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Evaluation of Yield and Yield Related Traits of Chickpea (*Cicer arietinum* L.) Genotypes under Water Stress Condition

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A B S T R A C T

Drought is the most common abiotic stress limiting chickpea production because chickpea is usually grown under the residual soil moisture. To identify and evaluate drought tolerant chickpea genotypes, the study was carried out during rabi season 2018 and 2019 with three biological replications at Agricultural biotechnology experiment field, SVPUAT, Meerut India. The experiment materials consisted of 10 chickpea genotypes. Chickpea genotypes were significantly different for evaluated traits under non stress and stress conditions, indicating that drought stress increased variation for these traits. Drought stress reduced seed yield and its attributes. Mean seed yield was decreased by 20.46 % and 19.31% in Vishal during 2018 and 2019, respectively under non stress condition than irrigated condition. ICC 14778, JG 11 and ICC 4958 genotypes were detected with high seed yield under non irrigated and irrigated condition. They were also observed superior to the seed yield under irrigated condition.

Introduction

Chickpea (*Cicer arietinum* L.; 2n = 2_= 16), a member of the Fabaceae, is the most essential legume crop after dry beans (*Phaseolus vulgaris*) and dry pea (*Pisum sativum*) with a genome size of ~738 Mb and 28 269 genes (Varshney *et al.*, 2013, Parthasarathy Rao *et al.*, 2010, Pandey *et al.*, 2018). Chickpea (*Cicer arietinum* L.) belong to Leguminosae family and Cicer genus consist of 43 mostly perennials species and 9 species those are annuals (Pundir *et al.*, 1985). In India, Chickpea cultivated almost in all parts of the country mainly as a rainfed crop (68% area) (DAC, Agricultural Statistics at a Glance 2019). During 2018–19, chickpea production has been estimated to be about 8.93 million tonnes (mt), total area 9.35 million hectares with an average yield is 955 Kg. /hectare, which is 46% of the total pulses production (23.95 mt) in India ((DAC, Agricultural Statistics at a Glance 2019). Due to nitrogen-fixing root nodulation capacity Chickpea is valuable crop for improvement of soil fertility especially in rainfed or dry regions (Katerji *et al.,* 2001, Kumar, S. 2016). Chickpea seed contains 17–31% protein it and biological activity of protein ranged from 52 to 78% has a prime significance for human food and animal feed. Essential amino acids like leucine, isoleucine, lysine, valine and phenylalanine are present in significant amount in the readily digestible seed protein (Williams and Singh 1980, Karim and Fattah 2006).

In globally chickpea can be divided into two grouped, that is 'Kabuli' and 'Desi'. Kabuli' type has large seeds with a thin and light coloured seed coat, grown mainly in the Mediterranean regions and used as whole seed in foods. 'Desi' type of chickpea is grown mainly in the Indo-Pak subcontinent and Ethiopia (Pundir *et al*., 1985). About 52 countries grow chickpea including several in North and East Africa, West and South Asia, Australia and South Europe (Ganjeali *et al*.2011). It is grown either as a dry weather crop in semi-arid zones or as a rainfed crop in cool climates (Tahir and Karim 2010). In practice, about 90% chickpea crop is grown in rainfed conditions without reliance on irrigation (Kumar and Abbo, 2001) and thus both vegetative and reproductive phases are adversely affected by water deficiency.

Plants are subjected to various stress conditions in their life cycle. Drought is the second major constraint on chickpea productivity after diseases (Singh *et al*.1994).

Drought limits the agricultural production by preventing the crop plants from expressing their full genetic potential. Many researchers believed that tolerance to drought stress must be done via genetic improvement of seed yield in crops (Passioura, 1996). Different workers used different methods to evaluate genetic differences in drought tolerance (Bidinger *et al.,* 1982). Breeding for drought tolerance is generally considered slow due to the quantitative and temporal variability of available moisture across years, the low genotypic variance in yield under these conditions, inherent methodological difficulties in evaluating component traits, together with the highly complex genetic basis of this character. Selection for drought resistance and production of tolerant cultivars with high yield potential is the main objective of breeding programmes.

Several morphological traits have been listed to play a significant role in crop adaptation to drought stress (Saxena and Johansen 1990; Subbarao *et al.*, 1995). In addition, information on the seed yield, number of pods per plant, number of seeds per pod, 100-seed weight and root traits and the phenotypic correlation among these traits will be useful for planning suitable breeding strategies to improve drought tolerance. The effective selection for traits under improvement depends on sufficient additive genetic variation of the traits. Phenotypic relationships among these traits are also important when simultaneous selection of multiple traits is to be carried out for high yield under drought stress conditions (Painawadee *et al.*, 2009).

Materials and Methods

Experimental plan and water stress treatment

The present experiment was conducted during Nov-2018 to April-2019 and Nov-2019 to April-2020. Ten chickpea genotypes were collected for present investigation from IIPR, Kanpur, NBPGR, New Delhi and MPKV, Rahuri. India. The description of chickpea genotype is given in Table 1. Each genotype was planted in plastic pots (39 × 33 cm^2 pot containing 25.0 kg of soil and 5.0 kg FYM) in completely randomized design, with three biological replications for each genotype. Ten seeds of each genotypes were planted in each pot. The experimental soil was sandy loam with initial pH 7.2 and ECe of 1.39 dSm^{-1}. After 18 days of planting, thinning was carried out and only three plants were left in each pot for further experiment. Similar management inputs like fertilizer and insecticides for proper growth and disease control were given during the experimental period. The water stress was applied by irrigation suppression during Vegetative stage (40 DAS). The plants were constantly irrigated till 40th day of planting. The stress was imposed by withholding irrigation for a period of 7-8 days at above stage. Visual appearance of wilting during morning hours was taken the criterion for the stress and take morphological observations.

Weather condition

The meteorological observations were recorded by an automatic weather station of Indian Institute of Farming System and Research (IIFSR), Modipuram, Meerut, India. The recorded observation are presented in following figure and table (Table 2 and Fig. 1). The observation recorded were min and max temp, percent relative humidity in morning and evening, average rainfall and bright sunshine for Nov-2018 to May-2019 and Nov-2019 to May-2020

Observation of morphological trait

Morphological trait was recorded after stress treatment in drought stressed and control plants. The traits Viz., days to 50% flowering, plant height, number of branches, number of pods per plant, 100 seed weight, yield per plant were recorded for three randomly selected plants for each replication for morphological trait analysis.

Statistical analysis

All the above data were recorded in triplicate ± SD and analyzed statistically using completely randomized design (Panse and Sukhatme, 1970). Graph pad prism version 5.0 were used to performed graph of results.

Results and Discussion

Meteorological observations

The meteorological variables during the experimental period from week 1st to week 17th (Nov-2018 to April-2019) are presented in Fig. 2 and Table 3. During the whole experimental period, the weekly min temperature ranged from 5.9 to 23.3 with a general mean of 11.4°C whereas, max temperature ranged from 15.4 to 40.7 with a grand mean of 27.7 °C. Total rainfall received was 39.3 mm, relative humidity varies from 57.9 to 96.8 having a general mean of 85.7% in morning wherein evening time it varied from 17.6 to 69.0 with an average of 38.9% in evening and 171.2 h of bright sunshine (BSS) during entire experimental period**.**

Effect of water stress on growth and yield attributes

The data pertaining to various yield attributes of chickpea crop viz. branches per plant, pods per plant, test weight and yield per plant are presented in Table 3.

Days to 50 per cent flowering

The data reveals that amongst the control and drought environment, significantly highest days to 50 per cent flowering $plants^{-1}$ were recorded in control during both the years. With drought stress under terminal moisture stress there was a significant and concomitant reduction in the Days to 50 per cent flowering $plants^{-1}$ during both the years. The detailed results evaluated under control condition as well as stress condition for both the years are represented in Table 3 and 4 respectively.

