Emir. J. Food Agric. 2012. 24 (1): 73-78
http://ejfa.info/

PLANT SCIENCE

Shoots, root and flowering time studies in chickpea (*Cicer arietinum* L.) under two moisture regimes

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Abstract

The shoot and root behavior and flowering time of two chickpea genotypes (kabuli and desi types) was examined under well watered and moisture stress conditions in split drainpipes in 2006. The data on shoot and root fresh weight and dry weight and plant and soil moisture percentage were recorded at the late flowering stage. The observations on root and soil moisture were recorded at three depth level with gap of 15 cm each. The results revealed that both the plant types of chickpea behaved alike except for days to flower initiation which was significantly different in the two varieties. Root and Shoot fresh weights were significantly greater in well watered conditions, but on the other hand, there was no any significant effect of moisture stress on shoot dry matter content, suggesting that higher weight of fresh shoot was due to high uptake of water under well watered conditions which evaporated after drying. Fresh root weight was only significantly affected at 30 cm depth level due to varieties and 45 cm depth level due to treatments. The root moisture percentage was significantly affected at 15, 30 and 45 cm depth level due to varieties × treatments interaction, varieties and treatments, respectively. There found no significant difference in dry weight among the rooting depths. The cultivar Sheenghar-2000 retained higher root moisture content (7.57%) at 15 cm depth level under well watered.

Key words: Chickpea, Root, Shoot, Flowering behavior, Different moisture levels

Introduction

Chickpea (*Cicer arietinum* L.) is in important winter grain legume in Indo-Pak subcontinent and Middle East grown on residual moisture preserved after monsoon rains. Chickpea in Pakistan is mostly cultivated as rainfed crop. The moisture preserved, depletes progressively with the growth of crop and therefore, crop faces moisture stress at reproductive stage. The majority of soils where the chickpea crop grown are sandy without facility of irrigation water. The drought is the major production constraint in the rainfed agriculture particularly in the arid region. The terminal drought occurs during the flowering/pod formation stage which is usually common in chickpea growing belt of Pakistan. About 90% of the world's chickpea is grown under rainfed conditions where the crop experiences terminal drought stress during the reproductive phase resulting in heavy yield losses of up to 3.4 million tons (Sharma, 2004-05). The Different yield loses are found due to moisture stresses experienced by crop at different growth stages (Silim and Saxena, 1993a). Studies on various drought management strategies on different field crop revealed that development of host plant tolerance is the most desirable approach to overcome this problem.

In Pakistan more than 95% chickpea production come from rain-fed area where the genotypes grown are without information on their response to various moisture regimes/drought stresses (MINFAL, 2009). Consequently, the yield level of chickpea in rainfed area is quite low (685 Kg per hectare). The only alternate to increase production in such area is the development of drought tolerant genotypes. Screening techniques, to identify drought tolerant genotypes and to evaluate the performance of selected lines, must be refined efficiently for evaluation of performance at critical developmental stage under moisture stress conditions**.** Various plant and root traits are needed to be identified to understand their contribution towards drought avoidance. Such studies also help understanding the drought tolerance mechanism and contribution of various traits for grain yield in moisture deficit soils. Saxena et al. (1993) have identified some drought tolerant lines of chickpea

Received 30 May 2011; Revised 13 August 2011; Accepted 13 August 2011

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showing comparatively good yield under moisture stress conditions. The drought tolerance in their case was found to be directly proportional to deep root system and high leaf water potential (LWP). Silim and Saxena (1993a) suggested screening for drought tolerance on the basis of the LWP. In another study Silim and Saxena (1993b) showed that drought tolerance in legume crops are closely related to the root system and rooting pattern. They further suggested that root length density, rooting depth and root dry matter are the parameters of the root system which could be useful as screening criteria for drought-tolerance. Subbarao et al. (1995), Turner et al. (2001) and Kashiwagi et al. (2005) had proposed root biomass, root length density and root depth as the main drought avoidance traits for higher seed yield under drought conditions in chickpea. They found 93% higher root dry weight in drought tolerant chickpea lines (ICC 4958) as compared to standard check. Anbessa and Bejiga (2002) and Matsui and Singh (2003) selected 18 drought tolerant genotypes among a lot of 482 chickpea lines and reported reduced water loss from plant and extensive extraction of soil moisture as the factors for adaptation of drought tolerant genotypes. The centre of root dry matter and root length density of two cowpea varieties moved downwards significantly, under water stress conditions (Matsui and Singh, 2003). Considering the above facts the present study was conducted to understand the role of shoot and root of chickpea genotypes for grain yield production under moisture stress and well watered conditions.

