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Genotypic Variations in Yield and Yield Components of Chickpea (*Cicer arietinum* L.) under Water Deficit at Flower Initiation and Pod Formation

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Abstract: A two-year field experiment was conducted to evaluate the best variety under different irrigation stress levels on growth and yield of chickpea. Experiment was performed at Research area Agronomy Section, Department of Agronomy, Shaheed Zulfiqar Ali Bhutto Agricultural College Dokri, Pakistan during rabi seasons of 2015-16 and 2016-17. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement and three replications. Two local varieties of chickpea i.e., V_1= DG-89 and V_2=DG-92 were placed in main plot and three irrigation regimes i.e., I_1=normal irrigation, I_2= irrigation skip at flower initiation and I_3=irrigation skip at pod initiation, were applied in subplots. Result show that varieties present non-significant response on plant height (cm), no. of branches per plant, no. of seeds per plant. 100 seed weight (g). Both varieties significantly differ in their capacity to produce no. of pods/plant and seed yield (kg ha^{-1}). Chickpea cultivar DG-92 performed better by producing significantly higher yield i.e., 6.3%, than DG-89 across the studied years. Among irrigation levels chickpea plants performed better under normal irrigation (I_1) resulted in significantly higher growth and yield during both experimental years. Water deficit at flower initiation (I_3) produced lowest plant yield which was 19.3% lower than the control. Yield reduction due to water deficit at pod development was 8.06% across studied years. Results presented here can be helpful for sustainable chickpea production under water deficit conditions.

Keywords: Climate change, drought, deficit irrigation, food security, legumes, stress, water shortage.

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1 Introduction

Crop plants are exposed to diversified stresses at different growth stages, including biotic and abiotic and stresses (Suzuki et al., 2014; Sah et al., 2016; Uddin et al., 2016). One of the major issues is drought, which is widespread in arid and semiarid areas especially rainfed agricultural ecosystems (Yu and Setter, 2003; Reddy et al., 2004; Wojtyla et al., 2016). Globally ~40% of land area is defined as semiarid or arid, which is more vulnerable to changing climatic conditions (Dai, 2011; Middleton and Sternberg, 2013; Pravalie, 2016). Productivity of agricultural crops is severely limited by water stress conditions (Blum, 2017).

Intensity, duration, frequency and timing of water stress determine degree of yield losses and ability of plants to recover when exposed to normal conditions either by irrigation or rainfall (Venkateswarlu and Shanker, 2012; Dubois et al., 2017). Different countries are facing water crisis due to erratic rainfall pattern, posing uncertain conditions for the availability of water especially for agriculture (Hanjra and Qureshi, 2010; Darand et al., 2017). Climatic models have predicted further extreme climatic conditions are predicted with anomalies in temperature and precipitation (Amin et al., 2017). Climate change induced anomalies will have significant influence on water losses through evapotranspiration, consequently will exacerbated problem of water shortage (Piao et al., 2010; Wheeler and von Braun, 2013; Haddeland et al., 2014; Nawaz et al., 2016; Darand et al., 2017; Daryanto et al., 2017; Nam et al., 2017). Therefore adoption of strategies is dire need of time to develop resilience in cultivated crops against water shortage (Allan et al., 2013; Anwar et al., 2013; Lal, 2013; Misra, 2014; Jez et al., 2016; Rey et al., 2017).

Legumes are considered as a key to future food security (Graham and Vance, 2003; Morel et al., 2012; Jain et al., 2013) and resilience to changing climatic conditions is required for sustainable legume production and food security (Garcia-Hernandez et al., 2010; Vadez et al., 2012). Chickpea or gram (*Cicer arietinum* L.) is a leading pulse crop (Flowers et al., 2010), cultivated across the world in different (more than 50) countries on marginal soils and water limited semiarid areas (Nasr Esfahani et al., 2014; Nasr Esfahani et al., 2016). Higher nutritive value of chickpea makes it vital source of dietary protein, carbohydrates, vitamins and micronutrients for humans, especially in developing countries (Jukanti et al., 2012; Rachwa-Rosiak et al., 2015; Sanchez-Chino et al., 2015). Being a legume it also increases soil fertility and is superior in ability to fix atmospheric nitrogen (Guar et al., 2012). By reducing nutrient requirement it help in reduction reliance on synthetic fertilizer and ultimately reduces environmental consequences of agricultural production (Jez et al., 2016). However water shortage imposes an important constraint on chickpea crop production (Guar et al., 2012; Kale et al., 2015; Sinha et al., 2017). Metabolic activities under water limited conditions controls nitrogen, water and carbon homeostasis in plants and regulate supplies of nitrogen and water from the soil, ultimately defines the fate of nitrogen fixation and crop yield (Sadras et al., 2016).