In Rabi season 2018-2019 among the genotypes, under non-stress condition maximum number of Days to 50 per cent flowering plants^{-1} was recorded in GNG-469 (76 ± 2.08) followed by DCP-92-3 (71 ± 1.15), Pusa-362 (70 ± 0.88) and JG 11 (63 ± 1.15) while minimum number of Days to 50 per cent flowering plants^{-1} was recorded in shows in Annigeri 1 (47 ± 1.15 whereas, under stress condition maximum number of Days to 50 per cent flowering plants^{-1} was recorded in GNG 469 (71.33 ± 0.66), followed by DCP-92-3 (66 ± 1.52), Pusa-362 (3.6), and JG 11 (58.33 ± 0.88) while minimum number of Days to 50 per cent flowering plants^{-1} was recorded in recorded in Vishal (43.33 ± 1.76) (Table 3). Maximum reduction precent was recorded in Vishal (12.75 %) and minimum was recorded in ICC 4958 (4.90 %) followed by ICC 867 (5.10 %) (Table 5). Therefore, the range from 47 to 76 and 43.33 to 71.33 Days to 50 per cent flowering plants^{-1} under non-stress and stress condition, respectively (Figure 2).

But, Rabi season 2019-2020 data w.r.t. Days to 50 per cent flowering plants^{-1} were having variation over the first year this variation w.r.t. number of Days to 50 per cent flowering plants^{-1} in both the year, may be due to environmental effects. The results revealed that Days to 50 per cent flowering plants^{-1} decreases significantly with water stress in all the ten varieties. Maximum percent reduction was recorded in Vishal (21.85%) while the minimum percent reduction was observed in ICC 4958 (4.48%) (Table 6). Result further showed under non stress condition variety GNG-469 (74.66±0.88) recorded the maximum number of Days to 50 per cent flowering plants^{-1} closely followed by Pusa-362 (71.33 ± 0.88), DCP-92-3 (68.33 ± 0.88) and JG 11 (61.33 ± 0.88) (Table 4) whereas, the minimum number of Days to 50 per cent flowering plants^{-1} was recorded in ICC 4958 (44.66 ± 1.45) While under water stress condition variety Pusa-362 (66 ± 1.52) showed the maximum number of Days to 50 per cent flowering plants^{-1} closely followed by GNG-469 (65 ± 1.73), DCP-92-3 (64.33 ± 2.33) and JG 11 (57.33 ± 2.33) whereas the minimum number of Days to 50 per cent flowering plants^{-1} was recorded in Vishal (39.33 ± 1.76) (Figure 3). Therefore, the range from 44.66 to 74.66 and 39.33 to 66 under non-stress and stress condition, respectively. ANOVA results have indicated that the number of Days to 50 per cent flowering plants^{-1} is found to be significant (Figure 4).

In the present study, significant difference were observed among the genotypes with respect to days to 50 percent flowering. Among the genotypes GNG 469 (76 days) and Annigeri 1 (47 days); ICC 4958 (44.66 days) had taken less days for days to 50 percent flowering in both experimental years. Similarly, Mathur and Mathur (1996) and Yadav *et al.,* (2001) also reported that days to 50 percent flowering negatively correlated with seed yield under moisture stress. Ahmed *et al.,* (2011) also reported range 41.03-72.33 in control and 41.0 to 72.33 drought stress to the days to 50 per cent flowering.

Plant height (CM)

Plant height (PH) w.r.t. different genotype was influenced by the environment/climatic condition. The detailed results evaluated under control condition as well as stress condition for both the years are represented in Table 3 and 4 at harvest time, respectively.

It is revalued as plant as plant growth progressed, plant height increased and it was positively correlated at different plant growth stages. There was genetic variation with respect to plant height among the genotypes.

Rabi season 2018-2019 plant height differs significantly with respect to treatment. The results revealed that plant height decreases significantly with water stress in all the ten varieties. Maximum reduction was recorded in Vishal (26.54%) while the minimum reduction was observed in ICC 4958 (6.38 %) followed by ICC 867 (8.27%) (Table 5). Result further showed under non stress condition variety Pusa 362 (86.43 ± 1.30 cm) recorded the maximum plant height closely followed by GNG-469 (84.06±1.28 cm), JG 11 (77.06 ± 1.12) and Annigeri 1 (74.78 ± 1.23cm) whereas, the minimum plant height was recorded in Digvijay (52.11 ± 0.73 cm). While under water stress condition variety GNG-469 (75.46 ± 0.52 cm) showed the maximum plant height closely followed by Pusa 362 (71.91 ± 1.48 cm), Annigeri 1 (69.41 ± 0.75 cm) and JG 11 (63.047 ± 1.55 cm) whereas the minimum plant height was recorded in Vishal (42.79 ± 1.20 cm). Therefore, the range from 52.11 ± 0.73 cm to 86.43 ± 1.30 cm and 42.79 ± 1.20 cm and 75.46 ± 0.52 under non-stress and stress condition respectively (Figure 4).

But, the Rabi season 2019-2020 data w.r.t. plant height were having variation over the first year this variation w.r.t. plant height in both the year, may be due to environmental effects. The results revealed that plant height decreases significantly with water stress in all the ten varieties. Maximum reduction was recorded in Vishal (11.49%) and minimum reduction was recorded in ICC 4958 (2.74%) followed by ICC 867 (5.02%) (Table 6). Result further showed under non stress condition variety GNG 469 (86.57 ± 1.08 cm) recorded the maximum plant height closely followed by Pusa 362 (80.94 ± 1.07 cm) and ICC 4958 (75.73 ± 0.13 cm) whereas the minimum plant height was recorded in ICC 867 (42.14 ± 1.08 cm). While under water stress condition variety GNG (74.76 ± 1.20 cm) showed the maximum plant height closely followed by ICC 4958 (72.98 ± 1.44cm), and Pusa 362 (70.43 ± 1.03 cm), and whereas the minimum plant height was recorded in ICC 867 (37.11 ± 0.84 cm) (Figure 5). Therefore, the range from 42.14 ± 1.08 cm to 86.57 ± 1.08 and 37.11 ± 0.84 cm and 74.76 ± 1.20 cm under non-stress and stress condition respectively. ANOVA results have indicated that the height of plant is found to be significant.

Though, plant height is basically a genetically controlled character, it is being influenced by environmental conditions and management practices and also a several reports indicating hat height will be reduced due to water stress (Evans, 1975; Rahman and Uddin, 2000). The present study revealed significant differences in plant height at all stages. Among the all genotypes, Pusa-362 (86.430cm) recorded significantly higher plant height as compared to other genotypes and lower was noticed in Digvijay (52.11 cm) and ICC 867 (37.11 cm) in both the year respectively. The results are similar to those of Katiyar *et al.,* (1977) and Rao and Kumar (2000) who also reported differences for plant height among different chickpea genotypes under water stress. The observations recorded in the present investigation were in agreement with the findings of Hussain *et al.,* (2015).

Primary branches per plant

The data reveals that amongst the control and drought environment, non significantly highest number of primary branches plants^{-1} were recorded in control during both the years. With drought stress under terminal moisture stress there was a non significant and concomitant reduction in the number of primary branches plant^{-1} during both the years. The detailed results evaluated under control condition as well as stress condition for both the years are represented in Table 3 and 4 respectively.

In Rabi season 2018-2019 among the chickpea genotypes, under non-stress condition maximum number of primary branches plant^{-1} was recorded in Pusa-362 (4.9±0.33) followed by Annigeri 1 (4.8±0.33), GNG-469 (4.5±0.57) and ICC 4958 (3.8±0.33) while minimum number of primary branches plant^{-1} was recorded in shows in ICC 867 (3.0±0.57), whereas under stress condition maximum number of primary branches plant^{-1} was recorded in GNG 469 (4.0±0.57), followed by Pusa-362 (3.6±0.57), Annigeri 1 (3.5±0.57) and ICC 4958 (3.5±0.57) while minimum number of primary branches plant^{-1} was recorded in recorded in Vishal (2.1±0.33) (Figure 6). Maximum reduction percent was recorded in Vishal (35.04 %) and minimum was recorded in ICC 4958 (8.70 %) followed by ICC 867 (8.89 %) (Table 5). Therefore, the range from 3.0 to 4.9 and 2.1 to 4.0 cm under non-stress and stress condition, respectively.