Materials and Methods

The experiment was conducted in Glasshouse at the research site of Centre of Arid Zone Studies and Natural Resources, (CAZS-NR) University of Wales, Bangor, UK during 2006-07. Two chickpea varieties Sheenghar-2000 (Desi type) and Lawaghar-2000 (Kabuli type) were tested under two moisture levels i.e. well watering (T_1) and moisture stress (T_2). The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having six replications. The seeds of each variety were first germinated in P-12 Plug Trays using compost to have healthy seedlings for main Split Drain Pipes (SDP). Twelve-days-old seedlings were then transferred to SDP with 80 cm height and 15 cm diameter. The soil used in SDP was a mixture of sand and Jons Innes No-2 (1:1 ratio). Each SDP was planted with a single plant. SDP filled with mere soil (containing no plants) was used as control for comparison of moisture depletion/evapo-transpiration against well watering (T_1) and T_2 (moisture stress). The experiment was harvested at late flowering/pod formation stage to record the observation on days to flower initiation, plant shoot length (cm), shoot biomass (g), root dry matter, root moisture percentage and post-harvest soil moisture at various depth along the length of SDP.

Treatments: T_1: Control- Well watering

T_2: Cyclical moisture stress

Varieties: V_1. Sheenghar-2000 (Desi)

V_2. Lawaghar-2000 (Kabuli)

In well watering the soil remained wet all the time, while in case of cyclical moisture stress the crop remained under moisture stress receiving light irrigation at very severe stress conditions.

Soil and Root sampling

After harvesting, fresh shoot, root and soil samples were taken for recording root dry matter and shoot moisture percentage. The SDPs were laid down on table and split with fine knife. The entire root length along with soil was then divided onto three equal portions by fixing the root by nail at the interval of 15 cm each. The soil was removed from roots using fine shower of water and root fresh weight was obtained. The soil samples were also taken from the all three portions divided for the root sampling. The fresh root and soil were then oven dried at 65°C for 72 hours and weighted and moisture percentage in root and soil samples were calculated on fresh samples basis.

Statistical Analysis

The data on various parameters were analyzed with the SPSS software package. The significant treatment means were further compared by the Least Significant Difference (LSD) test.

Results and Discussion

The present studies were conducted to asses shoot and root behaviour and soil moisture depletion in two chickpea varieties under two moisture levels. The results of analysis of variance regarding various plant and root traits and the comparison of individual means are given in Table 1 and Table 2, respectively. Whereas information regarding soil moisture percentage recorded after harvesting plants are given in Table 3.

Plant characteristics

The results revealed that plant traits studied (shoot length, shoot fresh weight, shoot dry matter and shoot moisture percentage) except days to flower initiation were non-significantly affected due to varieties. Variation in flower initiation period was found highly significant due to varieties.

The cultivar Sheenghar-2000 had started flowering after 61.92 days, while Lawaghar-2000 appeared late availing 70.42 days to flower initiation (Table 2). The flowering period can directly affect the grain yield. Ali et al. (2007) reported that number of days taken to flowering was positively and significantly correlated with the grain yield. Neil et al. (2007) reported that early .flowering chickpea produced in higher yields at different location and stresses.

The effect of various moisture levels was only significant for shoot fresh weight, shoot moisture percentage and days to flower initiation. Whereas it was non-significant, for shoot length and shoot dry weight. Significantly higher shoot fresh weight (78.86g) and shoot moisture (64.92%) was observed in well watering treatments while lower shoot fresh weight (51.25g) and low shoot moisture (40.07%) was recorded in moisture stress treatments (Table 1). The higher fresh shoot weight is attributed to higher water percentage available in plants grown in well watering treatment. As shoot dry weight was non-significant, it is, therefore, evident that highly significant differences in shoot fresh weight was not on part of plant development, it was rather due to variation in available moisture in plant tissues which had increased the total shoot fresh weight in well watering treatments. It was also interestingly noted that chickpea plant had only retained higher amount of water in their tissues under well watering with no significant progress in plant height and/or plant dry matter (Table 1).

Table 1. Pant shoot traits of chickpea under two moisture regimes.

Varieties	Treatments	Shoot length (cm)	Fresh shoot weight (g)	Shoot dry matter (g)	Shoot moisture (%age)	Days to flower initiation
Sheenghar-2000	T_1	79.67	75.76	11.95	63.82	66.67b
Sheenghar-2000	T_2	74.83	57.05	10.39	46.66	57.17c
Lawaghar-2000	T_1	85.00	81.96	15.92	66.03	76.67a
Lawaghar-2000	T_2	75.17	45.45	11.98	33.47	64.17b
Levels of significance	Variety	NS	NS	NS	NS	**
	Treatment	NS	**	NS	**	**
	Var x Treat. Interaction	NS	NS	NS	NS	NS

NS= Non-significant, ** = Significantly different at 0.1% level.

