SCREENING OF CHICKPEA (*Cicer arietinum* L.) LINES FOR DROUGHT TOLERANCE

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CERTIFICATE

This is to certify that the thesis entitled **"SCREENING OF CHICKPEA (*Cicer arietinum* L.) LINES FOR DROUGHT TOLERANCE"** submitted by **Mr. MAHESHANKAR** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **CROP PHYSIOLOGY** to the University of Agricultural Sciences, Raichur is a record of research work done by him during the period of his study in this University under my guidance and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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AFFECTIONATELY DEDICATED

TO

MY PARENTS

Mr. RAJSHEKHAR PATIL

AND

Mrs. MEENAKSHI

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LIST OF ABBREVIATIONS

Abbreviation		Expansion
DAS	:	Days after sowing
et al.	:	Co-workers
Viz.,	:	Namely
ha	:	Hectare/s
g	:	Gram/s
mg	:	Milligram/s
ppm	:	Parts per million
mol	:	mole
kg	:	kilogram/s
t	:	Tonne/s
q	:	Quintal
ml	:	Milliliter/s
dm	:	Decimeter/s
cm	:	Centimeter/s
m	:	Meter/s
n	:	Nano
µ	:	Micro
%	:	Per cent
hr	:	Hour
RH	:	Relative Humidity
S. Em.	:	Standard Error of mean
CD	:	Critical Difference
Fig.	:	Figure/s
RDF	:	Recommended dose of fertilizers
LAI	:	Leaf area index
AGR	:	Absolute growth rate
RWC	:	Relative water content

Abbreviation		Expansion
MII	:	Membrane injury index
CGR	:	Crop growth rate
$Plant^{-1}$	:	Per plant
m^{-2}	:	Per square meter
g^{-1}	:	Per gram
dm^{-2}	:	Per square decimeter
Fed	:	Feddan
wt.	:	Weight
ha^{-1}	:	Per hectare
s^{-1}	:	second/s

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INTRODUCTION

I. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is food legume belonging to family fabaceae grown in tropical, subtropical and temperate regions. Two types of chickpea, desi and kabuli type have been listed. The desi chickpea type have angular seed shape, having different seed coat color is grown in the semi-arid tropics while kabuli type having irregular seed shape, white seeded large seed size is grown in temperate region. It is the important grain legume grown for protein rich seeds for human consumption and to maintain the soil fertility by its nitrogen fixing capability through root nodules.

Chickpea is one of the predominant legume crops in the semiarid tropical regions of the world. However, about 90% chickpea crop is grown in rain fed conditions without irrigation (Kumar and Abbo, 2001) and thus both vegetative and reproductive phases are prone to adverse affected by water deficiency. Drought is the second major constraint on chickpea productivity after diseases (Singh *et al*., 1994). Global economic losses in chickpea due to drought are about 40–50% (Millan *et al*., 2006).

Huisman *et al*. (1994) reported that chickpea seed contains on average 17-23% protein, 54-60% total carbohydrates (47% starch, 6% soluble sugar), 4-5% fat, crude fiber 6% and 3% ash. Chickpea is also very rich in mineral content like phosphorus (340mg/100g), calcium (190mg/100g), magnesium (140mg/100g), iron (7mg/100g), zinc (3mg/100g) and 100g serving of cooked chickpeas provides 164 kilocalories (690 kJ).

Globally chickpea is cultivated on an area of 13.5 m ha with an average yield of 982.1 kg ha^{-1}(FAOSTAT, 2015). India is the largest producer of chickpea accounting for 68 per cent of world chickpea production. It is cultivated on an area of 9.6 m ha with a productivity of 974 $kgha^{-1}$ (Annon., 2017). Karnataka ranks fourth in the cultivation of chickpea with an area of 1.0 m ha and productivity of 590 kg ha^{-1} (Annon., 2017). In Karnataka, Kalaburagi district ranks first in both area and production followed by Vijayapur, Bidar, Gadag and Raichur.