But, in rabi season 2019-2020, data w.r.t. primary branches plant^{-1} were having variation over the first year this variation w.r.t. number of primary branches plant^{-1} in both the year, may be due to environmental effects. The results revealed that primary branches plant^{-1} decreases nonsignificantly with water stress in all the ten varieties. Maximum percent reduction was recorded in Vishal (27.00 %) while the minimum percent reduction was observed in 1CC 4958 (10.48 %) and ICC 867 (11.76%) (Table 6). Result further showed under non stress condition variety Pusa-362 (4.6±0.57) recorded the maximum number of primary branches plant^{-1} closely followed by GNG-469 (4.5±0.5); Digvijay (4.5±0.33) and ICC 14778 (4.1±0.33) (Figure 7) whereas the minimum number of primary branches plant^{-1} was recorded in ICC 4958 (2.8±0.57). While under water stress condition variety Pusa-362 (3.9±0.88) showed the maximum number of primary branches plant^{-1} closely followed by GNG-469 (3.8±0.72), Digvijay (3.7±0.44) and JG 11 (3.5±0.88), and whereas the minimum number of primary branches plant^{-1} was recorded in ICC 4958 (2.5±0.57) (Table 4). Therefore, the range from 2.8 to 4.6 and 2.5 to 3.9 under non-stress and stress condition, respectively. ANOVA results have indicated that the number of primary branches plant^{-1} is found to be nonsignificant.

Hussain *et al.,* (2015) also reported the similar genotypic variation in number of branches plant^{-1} was decline under the water stress at flowering and pod formation stage.

Secondary branches per plant

The data reveals that amongst the control and drought environment, significantly highest number of secondary branches plants^{-1} was recorded in control during both the years. With drought stress under terminal moisture stress there was a significant and concomitant reduction in the number of secondary branches plant^{-1} during both the years. The detailed results evaluated under control condition as well as stress condition for both the years are represented in Table 3 and 4 respectively.

In Rabi season 2018-2019 among the chickpea genotypes, under non-stress condition maximum number of secondary branches plant^{-1} was recorded in GNG-469 (17.50±0.57) followed by Annigeri 1 (15.50±0.57), ICC 867 (14.50±0.57) and ICC 14778 (14.40±0.57) while minimum number of secondary branches plant^{-1} was recorded in Pusa-362 (8.33±0.57), whereas under stress condition maximum number of secondary branches plant^{-1} was recorded in GNG 469 (14.50±0.57), followed by DCP-92-3

(12.66±0.88), ICC 14778 (12.60±0.57) and Annigeri 1; ICC 867 (12.50±0.57) while minimum number of secondary branches plant^{-1} was recorded in recorded in Pusa-362 (6.83±0.33) (Figure 8). Maximum reduction precent was recorded in Vishal (26.96 %) and minimum was recorded in ICC 4958 (3.11%) and ICC 867 (6.90 %) (Table 5). Therefore, the range from 8.33 to 17.50 and 6.83 to 14.50 under non-stress and stress condition, respectively.

But, the Rabi season 2019-2020 data w.r.t. secondary branches plant^{-1} were having variation over the first year this variation w.r.t. secondary branches plant^{-1}, may be due to environmental effects. The results revealed that secondary branches plant^{-1} decreases significantly with water stress in all the ten varieties. Result further showed under non stress condition variety Annigeri 1 (16.3±0.88) recorded the maximum number of secondary branches plant^{-1} closely followed by GNG-469 (15.50 ±0.57), DCP-92-3; ICC 14778 (14.00) and JG-11; ICC 867 (13.50 ±0.57) whereas the minimum secondary branches plant^{-1} was recorded in Pusa-362 (8.40 ±0.57). While under water stress condition variety GNG (13.83 ±0.88) showed the maximum secondary branches plant^{-1} closely followed by Annigeri 1 (13.50 ±0.57), ICC 14778; DCP-92-3 (12.00 ±0.57) and ICC 867 (11.50 ±0.33), and whereas, the minimum secondary branches plant^{-1} was recorded in Vishal (6.16 ±0.72) (Figure 9). Maximum reduction percent was recorded in Vishal (38.33 %) and minimum was recorded in ICC 4958 (5.80 %) and ICC 867 (9.88 %) (Table 6). Therefore, the range from 8.40 to 16.33 and 6.16 to 13.83 under non-stress and stress condition, respectively. ANOVA results have indicated that the secondary branches plant^{-1} is found to be significant.

Table.1 Description of chickpea genotypes used under study

S. No.	Genotypes	Parentage	Type	Originating center	Drought response
1.	Annigeri-1	Local selection from germplasm of Karanataka	Desi	MPKV, Rahuri	Tolerant, adapted variety
2.	JG 11	[(Phule G5 x Narsinghpur bold) x ICCC37]	Desi	MPKV, Rahuri	Tolerant
3.	ICC 4958	GW 5/7, a drought tolerant breeding line from ICRISAT	Desi	MPKV, Rahuri	Moderately tolerant
4.	Digvijay	Phule G-91028 × Bheema	Desi	MPKV, Rahuri	Susceptible
5.	Vishal	K 850 × ICCL 80074	Desi	MPKV, Rahuri	Susceptible
6.	Pusa 362	(BG 203 x P 179) x BC 203	Desi	MPKV, Rahuri	Susceptible
7.	DCP-92-3	Selection from germplasm	Desi	IIPR, Kanpur	Susceptible
8.	GNG-469	Derivative of Annegiri× H75-35	Desi	IIPR, Kanpur	Susceptible
9.	ICC 867	Germplasm accessions	Desi	NBPGR	Highly tolerant
10.	ICC 14778	Germplasm accessions	Desi	NBPGR	Highly tolerant

Table.2 Meteorological observations recorded during experimental period

Week	Temp Max (˚C)	Temp Min (˚C)	RH in Morning (%)	RH in Evening (%)	Rainfall (mm)	BSS (h)
week 45	26.0	10.7	96.8	69.0	0.0	1.4
week 46	27.7	13.1	94.8	52.7	0.0	4.6
week 47	25.1	6.7	57.9	28.1	0.0	7.7
week 48	24.9	6.1	95.7	28.4	0.0	7.4
week 49	24.3	7.9	87.7	28.6	0.0	5.3
week 50	20.0	8.4	90.9	52.1	10.0	3.5
week 51	23.3	7.9	96.3	38.1	0.0	4.5
week 52	23.0	6.4	94.3	41.9	0.0	5.7
week-1	15.4	5.9	91.9	68.7	0.0	2.5
week-2	21.9	6.4	96.0	35.9	0.0	6.6
week-3	23.6	6.9	91.7	40.4	0.0	6.8
week-4	19.7	6.6	94.3	55.3	0.0	4.6
week-5	24.7	7.8	94.4	32.9	0.0	7.6
week-6	23.9	6.6	90.6	26.6	0.0	6.4
week-7	23.3	9.0	87.9	45.4	3.6	7.4
week-8	30.1	11.1	87.6	34.9	0.2	7.1
week-9	31.4	13.4	76.4	31.6	0.0	7.5
week-10	31.3	12.3	83.7	31.3	0.0	8.9
week-11	32.3	14.3	84.4	30.3	0.0	8.3
week-12	33.7	15.9	81.0	37.7	0.0	8.0
week-13	35.3	16.7	80.7	33.6	0.0	8.4
week-14	37.6	20.7	78.0	44.1	0.0	7.2
week-15	33.1	19.1	84.4	48.6	24.0	8.4
week-16	39.7	22.0	65.0	19.4	0.0	8.9
week-17	40.7	23.3	61.4	17.6	0.0	9.8
Mean	27.7	11.4	85.7	38.9	1.5	6.6