The plants developed under two treatments had only difference of shoot moisture percentage whereas they were statistically similar in plant height and plant dry matter. It gives further evidence that plant development was not influenced by different moisture levels, and significant variation in water storage in plant tissues was found to be directly proportional to available soil moisture in root zone. This does not necessarily mean that chickpea plant behaves similarly under variable moisture levels. The plant developed under well watered condition retained more water in its tissue as compared to moisture stressed plants. The sufficient moisture retained by well watered plants would have direct effect on final yield by utilizing the available water for healthier pods and seeds formation as the crop will enjoy reqired moisture at during reproductive phase reducing the yield losses. (Sharma, 2004-05). While, the plant under stress conditions with lower moisture percentage would have experienced moisture deficiency at critical stage of seed formation, leading to poor yield. Kumar et al. (2004) have reported high grain yield of some recombinant inbred lines (RIL) of chickpea with high shoot biomass under terminal drought. Moinuddin and Chopra (2004) suggested that cultivars with high osmotic adjustment (OA) generally showed improved plant water potential and proved significantly superior to one with low OA with respect to grain yield and other parameters. Early plant vigour and fast ground cover are the yield enhancing traits under drought in chickpea (Singh et al., 1997). Shoot and root traits play an important role in regulating water use by crop plant (Subbaroa et al., 1995). Leaf moisture retention index (LMRI) is an easily measurable physiological trait reflecting leaf turger maintenance under moisture stress and may be related to drought tolerance (Gupta and Sharma, 2006).

Days to flower initiation were highly significantly affected due to moisture levels and the plant under moisture stress had produced early flowering (60.67) whereas well-watering treatment had delayed flowering (71.67 days). As a matter of fact, moisture stress always shortens the life cycle of crop plant which results in early flowering as well as early maturity. The interaction effects of varieties and moisture levels were found to be non-significant for all the parameters studied. Combination of various characters including early flowering, high harvest index and deep rooting has been proposed as suitable ideotype for drought environment (Wery et al., 1994).

Root characteristics

The variation in root dry matter and root moisture percentage was studied on three different depth levels. The entire root length was divided onto three equal portions with a interval of 15 cm each. The results revealed that various root segments at all the depth levels were uniformly distributed along the length of split drain pipes in all the treatments and differences in root dry matter were statistically identical due to varieties, moisture stress treatments and their interactions (Table 2). Ali et al. (2005) did not find any clear difference in root dry matter in chickpea genotypes when planted under stress at various phosphorus levels.

The root moisture percentage was not significantly different due to chickpea varieties at all the levels except middle part of root i.e. at 16-30 cm level. The cultivar Sheenghar-2000 had retained significantly more moisture (3.45%) as compared to Lawaghar-2000 with 1.39% moisture only. The main effect of various moisture treatments on the root moisture percentage was highly significant at lower root segment (31-45 cm level) whereas, it remained statistically similar at top (1-15 cm) and middle (16-30 cm) part of root. The well watering treatments had significantly higher moisture (9.50%) as compared to moisture stress treatments with 3.73% moisture in root (Table 2).

Table 2. Means and analysis of variance root shoot traits under two moisture levels.

Varieties	Treatments	Fresh root wt. (g) at15 cm	Fresh root wt. (g) at 30 cm	Fresh root wt. (g) at 45 cm	Root dry matter wt. (g) at15 cm	Root dry matter wt. (g) at 30 cm	Root dry matter wt. (g) at 45 cm	Root moisture (%) at 1-15 cm	Root moisture (%) at 16-30 cm	Root moisture (%) at 31-45 cm
Sheenghar-2000	T_1	8.58	4.65a	11.34a	1.02	0.41	1.05	7.57a	4.24a	10.29a
	T_2	4.46	3.04b	5.17c	0.80	0.39	0.91	3.67b	2.65b	4.26c
Lawaghar-2000	T_1	4.80	2.13c	9.71b	0.95	0.71	1.00	3.85b	1.42c	8.70b
	T_2	4.72	1.64d	3.71d	0.80	0.29	0.51	3.92b	1.35c	3.2c
Levels of significance	Variety	NS	**	NS	NS	NS	NS	NS	**	NS
	Treatment	NS	NS	**	NS	NS	NS	NS	NS	**
	Var x Treatment Interaction	NS	NS	NS	NS	NS	NS	**	NS	NS

NS= Non-significant, ** = Significantly different

Table 3. Means Soil Moisture at different depths under two moisture regimes.

