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Irrigation levels influenced on morphophysiological characters of chickpea (*Cicer arietinum* L)

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Abstract

An experiment was conducted at the Research farm and laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur during November 2012 to April 2013 to evaluate Morpho-physiological attributes, of Chickpea (*Cicer arietinum* L.) varieties affected by irrigations levels. The experiment was laid out in split plot design with three replications. Four irrigation levels {I_o-No irrigation (control), I_1-30 mm irrigation one at pre-flowering stage, I_2-30 mm irrigation one at pod formation stage and I_3 (30+30=60 mm irrigation one at pre-flowering stage and one at pod formation stage } were considered as main plot treatment and three chickpea genotypes (Barichhola-6, Barichhola-7 and Barichhola-9) were considered as sub plot treatment. Experiment showed that most of the morpho-physiological characters such as plant height, number of branches plant^{-1}, number of leaves plant^{-1}, MRC, RLWC, chlorophyll content, number of total flower plant^{-1}, number of effective flower plant^{-1} and distance from 1st pod to soil surface increased significantly due to application of irrigation. The above parameters were the maximum when the chickpea varieties were treated with I_3 followed by I_1 then I_2 over the control. But proline content increased due to lake of irrigation and I_o produced the maximum proline content.

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Introduction

Chickpea (*Cicer arietinum* L.) is one of the important pulse crops grown in Bangladesh. It belongs to the sub-family Papilionaceae under the family Leguminosae. There are different varieties of chickpea grown in Bangladesh which is locally known as chhola. In Bangladesh about 557508 acres of land are covered by pulses, which produced 203535 m. tons pulse and out of this pulses coverage, about 23101 acres are covered by chickpea, which occupying third position (BBS 2010). Production of pulses had decreased during the past decade. It is a future challenge for Bangladesh to better exploit the potential of pulse crops to meet the country's grain food requirement without endangering the environment.

Since chickpea is grown on residual soil moisture after rainy season, soil moisture is a critical factor from the very beginning of plant establishment until maturity. The problem of moisture stress in the post rainy season on soils on poor water-holding capacity has been tackled to some extent by selecting early-maturing varieties to fit in to the length of the said growing season.

Chickpea is grown in tropical, sub-tropical and temperate regions. Kabuli type is grown in temperate regions while the desi type is suitable in the semi-arid tropics (Muehlbauer and Singh 1987; Malhotra *et al.* 1987). Chickpea is valued for its nutritive seeds with high protein content (25.3-28.9%) after dehulling .The farmers in our country grow chickpea mainly in the rain fed condition and obtain very low yield (Shaikh *et al.* 1989). The lower yield of chickpea is associated with many factors. Soil moisture is one of the most important factors that limit crop yields in many areas of the world (Kramer 1982). Chickpea is cultivated in residual soil moisture and it is often subjected to water stress. Water stress adversely affects many aspects of plant growth, which ultimately reduce production and yield (Hsiao 1973 and Hsiao and Acevedo 1974). Such reduction in yield depends on the intensity and duration of stress, and the stage of crop growth at which stress occurs. In general for pulse crop in Bangladesh, the most sensitive growth stage to drought occurs at flower initiation, flowering, pollination, fertilization and pod filling. Under such situations, high degree of drought tolerance is necessary for the chickpea to maintain its growth and development.

About 35-45% chickpea is planted in December following Aman rice. Similarly, a vast area of land in Barind tract of Rajshahi and Tista floodplain of greater Bogra, Rangpur and Dinajpur districts remain fallow after the harvest of Aman rice, which would be utilized for chickpea cultivation. During 15th January to February last, moisture level declines and many cases chickpea suffers from a soil water deficit. Since most cultivators are not in a condition to irrigate chickpea crop, they could not irrigate properly; as a result, the seed yield is drastically reduced. Thus the national average of yield of chickpea is poor, although the yield potential is promising. Thus chickpea varieties tolerant to water stress with optimum yield potential have to be identified and developed.

Under the above circumstances, the present work was undertaken to study the effect of different irrigation levels on morpho-physiological and biochemical characters of some chickpea genotypes of different irrigation levels under field conditions.

Materials and methods

Site description and plant material used

The experiment was conducted at Research Field and Laboratory at the Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the period of November, 2012 to April, 2013.