Table.3 Morphological observations of chickpea genotypes under water stress (2018-2019) (n=03)

Character→ Genotypes ↓	DTF 50%		PH		NP		NPB		NSB		TW		SY	
	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
Annigeri 1	47.66±1.15	44.33±1.85	74.78±1.23	69.41±0.75	43.00±1.15	36.33±0.88	4.8±0.33	3.5±0.57	15.5±0.57	12.5±0.57	25.81±1.61	19.85±0.87	17.30±0.09	15.19±0.1
JG 11	63.00±1.15	58.33±0.88	77.06±1.12	63.47±1.55	51.00±1.15	44.67±2.40	3.1±0.57	2.8±0.57	14.5±0.57	11.5±0.57	23.50±.017	20.38±0.13	21.36±0.25	17.92±0.38
ICC 4958	47.33±1.45	45.33±2.02	60.86±1.29	56.98±1.06	35.00±1.73	31.33±0.66	3.8±0.33	3.5±0.57	12.6±0.57	12.2±0.59	30.10±0.20	27.95±0.22	20.48±0.14	18.85±0.03
Digvijay	57.66±1.15	52.66±0.88	52.11±0.73	43.60±0.81	79.66±0.88	64.00±1.52	3.5±0.57	2.8±0.33	12.6±0.88	10.6±0.88	24.73±0.12	22.83±0.38	17.39±0.13	14.52±0.16
Vishal	49.00±1.15	43.33±1.76	58.24±1.16	42.79±1.20	44.67±1.45	28.33±0.88	3.3±0.57	2.1±0.33	11.5±0.57	8.4±0.57	27.60±0.20	19.98±0.09	18.02±0.16	14.54±0.19
Pusa-362	70.00±0.88	65.00±1.52	86.43±1.30	71.91±1.48	74.66±0.66	65.33±1.45	4.9±0.33	3.6±0.57	8.33±0.57	6.8±0.33	20.39±0.03	18.79±0.09	20.33±0.26	17.49±0.25
DCP-92-3	71.66±1.15	66.00±1.52	71.00±1.07	62.66±1.62	48.00±0.57	41.66±0.88	3.6±0.66	3.0±0.57	15±0.57	12.6±0.88	22.28±0.02	20.36±0.23	19.25±0.55	16.64±0.18
GNG-469	76.33±2.08	71.33±0.66	84.06±1.28	75.46±0.52	78.66±0.33	70.00±1.52	4.5±0.57	4±0.57	17.5±0.57	14.5±0.57	26.24±0.29	23.76±1.02	18.13±0.32	15.24±0.12
ICC 867	52.00±0.57	49.66±0.88	57.67±0.53	52.90±1.29	73.33±2.02	65.33±1.45	3.0±0.57	2.7±0.33	14.5±0.57	13.5±0.57	14.40±0.12	13.31±0.03	17.12±0.27	15.48±0.25
ICC 14778	57.66±1.15	51.66±0.88	69.74±1.36	62.34±1.18	40.00±2.08	33.66±0.88	3.5±0.57	2.6±0.33	14.4±0.57	12.6±0.57	23.60±0.03	21.67±0.09	25.36±0.15	21.31±0.18
C.D.	3.557	4.083	3.389	3.569	3.973	4.01	N/A	N/A	1.826	1.883	1.619	1.245	0.796	0.616
SE(m)	1.197	1.374	1.141	1.201	1.337	1.35	0.527	0.494	0.615	0.634	0.545	0.419	0.268	0.208
SE(d)	1.693	1.944	1.613	1.699	1.892	1.909	0.745	0.699	0.869	0.896	0.771	0.593	0.379	0.293
C.V.	3.511	4.347	2.855	3.462	4.079	4.864	23.862	27.779	7.796	9.511	3.955	3.474	2.384	2.15

Table.4 Morphological observations of chickpea genotypes under water stress (2019-2020) (n=03)

Character→ Genotypes ↓	DTF 50%		PH		NPB		NSB		NPP		TW		SY	
	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
Annigeri 1	50.33±1.15	42.00±1.15	64.73±2.32	53.02±1.42	3.5±0.57	2.6±0.44	16.3±0.88	13.5±0.57	41.33±0.88	37.33±1.45	29.68±0.05	25.49±0.25	19.46±0.27	17.22±0.05
JG 11	61.33±0.88	57.33±2.33	69.87±1.24	63.54±0.83	4.1±0.57	3.4±0.88	13.5±0.57	10.4±0.49	50.00±1.73	45.33±1.45	22.4±0.22	19.98±0.09	24.30±0.08	19.49±0.11
ICC 4958	44.66±1.45	42.66±1.45	75.73±0.13	72.98±1.44	2.8±0.57	2.5±0.57	11.5±0.57	10.8±0.16	35.66±1.20	34.00±0.57	27.60±0.38	26.20±0.52	19.22±0.02	17.66±0.08
Digvijay	54.66±1.45	48.66±2.33	57.94±1.20	51.06±0.94	4.5±0.33	3.6±0.44	12±0.57	10±0.57	73.33±0.66	62.00±1.52	22.31±0.18	17.27±0.10	16.39±0.07	13.16±0.07
Vishal	50.33±1.45	39.33±1.76	48.93±1.26	37.44±1.04	3.8±0.88	2.8±0.57	10±0.57	6.1±0.72	42.33±1.45	30.33±1.45	27.07±0.46	20.15±0.03	17.27±0.10	13.74±0.25
Pusa-362	71.33±0.88	66.00±1.52	80.93±1.07	70.43±1.03	4.6±0.57	3.9±0.88	8.4±0.57	7.3±0.60	77.66±1.45	70.00±1.73	19.85±0.08	16.39±0.07	19.48±0.11	17.48±1.68
DCP-92-3	68.33±0.88	64.33±2.33	69.07±0.68	62.21±1.25	3.6±0.88	3.0±0.57	14±0.57	12±0.57	47.33±0.88	43.00±1.73	21.16±0.08	17.48±1.16	18.89±0.26	16.46±0.10
GNG-469	74.66±0.88	65.00±1.73	85.90±1.08	74.76±1.20	4.5±0.57	3.8±0.72	15.5±0.57	13.8±0.88	70.33±0.88	64.00±1.73	25.57±0.09	23.37±0.17	17.28±0.08	14.34±0.06
ICC 867	53.00±1	50.00±0.57	42.14±1.08	37.11±0.84	3.5±0.57	3.1±0.46	13.5±0.57	12.1±0.33	75.33±1.45	71.66±0.88	16.41±0.2	15.01±0.31	17.37±0.14	15.87±0.02
ICC 14778	56.00±0.57	52.33±1.20	65.86±1.71	59.18±1.03	4.1±0.33	3.1±0.33	14.0±0.57	12.0±0.8	37.00±1.52	32.66±0.66	17.28±0.08	13.43±0.04	20.15±0.39	18.35±0.18
C.D.	3.269	5.146	3.865	3.342	N/A	N/A	1.826	1.663	3.745	4.119	0.677	1.283	0.429	1.152
SE(m)	1.101	1.732	1.301	1.125	0.615	0.617	0.615	0.56	1.261	1.386	0.228	0.432	0.144	0.388
SE(d)	1.556	2.449	1.84	1.591	0.869	0.872	0.869	0.791	1.783	1.961	0.322	0.611	0.204	0.548
C.V.	3.262	5.685	3.408	3.349	27.086	33.136	8.27	8.956	3.967	4.897	1.722	3.841	1.317	4.1

Table.5 Percent changes in Morphological observations in Chickpea genotypes under water stress (2018-2019)