Pakistan is ranked second in chickpea producing countries (after India) by contributing 10% of annual chickpea production (Flowers et al., 2010). Chickpea is the largest rabi pulse crop accounting for 76% of total production of pulses in Pakistan. Crop was grown on an area of 0.94 million hectares and production was 0.286 million tonnes during 2015-16. It registered an increase of 25.5 percent in production during 2016-17 at cultivated area of 0.931 million hectares with production of 0.359 million hectare (Government of Pakistan, 2017).

It is mainly grown in rainfed conditions in Thal areas of Punjab and Kyber Pakhtunkhwa provinces. The crop is grown on residual moisture after rice harvest in the Baluchistan and Sindh provinces. The average yield (from farmer) of chickpea is lower than the potential yield (from research station). Higher yield gap is due to the poor soil and crop management (Dar et al., 2016).

Generally chickpea is recognized as drought tolerant, therefore widely grown in rainfed areas, without supplemental irrigation. However, its flowering period is vulnerable to drought, which leads to uncertainty and low chickpea productivity. Severe drought reduces vegetative growth, flower initiation and pod setting (Morton et al., 1982). Chickpea produce is very inevitable due to biotic stress and abiotic stress e.g. drought, high and low temperature stresses. Among abiotic stress, drought estimates of yield losses due to drought range from 15 to 60% depending on region, duration of the crop season and dry spell (Sabaghpour et al., 2006).

Drought stress affects various physiological processes and is deleterious for growth, development and economic yield of crops (Garg et al., 2004; Talebi et al., 2013; Sivasakthi et al., 2017a). It is usually acknowledged that chickpea grown in areas with reduced water availability and there are significant inter-varietal variations in resistance against drought stress (Ma et al., 2001; Jain and Chattopadhyay. 2010; Purushothaman et al., 2014; Chen et al., 2017; Kaur et al., 2017; Sivasakthi et al., 2017b). Therefore, there is a space to improve the yield. Moreover selection of suitable variety with better water use efficiency can help to improve chickpea crop production not only under optimum condition, but also under water deficient condition (Kashiwagi et al., 2013; Varshney et al., 2014; Ramamoorthy et al., 2016; Maqbool et al., 2017; Ramamoorthy et al., 2017).

The experiment was carried out to evaluate the impact of different stress levels at different stages on chickpea local varieties DG-89 and DG-92yield and yield components under the agroecological conditions of Dokri, Sindh, Pakistan.

2. Materials and Methods

Field experiment was performed at the Research Area of Agronomy Section, Shaheed Zulfiqar Ali Bhutto Agricultural College Dokri, Larkana Sindh, Pakistan, during rabi seasons of 2015-16 and 2016-17. The research was arranged in randomized complete block design (RCBD) with split plot arrangement. Experimental design included two chickpea varieties in main plot V_1 = DG-89 and V_2 = DG-92, three irrigation levels in sub plot i.e., I_1 = Normal irrigation, I_2 = Irrigation skip at flower initiation, I_3 = Irrigation skip at pod initiation with three replicates. Chickpea plants were sown on experimental plot of net area of 5.4 m^2 (L×W=3×1.8 m) with P×P and R×R distances of 15cm and 30cm with six rows and 120 plants per plot. Regarding fertilizer application, recommended dose was applied at the time of seed bed preparation.

Standard and uniform plant protection measures and agronomic practices were performed throughout the growing season. The observations were made based on randomly selected and averages of five plants were used each experimental unit, which were further averaged for treatments means used for statistical analysis. Data on various traits including plant height, branches per plant, pods per plant, seeds per pod, 100 seed weight and seed yield were recorded.

Plant height was recorded from surface of ground to top tip of leaves. Number branches per plant, pods per plant and seeds per pod were recorded by counting branches, pods and seeds of each plant separately and then averaged from each replication. After separating yield, five samples of 100 seeds were picked at random from each replication, and then weight was recorded. Twenty plants were selected from each experimental plot. Calculate the value by unit formulae and then converted to kg ha^{-1} (Calculated the seed yield of 20 plants and then divided aby 20. The obtained value was multiplied with standard plant population. Calculate the data and then averaged from each replication. The data collected were analyzed with one way ANOVA by MSTATC. For treatment mean discrimination LSD test was applied at 0.05 probability level (Fareed and Scott, 1986).

3. Results

3.1 Plant height

The results regarding plant height (Table 1 & 2) showed that varieties have non-significant difference on plant height during both experimental years. Among the different irrigation levels, maximum plant height was recorded from I_1 (40cm and 39 cm during 2015-16 and 2016-17 respectively) which was statistically similar with I_2 (35.5cm during both the years).Minimum plant height was recorded in I_2 (35.5 cm) that was 11.25% and 8.97% less then I_1 during 2015-16 and 2016-17.