The experimental site was located at 25° 38/ and 88° 41/ E longitude and at the elevation of 34.5 m above the sea level. The experimental field was medium high land, sandy loan textured soil belonging to Agro Ecological Zone 1 (AEZ-1) named Old Himalayan Piedmont Plain (UNDP and FAO, 1988). The experimental design was split-plot with three replications. Irrigation was given in main plot and

variety was in sub-plots. Each replication was divided into four equal main plots, randomly. Further each main plot was divided into three sub-plots. Unit plot size was 2m × 1.5m. The distance between block to block was 1m and plot to plot 1m. The experiment comprised of two sets of factors such as (A) three modern varieties (V_1=Barichhola-6,V_2=Barichhola-7 and V_3=Barichhola-9) and (B) Four irrigation level(I_0 - No irrigation (control),I_1 - 30 mm irrigation at pre-flowering stage,I_2 - 30 mm irrigation at pod formation stage andI_3 – 30 mm irrigation at pre-flowering and 30 mm at pod formation stage).

Experiment procedure

The land was first ploughed with a power tiller and then harrowed 7 days before sowing and then ploughed and cross ploughed with country plough. Weeds and stubbles were removed. The larger clods were broken into smaller pieces before sowing for loosening the soil and incorporating the basal fertilizers.

The land was uniformly fertilized with 45-85-35-11 kg for the supplement of N-P-K-B ha^{-1} in the form of Urea, TSP, MP, Boric acid respectively; in addition 10 ton cow dung ha^{-1} was applied in each experimental unit (BARC, 2013). Total amount of fertilizers were applied during final land preparation as basal. The individual plot was spaded and fertilizers were incorporated well before sowing.

Seeds were collected from Pulse Research Center, BARI, Ishuordi, Pabna. The seeds were sown on 5 December, 2012 in lines. Seeds were sown by hand in 40 cm apart rows. The seed to seed distance was 15 - cm and 2 seeds $hill^{-1}$. After sowing the seeds were covered well with the soil by land.

Intercultural operations were done to ensure normal growth of crop. Plants were thinning to maintain about 15 cm distance from one to another at 28 DAS. 1st two hand weeding was done at 37 and 58 DAS and the 3rd and final weeding was done at 79 DAS.

The plots were irrigated as per the experimental treatments as described earlier. At the time of irrigation sufficient care was taken to avoid the flow of irrigation water from one plot to another. Irrigation water coming through the channel was applied to each plot by using an 18 liter bucket to minimize inter plot run off and to apply required amount of water into different plots.

The field was frequently observed to notice any changes in plants, pests and diseases attract to the crop and necessary action was taken for normal plant growth. Insecticide was sprayed two times in 85 DAS and in 92 DAS to prevent the pod borer·

Procedure for data collection

Three plants per plot were randomly selected for data collection. The following parameters were recorded: Plant height (cm) at 45, 60, 75 and 90 DAS (Days After Sowing), Number of branches $plant^{-1}$ at 45, 60, 75 and 90 DAS, Number of leaves $plant^{-1}$ at 45, 60, 75 and 90 DAS, Chlorophyll content, Proline content, Moisture retention capacity, Relative leaf water content, Number of total flower $plant^{-1,}$ Number of effective flower $plant^{-1}$

Physio-chemical traits measurement

Chlorophyll content of leaves during the flowering stage was estimated with 80% aqueous acetone by using a mortar and pestle for grinding the tissue. The optical density (OD) of this solution was determined against 80% acetone as blank using a spectrophotometer (Model: SPECTRO UV-VIS RS, Labomed Inc, USA) at 645 and 663 nm. The total chlorophyll was determined according to the formulae used by Witham *et al.* (1986) as follows:

mg chlorophyll (a+b) g^{-1} leaf tissue = [20.2(D 645) + 8.02(D 663)] x [v/(1000 x w)]

Where, w = Fresh weight of leaf sample

v = Volume of the solution.

Proline content of the chickpea leaves during the flowering stage was measured. Chickpea leaves from each replication of each variety were collected and immediately kept in the ice-bag and brought to Laboratory for proline estimation. Subsequently

proline was estimated as Troll and Lindsley (1955) as follows.