Character→ Genotypes ↓	DTF 50%	PH	NPP	NPB	NSB	TW	SY
Annigeri 1	5.67	7.19	15.50	27.59	19.35	23.09	12.21
JG 11	7.41	18.19	12.42	10.44	20.69	13.28	16.09
ICC 4958	4.90	6.38	10.48	8.70	3.11	8.75	7.93
Digvijay	7.60	16.32	19.67	19.05	15.79	6.47	16.48
Vishal	12.75	26.54	36.57	35.04	26.96	27.61	19.31
Pusa-362	7.14	16.80	12.50	27.03	17.97	7.54	14.00
DCP-92-3	7.04	11.74	13.19	18.18	15.56	8.59	13.54
GNG-469	6.14	10.23	11.02	11.11	17.14	9.44	15.96
ICC 867	5.10	8.27	10.91	8.89	6.90	8.01	9.61
ICC 14778	9.36	10.61	15.83	23.81	12.50	8.20	15.96

Table.6 Percent changes in morphological observations in Chickpea genotypes under water stress (2019-2020)

Character→ Genotypes ↓	DTF 50%	PH	NPP	NPB	NSB	TW	SY
Annigeri 1	16.00	11.71	9.68	23.81	17.35	14.12	11.51
JG 11	6.52	6.33	9.33	15.95	22.96	10.80	19.79
ICC 4958	4.48	2.74	4.67	10.48	5.80	5.10	8.10
Digvijay	10.98	6.88	15.45	18.52	16.67	22.60	19.72
Vishal	21.85	11.49	28.35	27.00	38.33	25.55	20.46
Pusa-362	7.48	10.50	9.87	14.49	12.70	17.41	10.28
DCP-92-3	5.85	6.86	9.15	18.18	14.29	17.39	12.86
GNG-469	12.95	11.14	9.00	14.81	10.75	8.61	17.01
ICC 867	5.66	5.02	4.87	11.76	9.88	8.53	8.60
ICC 14778	6.55	6.67	11.71	24.00	14.29	22.31	8.95

Fig.1 Morphological Parameters Measurement

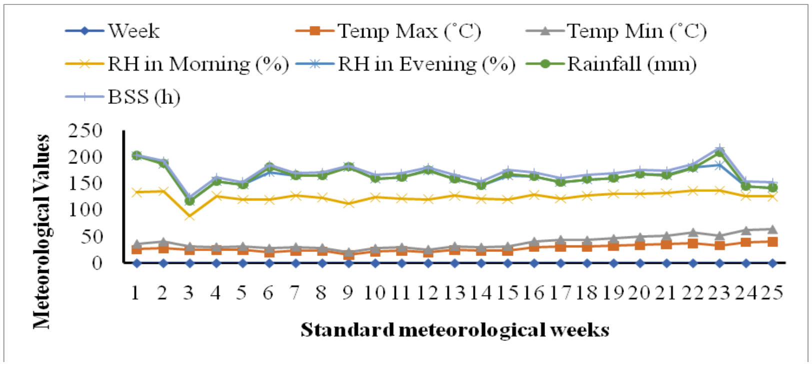


Fig.2 Days to 50 per cent flowering plants^{-1}of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean Days to 50 per cent flowering of three biological replication and error bars indicated the standard error (±SE)

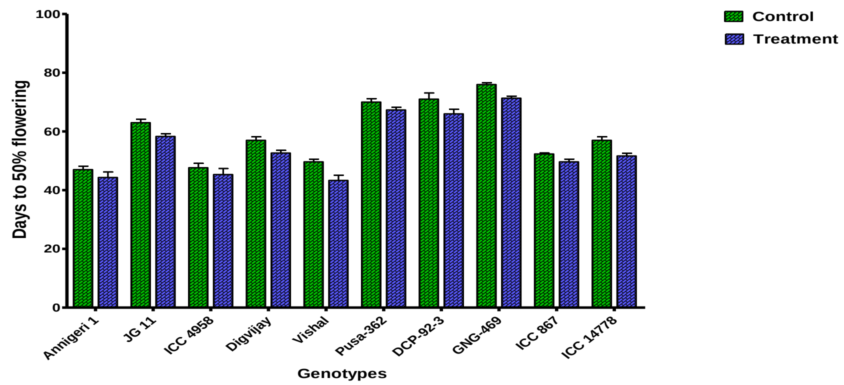


Fig.3 Days to 50 per cent flowering plants^{-1}of chickpea genotypes under two levels of water stress , season 2019. Bars represent mean Days to 50 per cent flowering of three biological replication and error bars indicated the standard error (±SE)

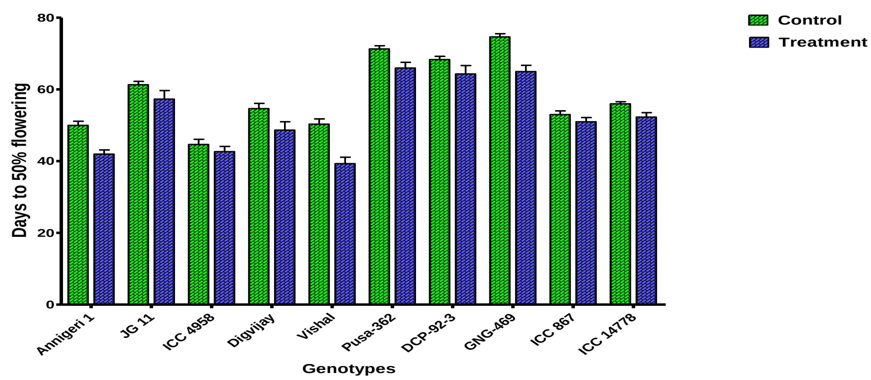


Fig.4 Plant height plants^{-1}of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean Plant height of three biological replication and error bars indicated the standard error (±SE)

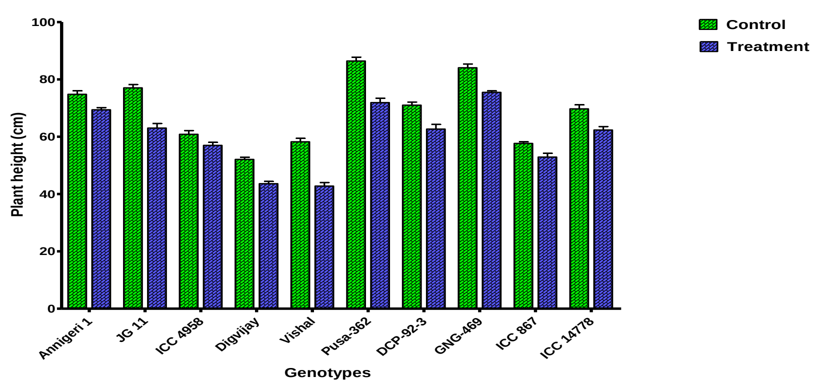


Fig.5 Plant height plants^{-1}of chickpea genotypes under two levels of water stress, season 2019. Bars represent mean Plant height of three biological replication and error bars indicated the standard error (±SE)

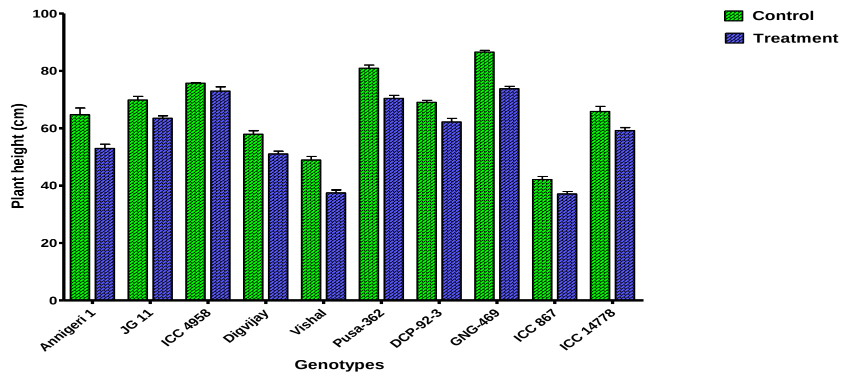


Fig.6 Primary branchesplants^{-1}of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean primary branches of three biological replication and error bars indicated the standard error (±SE)