The low production and productivity of pulses under Indian condition is mainly due to several biotic and abiotic constraints, especially the drought. Drought stress exerts drastic effects on nutrient uptake, hinders the nodule formation and adversely affects yield and yield components. Significant variability in chickpea germplasm exists on the basis of responses to moisture stress which may be due to drought escape, drought

avoidance and drought tolerance; these mechanisms may prevent chickpea genotypes from harmful effects of drought. The effects can be estimated from quantitative and qualitative parameters including seed emergence (Urbieta, 2008), seedling establishment (Daws *et al*., 2008), physiological parameters like, photosynthetic rate, transpiration rate (Rahbarian *et al*., 2011), biochemical parameters viz., chlorophyll content (Mafakheri *et al*., 2010), osmotic regulation (Turner *et al*., 2007), reactive oxygen species (Baby and Jini, 2011), level of antioxidants like, superoxide dismutase (Baby and Jini, 2011), molecular and gene expression regulation (Ingram and Bartels, 1996), nutrient uptake (Gunes *et al*., 2006), nodule formation (Gan *et al*., 2005), yield and yield components (Sabaghpour *et al*., 2006).

In chickpea, early seedling establishment stage is more prone to be affected by drought stress.Severity of drought stress is directly proportional to changes in several physiological responses of chickpea. Under moderate stress conditions, stomatal conductance (measure of stomatal activity) is reduced. Normally, stomatal conductance ranged from 31% to 91%, but is reduced up to 93% of normal conductance under severe drought stress conditions (Pouresmael *et al*., 2013) Chlorophyll contents (a & b) are significantly decreased by stress at vegetative growth stages and resultantly reduced the light harvesting capacity (Mafakheri *et al*., 2010). Reduction in chlorophyll contents might be due to increase in leaf temperature after stomatal closure and reduced transpiration followed by chlorophyll degradation (Pouresmael *et al*., 2012). The membrane stability index (MSI) reduced in response to moisture stress during seedling, early flowering and pod development stages (Rahbarian *et al*., 2011). Severe drought stress increases the temperature at cell level which damages the walls and increases the electrolyte leakage (Bhattacharjee, 2012 and Pouresmael *et al*., 2013). Osmotic adjustment (OA) is an important process that delayed the dehydration under drought stress and thus helps to maintain the turgor pressure and other life supporting physiological processes (Morgan, 1984).

Drought stress imposes the adverse effects on phenological phases of chickpea. The duration of vegetative growth stage, days taken for initiation of flowering, days taken for 50% or complete flowering, days taken for complete maturity and duration of reproductive stage are the characteristic traits for assessment of phenological responses. Changes in the duration of vegetative growth stage coupled with reproductive growth

stage change the duration of pod filling and seed size in chickpea (Ahmed, 2011 and Hussain *et al.*, 2015). Maintenance of physiological activity and harbouring plentiful economical yield known as drought tolerance breeding efforts are targeted to develop chickpea genotypes which have drought tolerance and give extensively higher seed yield under optimum water availability. Further the molecular studies indicate, the expression of different genes is either up regulated or down regulated in response to water deficit. The uptake of different micronutrients is also badly reduced due to water deficit which causes reduction in seed yield of variable magnitude depending on the micronutrient than germination (Schutz *et al*., 2002).

Largely, roots are the first organ to perceive and respond to drought stress, before other plant organs, and communicate this information to the shoot (Konings and Jackson 1979 and Bano *et al*., 1993).

Large root systems can maintain high water use efficiency (WUE) under drought stress conditions (Songsri *et al*., 2009). Therefore, an understanding of the traits associated with WUE such as the ability of roots to increase water uptake and maintain high photosynthetic capacity should be useful in improving WUE under drought stress conditions.

The various Physiological and biochemical traits related to drought tolerance as reviewed above can be used for screening of promising line/genotypes developed by plant breeders. As one of major constraint in productivity of chickpea under drought prone areas of this region a trail was planned for **"Screening of chickpea lines for drought tolerance"** was taken up with following objectives.