3.2 No. of branches plant^{-1}

Data presented in Table 1 and 2 indicate that the branches per plant were not significantly affected. Maximum branches were obtained by I_1 while the minimum were recorded from I_2 during both experimental years (2015-16 and 2016-17). Interactive effect of variety and irrigation show significant difference during both the years. Maximum no of branches were recorded from V_2I_1. Minimum branches (9) were recorded from V_1I_2 in 2015-16 and in V_1I_3 during 2016-17.

Table 1. Genotypic differences in chickpea growth and yield under irrigation levels during 2015-16.

Parameter	Plant height (cm)	No. of branches plant^{-1}	No of pods plant^{-1}	No of seed pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})
Varieties						
V_1 DG-89	39	10.33	20.67 b	1.07	23.67	951 b
V_2 DG-82	36.67	11	23.67 a	1.17	24.67	1023 a
	ns	ns	*	ns	ns	*
LSD Value	3.23	1.08	2.98	0.27	1.98	68.84
Irrigation levels						
I_1	40 a	11.5 a	23.5 a	1.25 a	25.5 a	1069 a
I_2	35.5 b	9.5 b	20.5b	1 b	22.5 b	900 c
I_3	38 a	11 a	22.5 a	1.1 b	24.5 a	992 b
	*	*	*	*	*	**
LSD Value	2.45	1.43	1.97	0.13	1.97	72.13
Interaction (V×I)						
V_I1_1	41 a	11 ab	22 b	1.2 a	25 ab	1036 b
V_I1_2	37 b	9bc	19 c	1 b	22d	864 d
V_I1_3	39 ab	11 ab	21 b	1 b	24bc	953 c
V_21_1	39 ab	12 a	25 a	1.3 a	26 a	1102 a
V_21_2	34 c	10 b	22 b	1 b	23cd	936 c
V_21_3	37 b	11 ab	24 a	1.2 a	25 ab	1031 b
	*	*	*	*	*	*
LSD Value	2.31	1.29	1.83	0.14	1.86	69.16

Means with different letters are statistically different at * = $P < 0.05$, ** = $P<0.01$ (n=3), ns = non-significant. Varieties V_1 = DG-89, V_2 = DG-92, Irrigation level I_1=Normal Irrigation, I_2 = Irrigation skip at flower initiation, I_3= Irrigation skip at pod initiation.

Table 2. Genotypic differences in chickpea growth and yield under irrigation levels during 2016-17.

Parameter	Plant height (cm)	No. of branches plant^{-1}	No of pods plant^{-1}	No of seed pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})
Varieties (V)						
V_1	38.3	10	21 b	1.2	24.3	984 b
V_2	36	11	24 a	1.3	25	1042 a
	ns	ns	*	ns	ns	*
LSD Value	3.19	1.05	2.98	0.23	1.91	54.13
Irrigation levels (I)						
I_1	39 a	11.5 a	24 a	1.5 a	26.5 a	1102 a
I_2	35.5 b	10 b	21.5 b	1.1 b	22.5 b	920 c
I_3	37 a	10 b	22.5 ab	1.2 b	25 a	1017 b
	*	*	*	*	*	*
LSD Value	2.41	1.39	1.92	0.11	1.93	86.9
Interaction (V×I)						
$V_1 1_1$	40 a	11 ab	23 ab	1.4 b	26 a	1076 a
$V_1 1_2$	37b	10 b	20c	1 d	23 b	894 c
$V_1 1_3$	38 a	9 c	21c	1.2 c	24 b	982bc
$V_2 1_1$	38 a	12 a	25 a	1.6 a	27 a	1128 a
$V_2 1_2$	34 c	10bc	23 ab	1.2 c	22 c	946 c
$V_2 1_3$	36 b	11 ab	24 a	1.2 c	26 a	1052 ab
	*	*	*	*	*	*
LSD Value	2.34	1.29	1.83	0.12	1.81	72.69

Means with different letters are statistically different at * = P < 0.05, ** = P<0.01 (n=3), ns = non-significant. Varieties V_1 = DG-89, V_2 = DG-92, Irrigation level I_1=Normal Irrigation, I_2 = Irrigation skip at flower initiation, I_3= Irrigation skip at pod initiation.