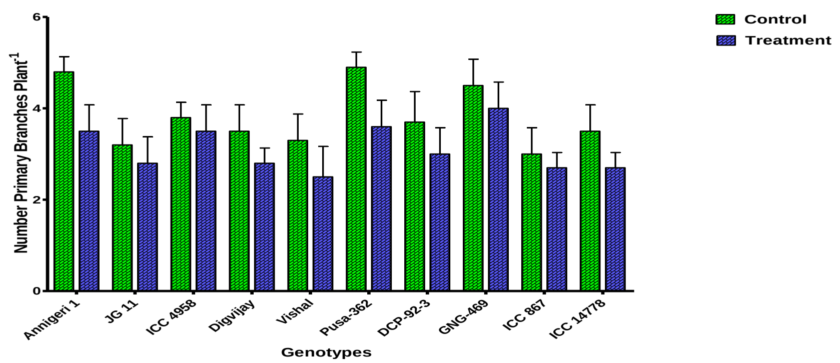


Fig.7 Primary branchesplants^{-1}of chickpea genotypes under two levels of water stress, season 2019. Bars represent mean primary branches of three biological replication and error bars indicated the standard error (±SE)

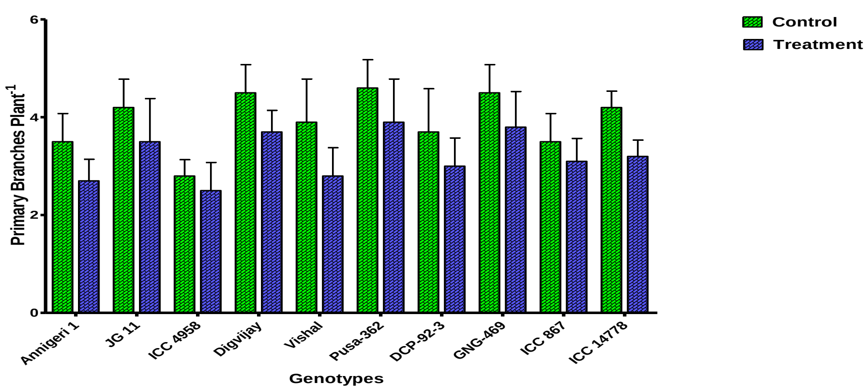


Fig.8 Secondary branchesplants^{-1}of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean secondary branches of three biological replication and error bars indicated the standard error (±SE)

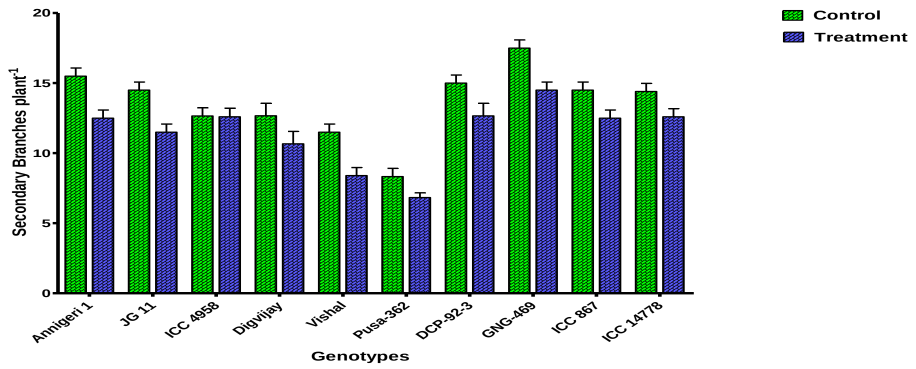


Fig.9 Secondary branchesplants^{-1}of chickpea genotypes under two levels of water stress, season 2019. Bars represent mean secondary branches of three biological replication and error bars indicated the standard error (±SE)

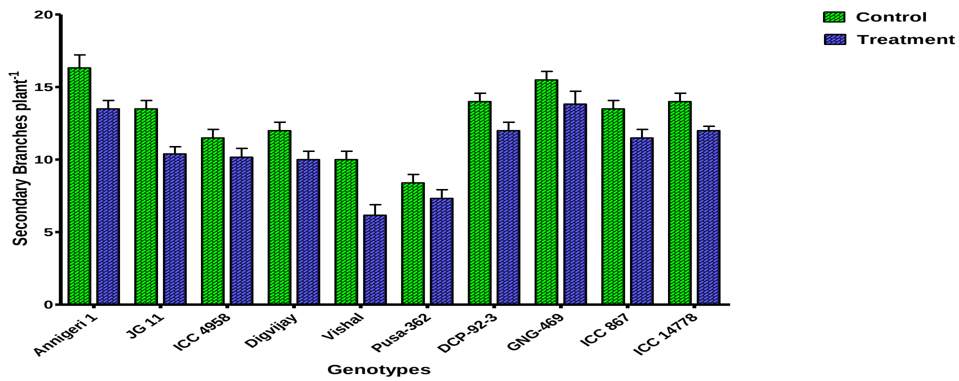


Fig.10 Podsplant^{-1}of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean Podsplant^{-1}of three biological replication and error bars indicated the standard error (±SE)

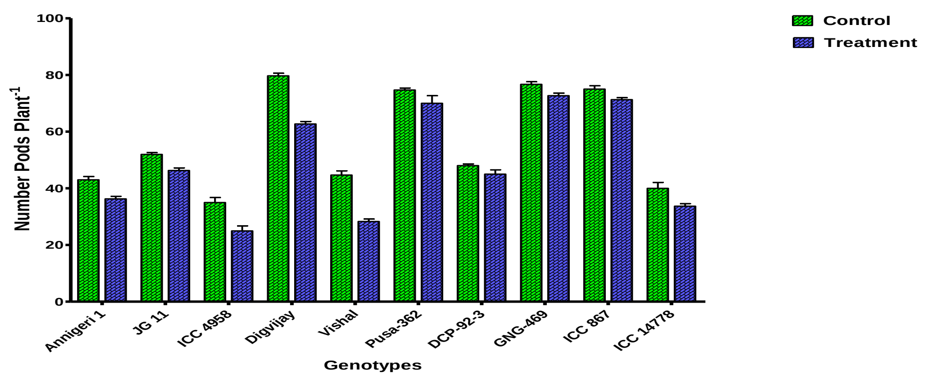


Fig.11 Podsplant^{-1}of chickpea genotypes under two levels of water stress, season 2019. Bars represent mean Podsplant^{-1} of three biological replication and error bars indicated the standard error (±SE)

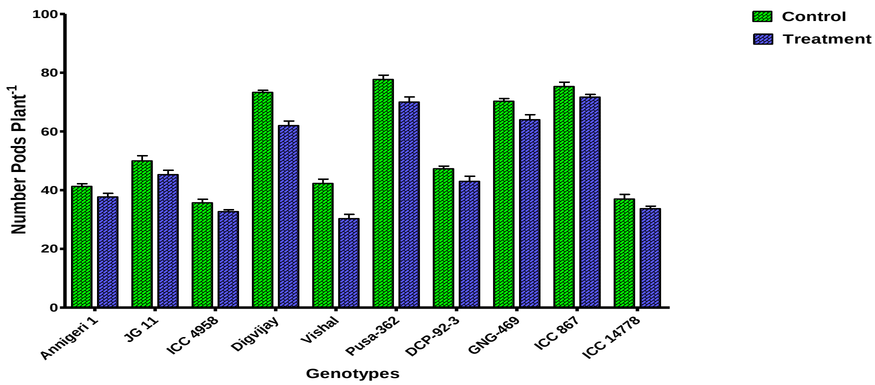


Fig.12 Test weight of chickpea genotypes under two levels of water stress, season 2018. Bars represent mean Test weight of three biological replication and error bars indicated the standard error (±SE)