At first, ninhydrin reagent was prepared in such a way so that it was utilized for proline estimation within two hours of preparation. For preparing ninhydrin reagent, addition of 30 ml glacial acetic acid and 30 ml 6M orthophosphoric acid were mixed with 1.25 g of ninhydrin. It was subsequently heated and stirred gently to dissolve but the temperature was not allowed to exceed 70°C. Proline standards were prepared for 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 ppm with distilled water. The fresh samples were crushed in mortar and pestle and homogenized the material in 10 ml 3% sulphosalicylic acid until no large segments of plant material remained. Homogenate was filtered through Whatman No. 2 filter paper and washed with 3% sulphosalicylic acid and the volume was set to 25 ml. Two ml of the filtrate and each standard proline solutions were then reacted with 2 ml of ninhydrin reagent and 2 ml of glacial acetic acid in a pyrex test tube and boiled for one hour at 100°C in water bath covering the tube with aluminium foil to prevent excess evaporation. Subsequently, it was cooled in ice bath and 4 ml of toluene was added to each tube using a dispenser. The absorbance of layer was measured through spectrophotometer at 520 nm with pure toluene as a blank. Proline content was expressed on a fresh weight basis from the standard curve, using standard L-proline. The formula is used as follows:

μ moles g^{-1} tissue = (μg proline ml^{-1}) / 115.5× 5 g^{-1} sample. Where, 115.5 is the molecular weight of proline.

Moisture retention capacity of the chickpea leaves was measured during the flowering stage of the crop. Leaves were collected in tightly fastened polythene bags. Three leaves/replication/cultivar were collected at 8:30 am and their fresh weight (FW) was taken immediately. Then the leaves were arranged systematically in a tray. After arrangement of the leaves, their fresh weight (FW) was taken at 30 minutes intervals for 8 times and thereafter 3 times at 90 minutes intervals. Finally, the leaves were dried in an oven at 85°C for 24 hours and their dry weight (DW) was taken with the help of an electric balance. The moisture retention capacity of leaves was calculated from the following formula.

Moisture retention capacity (%) = $\frac{FW - DW}{FW} \times 100$

Here, FW=Fresh weight of leaf

DW= Dry weight of leaf.

Relative leaf water content (RLWC) was determined from the leaves during the flowering stage. The leaves were collected at 8.00 am, 12.00 pm (noon) and 4.00 pm. Three leaves were taken from each replication. Their fresh weights were taken immediately and were sunk into water and kept in Petridis for four hours. After four hours when the cells of the leaves become fully turgid, they were taken out from water and their turgid weights were taken immediately removing the surface adhere water with blotting paper by an electric balance. Then the leaves were dried in an oven and weighed. The relative leaf water content was calculated from the following formula (Barrs and Weatherly, 1962).

Relative leaf water content (RLWC %) = $\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$

The experimental plots were harvested separately at full maturity. The central 3 rows of crops were harvested for collecting data on yield. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The bundles were dried on open sunshine, threshed and then seeds were cleaned. Prior to harvesting, 03 plants were selected from each plot randomly and uprooted carefully for collecting data on yield.

Data analysis

All the necessary parameters recorded and analyzed statistically. A program called Microsoft Excel 2000 was used for the spreadsheet analysis and numerical calculations. All the recorded data were statistically analyzed following the ANOVA technique and the significance of mean differences were adjusted by Duncan's New Multiple Range Test, DMRT (Gomez and Gomez 1984) with the help of computer package M-STATC.

Results and discussion

The result of the experiment as influenced by three chickpea varieties under four irrigation levels and their interactions on morpho-physiological characters are presented in Table 1 to 3 and Figure 1 to 4. The results of the experiment along with discussion are given below.

Table 1. Effect of irrigation on different morphological characters of chickpea.

Irrigation	*Plant height (cm)*	*No. of branch plant^{-1}*	*No. of leaves plant^{-1}*	*No. of total flowers*	*No. of effective flowers*	*First pod distance (cm)*
I_0	35.67 a	33.22 b	174.80 c	69.67 b	55.59 b	13.36 b
I_1	37.67 a	45.18 a	197.50 b	93.11 a	63.96 ab	15.30 a
I_2	36.74 a	40.22 ab	193.37 bc	86.37 ab	60.74 ab	14.03 ab
I_3	38.93 a	47.67 a	220.83 a	109.03 a	73.97 a	16.24 a
CV (%)	6.95	6.78	7.78	5.89	7.78	8.96

In each column, values with similar letter(s) are not significantly different at the 5% level of DMRT.

