduction due to drought condition was 19.3 %. Results showed also that under rainfed condition, Bouchra and Nayer genotypes required minimum number of days to maturity (145.7 and 144.7 respectively). Drought susceptibility index (DSI) values for grain yield ranged from 0.67 to 1.39. Nayer was relatively drought resistant (DSI values <1). This genotypes proved high yielding and drought tolerant and can be incorporated in stress breeding programme for the development of drought tolerant chickpea varieties.

Keywords: *Chickpea (Cicer arietinum L.), yield, yield components, rainfall, supplemental irrigation, Semi-arid, Tunisia*

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1. Introduction

Chickpea (*Cicer arietinum* L.) is the third most extensively planted grain legume in the world after dry bean and field pea [13]. It is cultivated in the arid and semi-arid regions of the world. In Mediterranean regions, it is traditionally grown as a spring-sown rainfed crop very dependent on rainfall. Chickpea is currently grown on about 13.5 million hectares worldwide with an average annual production of 13.1 million tons [6]. About 95% of chickpea cultivation and consumption is in the developing [10]. Drought has been considered as a major environmental constraint commonly encountered by plants [19], which cause significant damaging for plant growth, productivity and mineral nutrition losses to crop yield ([16,22,26]). It affects also many morphological and physiological processes as mentioned by [30].

Generally, legumes are highly sensitive to water deficit stress [11]. [7] have mentioned that chickpea seed yield decreased by 50% when stressed during pod formation and 44% when stressed during flowering. In different crops as well as in chickpea, differential genotypic response to drought stress as a result of variation in physiological parameters has been reported [8]. The morphological and physiological changes in response to drought stress can be used to help identify resistant genotypes or produce new genotypes of crops for better productivity under drought stress [14]. The reactions of plants to drought stress depend on the intensity and duration of stress as well as the plant species and its stage of growth [17]. Most studies on grain legumes for improving yield confirmed that pod development and seed filling stages were the most drought sensitive [1]. The identification of physiological traits responsible for drought tolerance should be considered in the breeding program because grain yield and drought resistance are controlled at independent genetic loci [12]. So it is necessary to gain knowledge concerning the genetics and physiology of tolerance mechanisms as mentioned by [9]. The relative water content (RWC) parameter, in particularly, is considered as one of the easiest agricultural parameters that can be used to screen for plants drought tolerance [4].

In Tunisia, Chickpea is the second major food legume. With faba bean and peas, it plays an important legume crop for human nutrition. It also plays an important role in increasing and maintaining soil fertility and the recovery of marginal lands, especially in semi-arid regions. The development of chickpea cropping in the Tunisian agricultural system is facing to biotic and abiotic constraints. Indeed, drought is the constraint that induces a highly negative effect on crop production. When subjected to this constraint, plants manifest a wide range of behaviours, varying from great sensitivity to high tolerance. In this respect, it is worthy mention that the major problem facing grain legumes production in Tunisia North West semi arid region is synchronizing of inadequate rainfall incidences during the most drought susceptible stage of growth and development. In this situation, supplemental irrigation can improve significantly the crop yield. The objective of this study was to evaluate the influence of supplemental irrigation on yield and yield components of 4 Tunisian chickpea genotypes in order to select the most suitable ones for the Tunisian semi arid region.

2. Materials and Methods

2.1. Field Experiments and Methodology

The experiment was conducted during 2012- 2013 cropping season at the research station of Higher Agriculture School of Kef (ESAK) located in a semi-arid zone in north-western Tunisia. Climatic data related to the research location and growing period are shown in Table 1. The treatments included 4 Tunisian chickpea genotypes (Béja 1, Bouchra, Neyer and Kasseb) and 2 water regimes (rain-fed 'I0' and supplemental irrigation 'I1'). Genotypes used in this study were shown in Table 2. Two supplemental irrigations were applied, as supplemental irrigation through sprinkler system, at the flowering and pod formation stages at the rate of 20 and 25mm respectively.