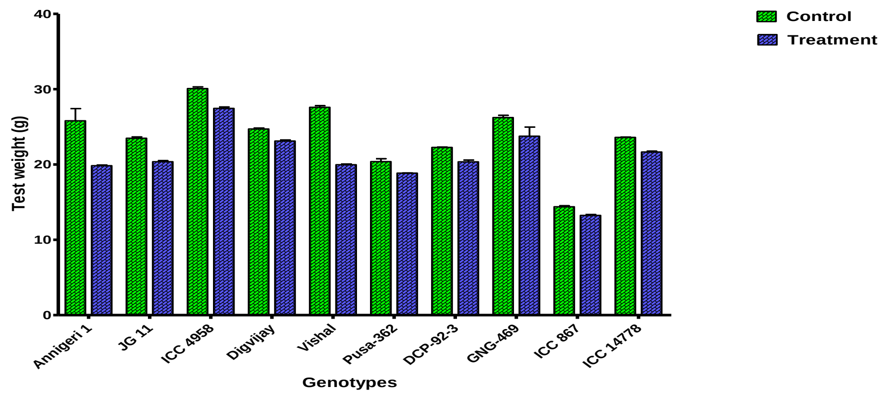


Fig.13 Test weight of chickpea genotypes under two levels of water stress, season 2019. Bars represent mean Test weight of three biological replication and error bars indicated the standard error (±SE)

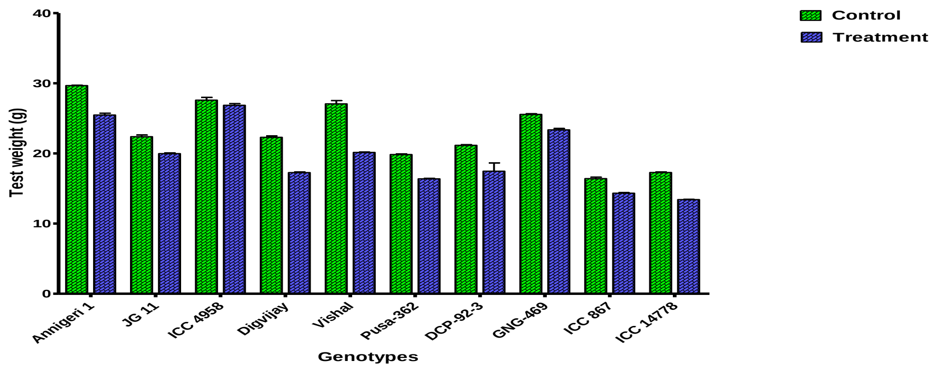


Fig.14 Yield plant^{-1} of chickpea genotypes under two levels of water stress rabi season 2018. Bars represent mean Yield plant^{-1} of three biological replication and error bars indicated the standard error (±SE)

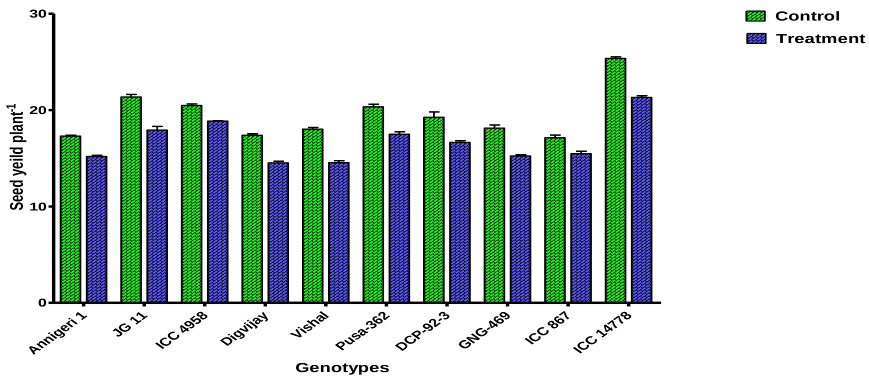
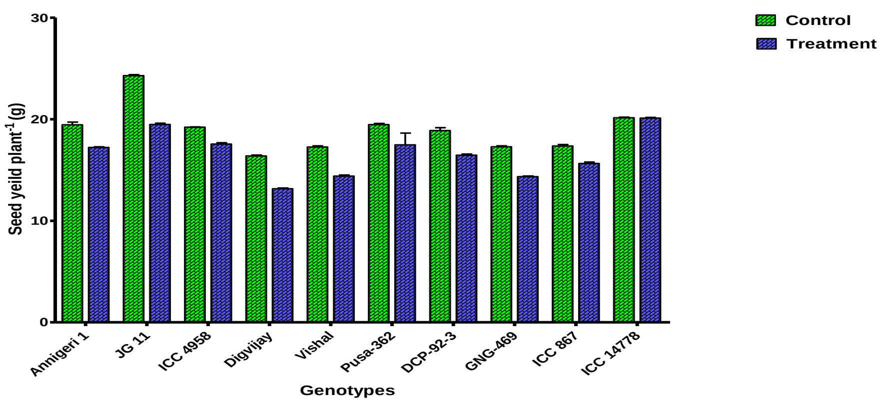


Fig.15 Yield plant^{-1} of chickpea genotypes under two levels of water stress rabi season 2019. Bars represent mean Yield plant^{-1} of three biological replication and error bars indicated the standard error (±SE)



In the present study, significant difference among the genotypes in response to number of secondary branches plant^{-1} presented in Table 3 and 4 reveals that the rainfed environment led to a drastic decline in the number of secondary branches plant^{-1} in comparison to the control and water stress treatment. This might be due to the shortage of assimilates required for increased branching due to lower leaf area under moisture deficit environment. Similar results were reported by Rahman and Uddin (2000). Hussain *et al.*, (2015) also reported that the secondary branches plant^{-1} also decline water stress treatment as compare to the control.

Number of pods per plant

The data reveals that amongst the control and drought environment, significantly highest number of pods plants^{-1} was recorded in control during both the years. A reference to the data shown in Table 3 and 4 illustrates the impact of water stress on the number of *Pods plant^{-1}* in ten genotypes of chickpea at harvest time. Rabi season 2018-2019 data shows that, with water stress, the amount of *Pods plant^{-1}* decreased significantly in all ten genotypes. The minimum decrease was reported in ICC 4958 (10.48 %) followed by ICC 867 (10.91%) and the maximum decrease in

Vishal (36.57 %) (Table 5). The Digvijay (79.66±0.88) variety shows the maximum number of seeds per pod under environments of non-stress followed by GNG-469 (78.66±0.33), Pusa-362 (74.66±0.66) and ICC 867 (73.33±2.02) whereas the minimum number of *Pods plant*$^{-1}$ was recorded in ICC 4958 (35±1.73). While under water stress condition variety GNG (70±1.52) showed the maximum number of *Pods plant*$^{-1}$ closely followed by ICC 867; Pusa-362 (65.33±1.45), and Digvijay (64±1.52) and whereas, the minimum number of *Pods plant*$^{-1}$ was recorded in Vishal (28.33 ±0.88) (Figure 10). Therefore, the range from 35.00 to 79.66 and 28.33 to 70.00 under non-stress and stress condition, respectively. ANOVA results have indicated that the number of *Pods plant*$^{-1}$ is found to be significant.