Plant height (cm)

Irrigation levels had minor effect on plant height of chickpea (Table 1). The effect was insignificant. The highest plant height (38.93 cm) was recorded in I_3 (irrigation one at pre-flowering stage and one at pod formation stage). The lowest plant height (35.67 cm) was observed in I_0 (no irrigation).

The effect of different genotypes on plant height was significant (Table 2). The result indicated that Barichhola-9 produced the tallest plant under all irrigation levels. The highest plant height (42.31 cm) was obtained from V_3 (Barichhola-9) and the lowest plant height (35.28 cm and 34.17 cm) were noticed in V_2 (Barichhola-7).

Table 2. Effect of variety on different morphological characters of chickpea.

Variety	*Plant height (cm)*	*No. of branch plant^{-1}*	*No. of leaves Plant^{-1}*	*No. of total flowers*	*No. of effective flowers*	*First pod distance (cm)*
V_1	34.17 b	39.58 a	171.78 b	82.11 a	68.75 a	12.76 b
V_2	35.28 b	41.56 a	187.13 ab	91.55 a	58.22 b	15.19 a
V_3	42.31 a	43.58 a	230.98 a	94.98 a	63.72 ab	16.25 a
CV (%)	6.95	6.78	7.78	5.89	7.78	8.96

In each column, values with similar letter(s) are not significantly different at the 5% level of DMRT.

The interaction effects between irrigation levels and genotypes on plant height were highly significant (Table 3. The highest plant height (43.22 cm) was noticed in V_3I_3 (Barichhola-9 with irrigation one at pre-fowering stage and one at pod formation stage) .The lowest plant height (32.44 cm and 33.00 cm) were obtained from V_1I_0 (Barichhola-6 with no irrigation) and V_2I_0 (Barichhola-7 with no irrigation) but V_1I_1, V_2I_1, V_1I_2, V_1I_3 and V_2I_2 also gave similar results.

Number of branches plant^{-1}

The effect of different irrigation levels on number of branches plant^{-1} was found statistically significant (Table 1). The results indicated that number of branches plant^{-1} increased with increasing soil water level. The maximum number of branches plant^{-1} (47.67 and 45.18) was recorded in I_3 and I_1. The minimum number of branches plant^{-1} (33.22) was observed in I_0. Reduced number of branches plant^{-1} might be due to inhibition of cell division/cell enlargement under water stress. The result is in confirmation with Palled *et al.* (1985) where they reported that the number of branches plant^{-1} increased due to irrigation (in Black gram).

The effect of different genotypes on number of branches plant^{-1} was insignificant (Table 5). The maximum number of branches plant^{-1} (43.58) was obtained from V_3 (Barichhola-9) and the minimum number of branches plant^{-1} (39.58) was found in V_1 (Barichhola-6).

Table 3. Effect of interaction of irrigation and variety on different morphological characters of chickpea.

Treatments	*Plant height (cm)*	*No. of branch plant^{-1}*	*No. of leaves plant^{-1}*	*No. of total flowers*	*No. of effective flowers*	*First pod distance (cm)*
V_1I_0	32.44 d	29.22 b	158.80 d	63.00 c	55.56 b	10.97 d
V_1I_1	34.56 cd	44.89 ab	162.40 cd	88.00 abc	68.00 ab	13.56 bcd
V_1I_2	34.22 cd	37.89 ab	161.90 cd	78.44 abc	66.78 ab	12.72 cd
V_1I_3	35.45 cd	46.33 a	204.00 bcd	99.00 abc	84.67 a	13.78 bcd
V_2I_0	33.00 d	34.33 ab	174.30 cd	72.45 bc	51.11 ab	13.50 bcd
V_2I_1	35.67 cd	45.11 ab	186.70 cd	94.44 abc	61.11 ab	16.11 ab
V_2I_2	34.34 cd	39.00 ab	182.30 cd	90.00 abc	55.00 b	13.69 bcd
V_2I_3	38.11 bc	47.78 a	205.20 bc	109.30 ab	65.67 a	17.44 a
V_3I_0	41.56 ab	36.11 ab	191.30 cd	73.56 bc	60.11 ab	15.61 abc
V_3I_1	42.78 ab	45.55 ab	243.40 ab	96.89 abc	62.78 a	16.22 ab
V_3I_2	41.67 ab	43.78 ab	235.90 ab	90.67 abc	60.44 ab	15.67 abc
V_3I_3	43.22 a	48.89 a	253.30 a	118.80 a	71.56 a	17.50 a
CV (%)	6.95	6.78	7.78	5.89	7.78	8.96