3.4 No. of pods plant^{-1}

No. of pods per plant is an important parameter related with the yield components. Different varieties show the significant difference among each other. V_2 show the maximum no. of pods per plant during both the years. Irrigation levels show statistically significant difference among all the treatments. During 2015-16 maximum no of pods were recorded from I_1 (23.5). During 2016-17 results highlighted contrasting differences. Irrigation I_1 (24) produce maximum no. of pods per plant while these result were statistically similar with I_3 (22.5). Treatment I_2 (21.5) produced the minimum no of pods per plant but statistically similar with I_3. Interaction of varieties and irrigation levels show the significant difference among each other during both the years. Maximum no of pods were produced by V_2I_1 (25) against the minimum was produced by V_1I_2 (19) in 2015-16 and V_1I_2(20)

3.4 No. of seeds per pod

Data show that no of seeds per pod were not statistically significant with each other for varieties. Irrigation treatment significantly improved the no. of seeds per pod. Maximum no. of seeds per pod were recorded from I_1 (1.25 and 1.5 during 2015-16 and 2016-17 respectively). Interaction of variety and irrigation show the significant difference. Highest no of seeds per pod were obtained by V_2I_1(1.3 and 1.6 during 2015-16 and 2016-17). Minimum no of seeds were recorded in V_1I_2.

3.5 100 seed weight (g).

Experimental data revealed non-significant different in studied varieties regarding 100-seed weight. Normal irrigation level I_1 (25.5g and 26.5g during 2015-16 and 2016-17 respectively) produce maximum 100 seed weight. Treatment I_2 (22.5g during both experimental years) produce 11.76% and 15.09% less seed weight during 2015-16 and 2016-17 respectively. Variety and irrigation interaction was significant. Statistically similar results were produced by V_2I_1 (26g) V_2I_3 (25g) V_1I_1 (25g) during 2015-16. Same trend was seen in 2016-17.

3.6 Seed yield (kg ha^{-1})

Data presented in table show that V_2 (1023 and 1042 kg ha^{-1} during 2015-16 and 2016-17 respectively) produced better yield then V_1 (951 and 984 kg ha^{-1} during 2015-16 and 2016-17 respectively). Irrigation level produced the significant difference among all the treatments. Irrigation level I_1 produce 15.81% and 16.52% higher seed yield then I_2 and 7.2% and 7.71% higher seed yield then I_3 during 2015-16 and 2016-17respectively. Interaction of variety and irrigation level show the significant difference among each other. The best produced treatment was V_2I_1(1102 and 1128 kg ha^{-1} during 2015-2016 and 2016-17 respectively). Minimum seed yield was recorded from V_1I_2 (864 and 894 kg ha^{-1} during 2015-16 and 2016-17).

4. Discussion

The investigations showed the negative impact of water stress on growth and yield parameters of chickpea. Treatment I_2 = irrigation skip at flower initiation was affected most followed by the stress at pod initiation (I_3). Chickpea significantly reduce the yield at flower initiation, and it considered as most critical stage of chickpea. (Yaqoob et al., 2012). Under stress condition plant height reduced due to the inhibition of cell division and enlargement (Maqbool et al., 2017; Farooq et al., 2017). Similarly, these factors directly affect the water flow to xylem and cell elongation that reduce the no. of branches per plant (Manivannan et al., 2007).

Yield parameter including no. of seeds per pod and pods per plant reduced due to irrigation stress due to the abscission of the reproductive structure (Farooq et al., 2017). Decrease in seed index and seed yield under irrigation stress conditions might be due to lower photosynthetic translocation in the developing grain (Ma et al., 2001). The yield loss caused was mainly due to more floral and pod abortion and negative effects of drought avoidance on CO_2 assimilation (Shaban et al., 2012). Growth, yield and yield components are correlated with each other. R eductionin the No. of seed per pod and pods per plant is were significantly correlated with the yield parameters (AllaJabow et al., 2015; Dar et al., 2016).

5. Conclusion

A field experiment was conducted to investigate comparative performance of two chickpea varieties under different irrigation regimes and to suggest irrigation practice under limited water supply with minimal impact on chickpea yield. Study was conducted using randomized complete block design with split arrangement in triplicate. Three irrigation regimes, i.e., control (stress free irrigation), skipping irrigation at flowering and pod initiation were randomly assigned within subplots. Two commonly grown chickpea cultivars i.e., DG-89 and DG-92 were randomly assigned in main plots. Results showed overall better performance of chickpea variety DG-92 by producing higher yields (1023 and 1042 kg ha^{-1} in 2015-16 and 2016-17) as compared to DG-89 (951 and 984 kg ha^{-1} in 2015-16 and 2016-17) under agroclimatic conditions of Dokri, Sindh. Higher yield of DG-92 can be attributed to higher number of branches per plot and number of seeds per pod. There were similar results were obtained in both experimental years. Irrigation regimes and their interaction with cultivars significantly influenced all studied parameters of yield and yield attributes. Water stress imposed at flower initiation (I_3) proved to more detrimental by maximum reduction (19.3%) in chickpea grain yield, indicating it as most sensitive stage to water stress. Although yield reduction due to water deficit at pod development was significant (8.06%), however significantly lower than the yield reduction when water stress was imposed at flower initiation.

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