In rabi season 2019-2020 the data shows that, with water stress, the amount of *Pods plant*$^{-1}$ decreased significantly in all ten genotypes. The minimum decrease was reported in ICC 4958 (4.67%) followed by ICC 867 (4.87%) and the maximum decrease in Vishal (28.35%) (Table 4). The ICC 867 (71.66±0.88) variety shows the maximum number of seeds per pod under environments of water stress followed by Pusa-362 (70±1.73), and GNG-469 (64±1.73) whereas the minimum number of *Pods plant*$^{-1}$ was recorded in ICC 4958 (30.33±1.45). While under non water stress condition variety Pusa-362 (77.66±1.45) showed the maximum number of *Pods plant*$^{-1}$ closely followed by ICC 867 (75.33±1.45), Digvijay (73.33±0.66) and GNG-469 (70.33±0.88) whereas, the minimum number of *Pods plant*$^{-1}$ was recorded in ICC 4958 (35.66±1.20) (Figure 11). Therefore, the range from 30.00 to 71.66 and 35.66 to 77.66 under stress and non-stress condition, respectively. ANOVA results have indicated that the number of *Pods plant*$^{-1}$ is found to be significant.

In the present study the number of pods per plant in different genotypes ranged from (35.00 to 79.66 and 28.33 to 70.00) and (30.00 to 71.66 and 35.66 to 77.66) in both year under control and water stress, respectively. It was observed that the genotypes Digvijay and ICC 867 produced significantly higher number of pods and the genotype Vishal and ICC 4958 produced significantly lowest number of pods per plant due to significantly less number of seeds per pod, number of seeds per plant and 100 grain weight (g). Similar results were obtained by Hussain *et al.*, (2015) and Tripathi *et al.*, (1995). Reddy and Ahlawat (1998) also reported the variation in chickpea in relation to the number of pods per plant under control and stress condition.

Test weight (g)

Data presented in table 3 and Table 4 showed that the test weight differ significantly with respect to control and treatment during both years. The test weight decreases significantly under water stress condition.

Results further showed that the test weight also differed significantly under different varieties of chickpea. Under non stress condition variety ICC 4958 (30.1±0.20 g) shows highest test weight closely followed by Vishal (27.6±0.20 g), GNG-469 (26.24±0.29 g) and Annigeri 1 (25.81±1.61 g) whereas the minimum test weight was recorded in ICC 867 (14.40±0.12). While under stress condition variety ICC 4958 (27.95±0.22 g) shows highest test weight closely followed by GNG-469 (23.76±1.02 g), Digvijay (22.83±0.38 g) and ICC 14778 (21.67±0.09 g) whereas the minimum test weight was recorded in ICC 867 (13.31±0.03) (Figure 12). The minimum reduction was recorded in ICC 4958 (8.75%) followed by ICC 867 (8.01%) and maximum reduction found in Vishal (27.61%) (Table 5). Therefore, the range from 14.40 to 30.1 and 13.31 to 27.95 under non-stress and stress condition, respectively.

In rabi season 2019-2020 results further showed that the test weight also differed significantly under different varieties of chickpea. Under non stress condition variety Annigeri 1 (29.68±0.05 g) shows highest test weight closely followed by ICC 4958 (27.60±0.38 g), Vishal (27.07±0.46 g) and GNG-469 (25.57±0.09 g) whereas the minimum test weight was recorded in ICC 867 (16.41±0.2).

While under stress condition variety ICC 4958 (26.2±0.52 g) shows highest test weight closely followed by Annigeri 1 (25.49±0.25 g), GNG-469 (23.37±0.17 g)and Vishal (20.15±0.03 g) whereas the minimum test weight was recorded in ICC 14778 (13.43±0.04) (Figure 13). The minimum reduction was recorded in ICC 4958 (5.10%) followed by ICC 867 (8.53%) and maximum reduction found in Vishal (25.55%) (Table 6). Therefore, the range from 16.41 to 29.68 and 13.43 to 26.02 under non-stress and stress condition, respectively.

100 seed weight in chickpea in different genotypes were showing statistically significant indicating the considerable variations. 100 seed weight ranged from 14.40 to 30.1 and 13.31 to 27.95 under non-stress and stress condition, respectively. It was observed that the genotypes ICC 4958 and Annigeri 1 produced significantly higher 100 seed weight and the genotype ICC 867 and ICC 14778 recorded significantly lowest 100 seed weight in gram. Similar findings were also obtained by Khourgami and Rafiee (2009) stated that the 100 seed weight in chickpea cultivars were significantly different. Hussain *et al.,* (2015) also reported the similar results in chickpea under normal and rainfed condition.

Yield (g)

The effect of water stress on seed yield per plant (gm) in ten chickpea genotypes at harvest was demonstrated in table 3 and 4 Rabi season 2018-2019 the data showed that, with water stress, seed yield per plant significantly decreased in all ten genotypes. Under non-stress condition variety ICC 14778 (25.36±0.15 gm) indicates maximum seed yield per plant closely followed by JG 11 (21.36±0.25 gm), ICC 4958 (20.48±0.14 gm) and Pusa-362 (20.33±0.26 gm) whereas, the minimum seed yield per plant (gm) was recorded in ICC 867 (17.12±0.27 gm). While under water stress condition ICC 14778 (21.31±0.18 gm) produced maximum seed yield per plant closely followed by ICC 4958 (18.85±0.03 gm), JG 11 (17.92±0.38 gm) and Pusa-362 (17.49±0.25 gm) whereas, the minimum seed yield per plant (gm) was recorded in Digvijay (14.52±0.16 gm) (Figure 14).

The maximum reduction in Vishal (19.21%) was reported and minimum reduction was reported in ICC 4958 (7.93%) followed by ICC 867 (9.61%) (Table 5). Therefore, the range from 17.12 to 25.36 and 14.52 to 21.31 under non-stress and stress condition, respectively.

In 2019-2020 under non-stress condition variety JG 11 (24.3±0.08 gm) indicates maximum seed yield per plant closely followed by ICC 14778 (20.15±0.39 gm), Pusa-362 [19.48±0.11 gm and Annigeri 1 (19.46±0.27 gm)] whereas, the minimum seed yield per plant (gm) was recorded in Digvijay (16.39±0.07 gm). While under water stress condition JG 11 (19.49±0.11 gm) indicates maximum seed yield per plant closely followed by ICC 14778 (18.35±0.18 gm), ICC 4958 (17.66±0.08 gm) and Pusa-362 (17.48±1.68 gm) whereas, the minimum seed yield per plant (gm) was recorded in Digvijay

(13.16±0.07 gm) (Figure 15). The maximum reduction in Vishal (20.46%) was reported and minimum reduction was reported in ICC 4958 (8.10%) followed by ICC 867 (8.60%) (Table 6). Therefore, the range from 17.12 to 25.36 and 14.52 to 21.31 under non-stress and stress condition, respectively.

The yield (g) per plant due to chickpea genotypes were statistically significant indicating considerable amount of genetic variation in yield potential. The highest yield per plant was recorded by genotypes ICC 14778 (25.36 gm) and JG 11 (24.3 gm) in 2018 and 2019, respectively. Results are conformity with the findings of Hussain *et al.*, (2015) stated that the yield per plant n chickpea cultivars were significantly different. Findings of similar genotypic variations were reported by Hegde *et al.*, 2002 and Kumar *et al.*, 2002. The results on yield plant^{-1} indicate that the no-stress environment under normal irrigations gave highest yield plant$^{-1.}$

In conclusion the yield data of tested genotypes showed a great variation in both non stress and stress conditions. In general, seed yield of genotypes under non irrigated condition was remarkably lower than irrigated condition. The seed yield per plant under non irrigated chickpea ranged from 13.74 g to 19.49 g and under irrigated condition 17.12 to 25.36 g per plant. The results of the present study indicated that ICC 4958 was determined as the best drought tolerant genotype followed by ICC 867. In conclusion, genotypes or cultivars can be developed or selected on the basis of yield, early maturity under non stress conditions. Nevertheless, the genotypes identified in this study for traits related to higher productivity under non irrigated (drought stress) have important implications on accelerating the process of future breeding of adopted genotypes for drought prone area.

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