In each column, values with similar letter(s) are not significantly different at the 5% level of DMRT

I_0 = no irrigation
I_1 = one irrigation at pre-flowering stage
I_2 = one irrigation at pod formation stage
I_3 = irrigation one at pre-flowering stage and one at pod formation stage.

V_1 = Barichhola-6
V_2 = Barichhola-7
V_3 = Barichhola-9

The interaction effects between irrigation levels and genotypes on number of branches plant^{-1} were significant (Table 6). The maximum number of branches plant^{-1} (48.89, 47.78 and 46.33) was noticed in V_3I_3, V_2I_3 and V_1I_3 but the most interaction combinations gave the similar results. The minimum number of branches plant^{-1} was (29.22) obtained from V_1I_0.

Number of leaves plant^{-1}

The effect of different irrigation levels on number of leaves plant^{-1} was found significant (Table 1). The results indicated that number of leaves plant^{-1} increased with increasing soil water level. The maximum number of leaves plant^{-1} (220.83) was recorded in I_3 which was followed by I_1 (197.50). The minimum number of leaves plant^{-1} (174.80) was observed in I_0 which was at per with I_2. Reduced number of leaves plant^{-1} might be due to inhibition of cell division/cell enlargement under water shortage condition.

The effect of different genotypes on number of leaves plant^{-1} was significant (Table 2. The maximum number of leaves plant^{-1} (230.98) was obtained from V_3 (Barichhola-9) followed by V_2 (Barichhola-7) and the minimum number of leaves plant^{-1} (171.78) produced by V_1 (Barichhola-6).

The interaction effects between irrigation levels and genotypes on number of leaves plant^{-1} were highly significant (Table 3).The result indicated that

Barichhola-9 produced the highest number of leaves plant^{-1} under all soil water regimes. The maximum number of leaves plant^{-1} (253.30) was noticed in V_3I_3 but V_3I_1 (398.60) and V_3I_2 (381.50) gave the similar results. The minimum number of leaves plant^{-1} (158.80) was obtained from V_1I_0.

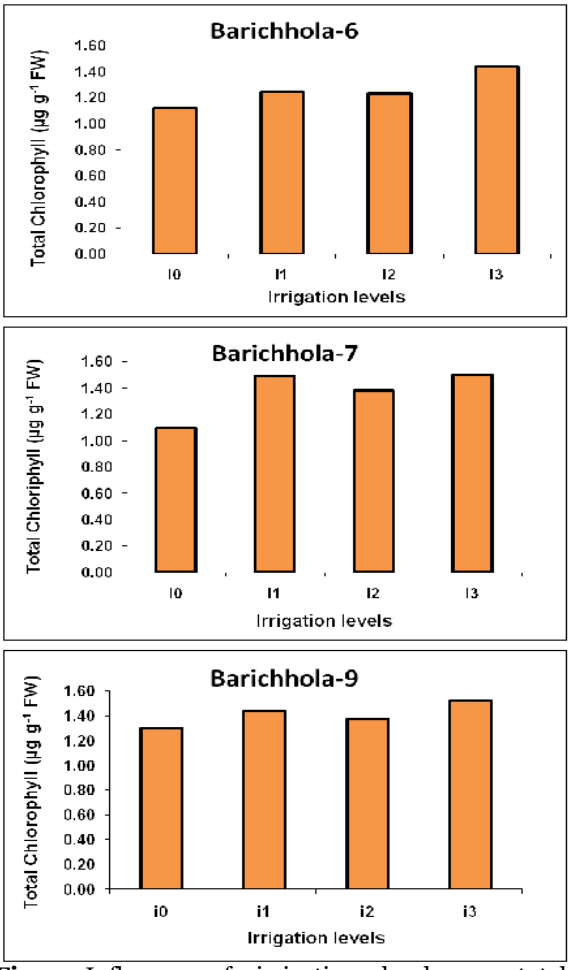

Fig. 1. Influence of irrigation levels on total chlorophyll content of leaf at flowering stage of three chickpea varieties.