Table 1. Mean monthly temperature and precipitation during the cropping season 2012/2013

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Precipitations (mm)	43.8	57.6	11	18.6	33.6	47.4	35.6	21.4	14.2	3.2
Temperatures (°C)	22.3	18.8	14.2	8.8	8.1	7	12.6	15.3	17.9	21.8

The experiment was laid out in a randomized complete block design with three replications. The seeding rate and rows spacing was maintained at 100 kg/ha and 50cm, respectively with row length of 4m. All the cultural practices were performed as recommended for chickpea production. The crop was maintained free from weeds, diseases and pests by adopting appropriate plant protection measures. Sowing was made on 26 December 2012.

Table 2. Tunisian chickpea genotypes and their pedigree

Varieties	Pedigree
Béja 1	(Amdoun 1 × ILC 3279) × ILC 200
Kasseb	ILC72 × ILC 215 (FLIP 83-46)
Neyer	ILC72 × ILC 215 (X80TH176)
Bochra	ILC72 × ILC 215 (X80TH176)

2.2. Studied Parameters

2.2.1. Relative Water Content (RWC)

Relative water content at flowering (RWCF) and pod formation (RWCP) stages were determined according to [2]. Fresh weight of the young leaf was determined after excision. Turgid weight was obtained after soaking the leaf for 24 h in distilled water. After soaking, the leaves were quickly and carefully blotted dry with tissue paper prior to determination of turgid weight. Dry weight was obtained after drying the leaf sample for 48 h at 80°C. Relative water content was calculated from the following equation:

$$RWC\% = \left[\frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}}\right] \times 100.$$

2.2.2. Agronomic Parameters

The collected data for biological yield per plant (BY/P), seed number per plant (GN/P), grain yield per plant (GY/P), 100-seed weight (100 SW), grain yield per m^2 (GY/m^2), harvest index (HI) and number of days to maturity (NDM) were recorded under rain fed and supplemental irrigation.

Drought susceptibility index (DSI): was estimated by the formula suggested by Fischer and Maurer (1978):

DSI= (1 -Yd/Yp)/D. Where, Yd = Grain yield of the genotype under rain fed condition, Yp = Grain yield of the genotypes under supplemental irrigation condition.

D= (1 -YD/YP). Where, YD= Mean yield of all genotypes under rain fed condition, YP= mean yield of all genotypes under supplemental irrigation condition.

2.3. Statistical Analysis

Analysis of variance and mean comparison were performed by using ANOVA procedure in statistica software.

3. Results and Discussion

3.1. Relative Water Content (RWC)

The effect of supplemental irrigation on RWC was significant at flowering and pod formation stages. However, for this trait, genotype and drought stress x genotype interaction effects were not significant in both stages (Table 3). Thus, chickpea genotypes having been subjected to supplemental irrigation has accumulated more water in its leaves (Table 4).

Table 4 illustrates the influence of supplemental irrigation in the relative amounts of water on chickpea leaves at flowering and pod formation stages. The effect of water stress on relative water content (RWC) varied between genotypes and water stress treatment. Indeed, at flowering stage, Kesseb genotype showed a significant increase in RWC under supplemental irrigation. However, Beja1, Neyer and Bochra genotypes showed no significant change in their RWC under supplemental irrigation treatment. Results observed at pod formation stage showed that RWC of Beja1 genotype increased. Whereas, relative water content of Neyer, Kasseb and Bochra genotypes were not affected.

Table 3. Analysis of variances for Relative Water Content at flowering, Relative Water Content at pod formation, biological yield per plant, seed number per plant, grain yield per plant, 100-seed weight, grain yield per m^2, harvest index and number of days to maturity of chickpea genotypes grown under rain fed and supplemental irrigation conditions

	Genotype (A)		Treatment (B)		Interaction A*B	
	M.S.	F value	M.S.	F value	M.S.	F value
RWC at flowering	280.55	2.45ns	1018.48	8.89*	72.09	0.63ns
RWC at pod formation	749.11	3.06ns	2128.91	8.69*	209.02	0.85ns
BY/P	19.02	1.05ns	242.44	13.44*	14.44	0.8ns
SN/P	167.15	4.11*	1134.38	27.86**	70.26	1.73ns
GY/P	6.80	2.36ns	53.31	18.47**	1.46	0.51ns
100 SW	32.47	10.51**	330.78	107.09**	21.13	6.84*
GY/m^2	0.02	2.34ns	0.043	5.14*	0.01	1.51ns
HI	4587.1	2.22ns	21693.7	10.49**	1558.28	0.75
NDM	1.2	2.54ns	160.2	349.5**	2.27	4.9*

For each row and column, means followed by similar letters are not significantly different at 5% level of probability.