Treatments detail		Soil moisture (%(at 1-15 cm level**	Soil moisture (%) at 16-30 cm level**	Soil moisture (%) at 31-45 cm level **	Total Moisture (%) age	Mean
T1	Sheenghar-2000 under well-watering (SWW)	10.28 a	9.65 a	8.81 a	28.74	9.58
T2	Sheenghar-2000 under moisture stress (SMS)	4.53 b	5.77 b	5.74 b	16.04	5.35
T3	Lawaghar-2000 under well-watering (LWW)	10.09 a	10.32 a	10.65 a	31.06	10.35
T4	Lawaghar-2000 under moisture stress (LMS)	3.89 b	5.94 b	4.79 b	14.62	4.87
T5	Empty Split Drain Pipes (with no plant)	7.29 a	9.64 a	9.99 a	26.92	8.97

The interaction effect between chickpea varieties and root moisture percentage at various depths was only significant at upper root segment i.e. 1- 15 cm levels. The cultivar Sheenghar-2000 had retained maximum moisture (7.57%) in upper part of root under well watering treatments; which was significantly higher then rest of the interaction effects. The cultivar Lawaghar-2000 showed only 3.85% moisture under well watering and remained statistically similar at both the moisture stress treatments (Table 2). Krishnamurthy et al. (1996) noted large variation at maximum rooting depth. Mia et al. (1996) and Sarker et al. (2005) have observed significant variation in tap root length, lateral root number, total root length and total root in various legumes under drought. Thoma et al.

(1996) have reported decreased root length density and extractible soil moisture in deeper layer in chickpea. Anbessa and Bejiga (2002) had also found significant decreased in dry root weight, root volume and rooting depth under low moisture stress. The roots activity at deeper moist layer of soil is directly dependent upon available amount of moisture in that zone higher root activities moved to moist deeper soil layer with the advancement in crop growth and dry up of the surface layer, over time (Ali et al., 2005). Matsui and Singh (2003) have also observed similar trend of root distribution in various cowpea genotypes while grown under moisture deficit conditions. They further observed that root distribution shifted downward under water stress conditions and deep and prolific root system was associated with enhanced avoidance of terminal drought in chickpea.

Soil Moisture percentage

The soil moisture percentage was also recorded at three different depth levels after harvesting the plants. The soil moisture of treatments like, Sheenghar-2000 under well watering (SWW), Lawaghar-2000 under well watering (LWW), Sheenghar-2000 under moisture stress (SMS) and Lawaghar-2000 under moisture stress (LMS) were compared with that of mere Split Drain Pipe containing no plant. A separate statistical analysis using simple RCBD was run on these five treatments including control. The results revealed highly significant differences in the moisture percentage at all the depth levels due to various treatments. The soil moisture percentage at the top 15 cm levels was significantly higher in well watering i.e. in SWW (10.28%) and LWW (10.09%) than rest of three treatments. Both the treatments were followed by control with 7.29% soil moisture. The moisture percentage in control remained statistically higher than rest of the two moisture stress treatments i.e. SMS (4.53%) and LMS (3.87%). The highest soil moisture at middle portion i.e. 16-30 cm levels was recorded in LWW (10.32%) followed by SWW and control with 9.65% and 9.64% moisture respectively. All these treatments were statistically at par with each other and significantly higher than both the moisture stress treatments SMS (5.77%) and LMS (5.94%) (Table 3). The soil moisture percentages recorded at bottom had shown the same trend as in case of middle levels. The significantly higher moisture of 10.65%, 9.99% and 8.81%, respectively was recorded in LWW, control, and SWW treatments. This is further supported by the root moisture percentage at the bottom where cultivar Sheenghar-2000 and Lawaghar-2000 had shown highest root moisture percentage under well watering treatment (Table 2). It was found interesting to note that moisture percentage in soil under stress conditions either having plant or empty (control) had increasing trend from top to bottom. This is mostly due to downward movement of water contents in stress conditions in SDP which was more pronounced and highly significant in control, with 7.29% from top to 9.99% at the bottom. This was due to lack of water uptake and evapotranspiration in control treatment. Sharma and Prasad (1984) have recorded maximum soil moisture depletion at 0-30 cm depth followed by 30-60 cm depth level. The highest soil moisture was recorded at the bottom (90 to 120 cm level). They also observed the pattern of soil moisture depletion according to soil moisture regimes. Anbessa and Bejiga (2002) concluded that reduced water loss from the plant and extensive extraction of soil moisture are factors involved in the adaptation chickpeas to drought conditions.

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