Number of total flowers

The results showed that the number of total flowers was affected by irrigation and was significant (Table 1).The maximum number of total flowers (109.03 and 93.11) was noticed in I_3 and I_1 which was similar to I_2 (86.37). The minimum number of total flowers (69.67) was noticed in I_0.

The effect of genotypes on number of total flowers was insignificant (Table 2).Barichhola-9 with (94.98) relatively produced the most number of total flowers in between rather the other genotypes.

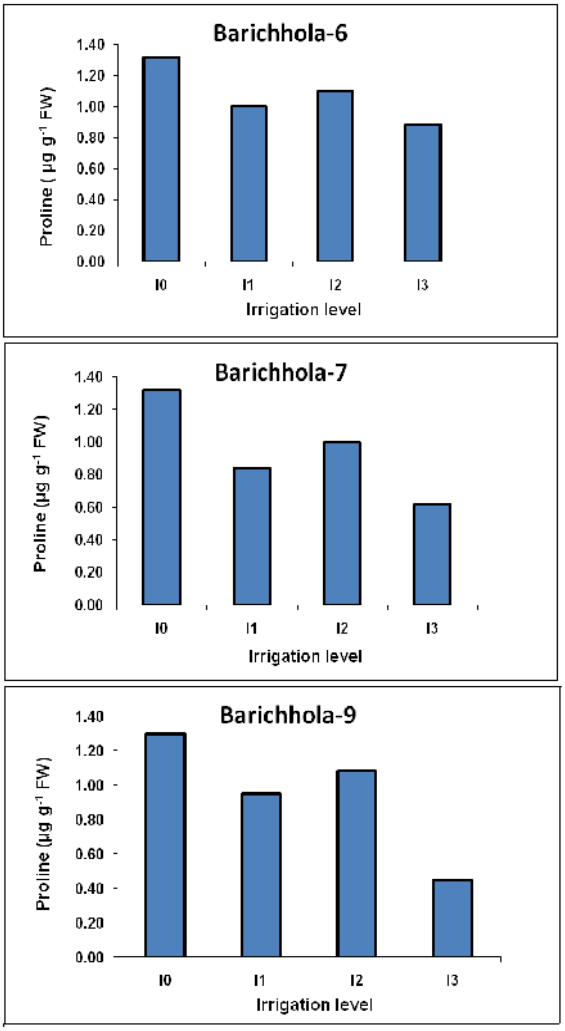

Fig. 2. Influence of irrigation levels on proline content of leaf at flowering stage of three chickpea varieties.

The interaction effects between irrigation levels and genotypes on number of total flowers were highly significant (Table 3).The highest number of total flowers (118.80) was noticed in V_3I_3 which was followed by V_2I_3 but most of the treatment combinations gave similar results. The lowest number of total flowers (63.00) was noticed in V_1I_0.

Number of effective flowers

The results showed that the number of effective flowers was affected by irrigation and was significant (Table 1).In the present experiment due to irrigation levels was an important impact on number of effective flowers. The maximum number of effective flowers (73.97) was in I_3. And the minimum number of effective flowers (55.59) was in I_0.