Table 4. Relative water content at the flowering and at pod formation stages of four chickpea genotypes under non irrigation and supplemental irrigation

Stage	Genotypes	Supplemental irrigation	Stress condition	Mean	Variation%
RWCF	Beja 1	54.5 ab	51 a	52.8	6.4
	Kesseb	76.5 d	56.4 abc	66.5	26 .2
	Neyer	71.5 bcd	57.3 abc	64.4	19.9
	Bouchra	74.8 cd	60.5 abcd	67.6	19. 2
	Mean	69.3b	56.3a	62.8	17.9
RWCP	Beja 1	71 b	38.6 a	54.8	45.6
	Kesseb	52.2 ab	35.5a	43.8	31.9
	Neyer	75.3 b	53 ab	64.1	29.6
	Bouchra	71.3 b	67.2 b	69.2	5.7
	Mean	67.4b	48.6a	58	28.2

For each row and column, means followed by similar letters are not significantly different at 5% level of probability.

Results showed also that supplemental irrigation has exerted a positive effect on RWC (combined genotypes). This reduction is much greater at pod formation stage. Indeed, during this stage, the percentage of reduction varies between 28.2% compared to the irrigated plots. Furthermore, Neyer and Bouchra genotypes maintain higher relative water content under drought stress (67.2% and 53% respectively). Plant water status is a good indicator of plant performance under drought stress. So the tolerance or sensitivity of chickpea to drought is related to its capability to maintain good leaf water status. The results of this study are in good agreement with the early findings of [29] when they reported considerable decreased of relative water content and leaf water potential in response to drought stress. In this study, Neyer and Bouchra genotypes maintain higher relative water content under drought stress so they can be considered as drought resistant genotype. This is in agreement with results of [27] who have shown that genotypes that maintain higher relative water content under drought stress are believed to be more tolerant and give higher yield than others. [27] reported that drought tolerant plant species keep high RWC compared with drought-sensitive species in cultivars of beans. Genotypic variation of leaf water potential may be attributed to differences in the ability to absorb more water from the soil and the ability to reduce water loss through stomata as reported by [23]. It may also be due to differences in the ability of genotypes to maintain tissue turgid and hence physiological activities as reported by [29].

3.2. Yield and Yield Components

There were significant effect of supplemental irrigation on biological yield (BY/P), seed number per plant (SN/P), grain yield per plant (GY/P), 100-seed weight (100 SW), grain yield per m^2 (GY/m^2), harvest index (HI) and number of days to maturity (NDM) under rain fed and supplemental irrigation conditions. Means of yield and yield components of each chickpea genotype under supplemental irrigation and rainfed conditions are given in Table 5. Results showed a clear effect of supplemental irrigation on biological yield. Indeed, results showed that chickpea genotypes significantly gave better biological yields under supplemental irrigation compared to under rainfed condition. Nayer comparatively was the highest biological-yielding genotype under both conditions. Increase of biological yield under supplemental irrigation regime was significant in both Beja1 and Nayer genotypes. The effect of drought and supplemental irrigation regimes on grain yield (calculated as g/m^2) is displayed in Table 4. Grain yields under supplemental irrigation varied from 62.3 to 140.4 g/m^2, and they varied from 28.1 to 94.3 g/m^2 under the drought condition. Average yield reduction due to drought condition was 55.8 %. Beja1 and Nayer were the best yielding under supplemental irrigation conditions, mainly due to higher seed number and grain yield per plant, whereas Bochra was the lowest yielding because of its lower seed number per plant. Increase of grain yield under supplemental irrigation regime was significant in

Beja1 genotype. Grain yield was greater under supplemental irrigation than under rain fed condition, a consequence of more seed number per plant, heavier grains, and grain yield per plant.