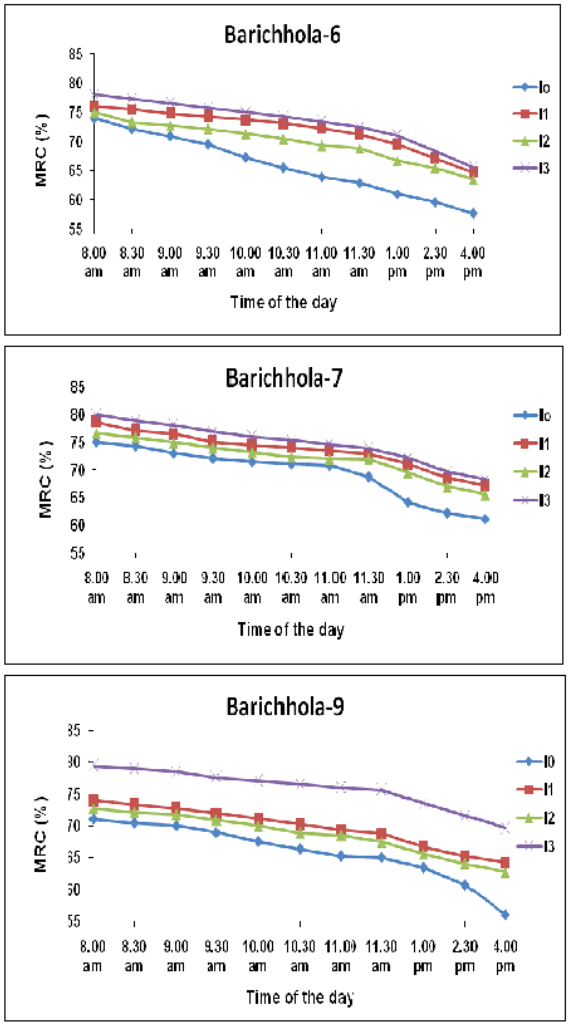

Fig. 3. Influence of irrigation levels on moisture retention capacity (MRC) of leaf at flowering stage of three chickpea varieties.

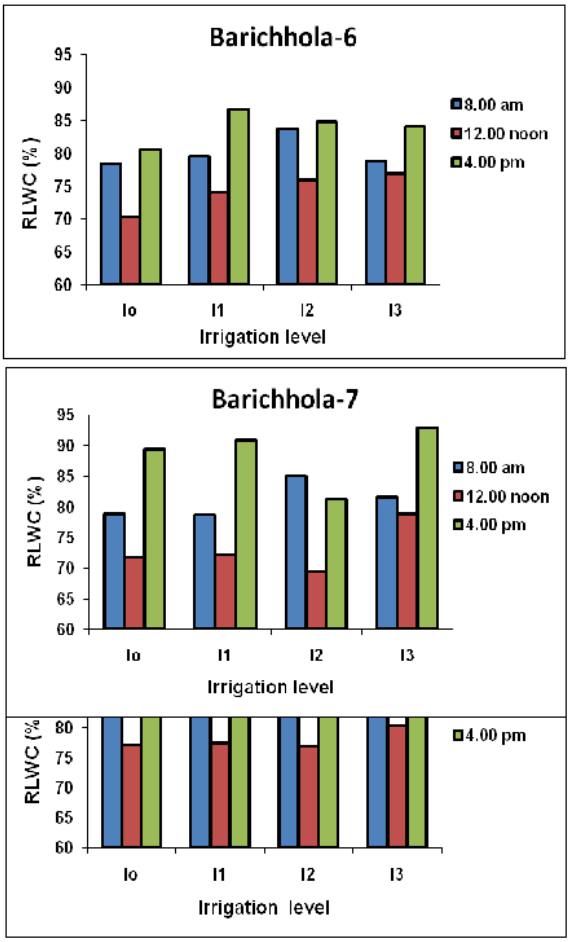

Fig. 4. Influence of irrigation levels on relative leaf water content (RLWC) of leaf at flowering stage of three chickpea varieties.

The effect of genotypes on number of effective flowers was significant (Table 2).The maximum number of effective flowers (68.75) was produced by Barichhola-9 and the minimum number of effective flowers (58.22) was produced by Barichhola-7.

The interaction effects between irrigation levels and genotypes on number of effective flowers were highly significant (Table 3). The maximum number of effective flowers was (84.67) noticed in V_1I_3 which was similar to V_2I_3, V_3I_2 and V_3I_3. The minimum number of effective flowers (55.00) was noticed in V_2I_o which was similar to V_1I_o. Singh *et al* (1994) and Pannu and Singh (1993) respectively, reported that among yield components, the number of effective flowers is more sensitive to drought stress.

First pod distance (cm)

The effect of different irrigation levels on first pod distance from soil surface was found significant (Table 1). The results indicated that first pod distance decreased with increasing irrigation level. The highest first pod distance (16.24 cm) was recorded in I_3 . The lowest first pod distance (13.36 cm) was observed in I_o which was similar to I_2. Reduced first pod distance might be due to inhibition of cell division/cell enlargement under water stress.

The effect of different genotypes on first pod distance was significant (Table 2).The results indicated that Barichhola-9 produced the highest first pod distance under all irrigation levels. The highest first pod distance (16.25) was obtained from V_3 (Barichhola-9). V_1 (Barichhola-6) produced the lowest first pod distance (12.76).

The interaction effects between irrigation levels and genotypes on first pod distance were highly significant (Table 3). The highest first pod distance (17.50 and 17.44) was noticed in V_3I_3 and the lowest first pod distance (10.97) was obtained from V_1I_0 This result was similar to Shamsi *et al.* (2010).

Physiological characters

Total chlorophyll content

Total chlorophyll content (chlorophyll-a and chlorophyll-b) under different irrigation levels was shown in Figure 1.The Barichhola-9 was shown the highest total chlorophyll content with all irrigation levels. The maximum total chlorophyll content was shown in I_3 which was followed by I_1 and I_2. The lowest total chlorophyll content always was shown in I_0. This result was similar to Hafiz (2007). Working with 4 irrigation frequencies in barley Hafiz (2007) reported that chlorophyll in flag leaves of barley significantly increased by irrigation frequency.

Proline content

Proline content in leaf of different chickpea genotypes at flowering stage was influenced by irrigation level (Figure 2). Under I_0 (no irrigation) condition the highest amount of proline was found among all the chickpea varieties and which was followed by I_2 (one irrigation at pod formation stage). And the lowest amount of proline was found in I_3 (irrigation one at preflowering stage and one at pod formation stage) among all three chickpea varieties. Increasing amount of proline content in leaf was also observed by Bahadur (2008) due to shortage of soil water.

It has been widely reported that plant cells achieve their osmotic adjustment by the accumulation of some kind of compatible solutes such as proline (Delauney and Verma 1993). This compound mainly accumulated high amounts in cytoplasm of stressed cells without interfering with macromolecules and behaves as osmoprotectants (Yancey 1994). It has been shown that proline also have a key role in stabilizing cellular proteins and membranes in presence of high concentrations of osmoticum (Yancey 1994, Errabii *et al.* 2006). Zlatev and Stoyanov (2005) suggested that proline accumulation of plants could be only useful as a possible drought injury sensor instead of its role in stress tolerance mechanism.

Moisture retention capacity

Moisture retention capacity of three chickpea varieties was shown in Figure 3. Always the maximum moisture retention capacity was shown in I_3 which was followed by I_1 and I_2. The lowest moisture retention capacity always was shown in I_0. The Barichhola-9 had the highest moisture retention capacity with all irrigation levels.

Relative leaf water content

Effect of different irrigation levels on relative leaf water content at flowering stage of the leaves of three chickpea varieties are shown in Figure 4. At the early morning and at the late afternoon, the higher RLWC was observed but during noon these values was lowest in every treatments. The I_3 irrigation level had higher relative leaf water content than I_2, I_1 and I_0. At 8.00 am the highest relative leaf water content (88.89) was found in V_3I_3 and the lowest leaf water content (78.43) was found in V_1I_0. At 12.00 noon the highest relative leaf water content (80.39) was found in V_3I_3 and the lowest leaf water content (70.37) was found in V_1I_0. It again increased at 4.00 pm. At 4.00 pm the highest relative leaf water content (92.86) was found in V_2I_3 and the lowest leaf water content (80.61) was found in V_1I_0. This result is similar with the results of Singh and Patel (1996). They reported that relative leaf water content was low in water stressed leaf. Siddique *et al.* (1999) and Bahadur (2008) reported that plant subjected to water shortage significantly reduced relative leaf water content.

Fro the above discussion it was concluded that, most of the morpho-physiological characters such as plant height, number of branches plant^{-1}, number of leaves plant^{-1}, MRC, RLWC, chlorophyll content, number of total flower plant^{-1}, number of effective flower plant^{-1} and distance from 1st pod to soil surface increased significantly due to application of irrigation. The above parameters were the maximum when the

chickpea varieties were treated with I_3 followed by I_1 then I_2 over the control. But proline content increased due to lake of irrigation and I_0 produced the maximum proline content.

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