Table 5. Means of yield components of each four chickpea genotypes under supplemental irrigation and rain fed conditions

Genotypes	TRAI	BY/P (g)	SN/P	GY/P (g)	100 SW	GY/m^2	HI	NDM	DSI
Beja 1	rain fed	2.2a	3 a	1a	33.7b	28.1a	0.46c	146.3b	1.39
	Sup. irr	12.1cd	15.7b	4.4cd	37.3cde	128.1c	0.41bc	150.7cd	
Kesseb	rain fed	4.7ab	4a	1.4ab	27.5a	46.2ab	0.28ab	146.7b	1.09
	Sup. irr	9.8bcd	18.3b	4.3bcd	39.3de	115.7bc	0.44c	151.7d	
Neyer	rain fed	6.9abc	7.7ab	2.7abc	27.2a	94.3 abc	0.36abc	144.7a	0.67
	Sup. irr	14.6d	30c	6.7d	36.5bcd	140.4c	0.46c	151.3cd	
Bochra	rain fed	5.7abc	3.7a	1.4ab	34.6bc	37.4ab	0.24a	145.7ab	0.80
	Sup. irr	8.5abcd	9.3ab	3.1abc	39.7e	62.3abc	0.37abc	150.3c	
Mean	rain fed	4.9A	4.6A	1.6A	30.8A	51.5A	0.33A	145.8A	0.99
	Sup. irr	11.2B	18.3B	4.6B	38.2B	111.6B	0.43B	151 B	

For each row and column, means followed by similar letters are not significantly different at 5% level of probability.

The 100 seeds weight was significantly affected by irrigation (Table 3). In fact, drought stress reduced the 100-seed weight (Table 5). 100-seed weight varied from 9.7 % to 30% respectively for Beja 1 and Kesseb genotypes. Average 100-seeds weight reduction due to drought condition was 19.3 %. The 100-seed weight under supplemental irrigation varied from 36.5 to 39.7 g and from 27.2 to 34.6 g under the drought condition. Our results were agreed with those of [3] who reported that chickpea 100 seeds weight was affected by irrigation. Negative effects of moisture defect on chickpea grain yield and yield components were also found by [20,24,25,28]. [15] reported a significant negative effect of drought stress on grain yield and biomass of chickpea at final growth stages.

Harvest index (HI) was significantly affected by supplemental irrigation (Table 3). The means of harvest index ranged from 0.37 for Bouchra to 0.46 for Nayer under supplemental irrigation and ranged from 0.24 to 0.46 for Bouchra and Beja1 genotypes under drought stress conditions (Table 5). It is interesting to note that Beja 1 and Nayer genotypes maintained highest values of harvest index under raifed as well under supplemental irrigation conditions. However, under drought stress condition, a significant decrease of harvest index was observed in Kesseb genotype. Chickpea genotypes which gave higher seed yield under water-stressed conditions could play an important role in sustaining crop production in semi arid regions. [31] results revealed that the ability of genotypes to produce more biomass in stress conditions also produced more seed yield. In this study, yield and yield components of chickpea under rain fed condition are reduced even in tolerant genotypes. [18] showed that the mean yield and relative yield performance under rain fed and supplemental irrigation environments are the most widely used criteria for selecting genotypes for stress conditions. So, relative yield performance could be used to assess the yield potential of a genotype under water stressed conditions.

Early maturity is an important trait to avoid drought stress due to the onset of severe water deficits. In the present investigation, days to maturity reduced by 5 days (Table 5). Bouchra and Beja1 genotypes required minimum number of days to maturity under supplemental irrigation (150.3 and 150.7 days respectively). While under rainfed condition, Bouchra and Nayer genotypes required minimum number of days to maturity (145.7 and 144.7 respectively). [21] and [24] reported that yield potential and early flowering are two major components of drought escape in lentil and chickpea.

Yield is the principle selection index used under drought stress conditions. DSI values for grain yield (Table 5) ranged from 0.67 to 1.39. Nayer and Bochra genotypes were relatively drought resistant (DSI values <1), while Beja1 and Kesseb genotypes were relatively drought susceptible (DSI > 1). Genotypes with low DSI values (less than 1) can be considered to be drought resistant [5], because they exhibited smaller yield reductions under water stress compared with well-watered conditions than the mean of all genotypes.

4. Conclusions

This study was conducted to determine the effect of supplemental irrigation on chickpea yield and its components under semiarid climatic conditions. It was concluded that Nayer proved high yielding and drought tolerant and can be incorporated in stress breeding programme for the development of drought tolerant chickpea varieties.

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