1. To evaluate chickpea lines for drought tolerance
2. Characterization of morpho-physiological traits of chickpea lines for drought
3. To study the root characteristics of chickpea lines for drought tolerance

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature pertaining to the screening of chickpea lines for drought tolerance is presented in this chapter.

2.1 Evaluate chickpea genotypes for drought tolerance

Rahman *et al.* (2000) noted that the leaf area was significantly reduced by water stress treatment. The degree of reduction was very high in the cultivars ICCV 88202, ICCN 12464 and Dharmashala-2, and the reduction was minimum in cultivars ICC 10448, BCL 155, Bheema and Hyprosola. Leaf area was highest in cv. Bheema in both control and stress treatments. Cultivars ICC 10448, BCL 199, BCL 155, Sreenagar-2 and Ahamedpur local did not show significant differences between control and stress treatments on the whole. Based on the results of the treatments, the best performing cultivars were ICC 10448, BCL 155, Bheema and Hyprosola.

Shrivastava *et al.* (2000) revealed that under rainfed conditions, JAKI 9226 performed the best in terms of grain yield. However, comparable yields were also obtained for JAKI 9218, Phule G-81-1-1, JG-74, JG-315 and BG-256. On the contrary, under irrigated conditions, RG 9218 gave significantly higher grain yield over the others except JAKI 9226, JG-74, JG-315, BG-256, Phule G-5 and BKG-1 09 which were significantly at par statistically.

Sharma *et al.* (2007) evaluated six chickpea genotypes for partitioning of biomass in different plant parts under moisture stress. The moisture stress reduced the plant height significantly but reverse was true for root depth. The biomass allocation to leaves, stem and roots was 22.2%, 32.3% and 30.4% of total biomass, respectively, which reduced to 12.3% and 13.0% in roots and leaves at harvest.

Ghodke *et al.* (2008) evaluated thirteen genotypes of chickpea under non-stress and moisture stress conditions for characterization of adaptive traits conferring tolerance to drought. The genotypes viz. Phule G 9409-1 and Vijay showed minimum drought index (DI), high drought tolerance efficiency (DTE) and least drought susceptibility index (DSI). Phule G 9409-1 maintained higher biomass under non-stress as well as moisture stress condition whereas Vijay recorded high harvest index under moisture stress condition.

Ulemale *et al*. (2013) evaluated fourteen chickpea genotypes under moisture stress and non-stress condition to study the physiological indices for drought tolerance. Significant differences exhibited amongst the genotypes for phenology, vegetative growth source, generative growth sink capacity, physiological parameter and drought characteristics under moisture stress and non-stress conditions. The genotypes, Phule G 09103, Phule G 2008-74, Digiijay, Phule G 0302-26 recorded minimum percent reduction in yield due to moisture stress. RLWC, membrane injury index, chlorophyll content, chlorophyll stability index, proline accumulation and nitrate reductase activity were found to be the most useful parameters while selecting genotypes for drought tolerance.

2.2Characterization of morpho-physiological traits of chickpea lines for drought

Bennet *et al.* (1987) and Schonfeld *et al.* (1988) found superior performance of drought tolerant soybean, maize and wheat under water stress environment that was attributed to osmoregulation. Variations in RWC in these cultivars could be used as an index to select high yielding genotypes (Ritchie *et al.*, 1990). These findings suggest RWC as an important drought screening indicator.

Pastori and Trippi (1992) showed that drought sensitive wheat cultivars (Leones) had greater loss of chlorophyll on moisture stress, when compared with the drought tolerant ones.

Gupta *et al*. (2000) studied responses of chickpea cultivates to water stress. The greater reduction in osmotic probably helps the genotypes in maintenance of RWC under stress condition and chlorophyll stability index can be a good parameter for the measurement of drought tolerance / susceptibility.

Deshmukh *et al*. (2002) suggested the possibility of using simple traits like relative water content (RWC) and membrane injury index (MII) for screening chickpea genotypes for drought tolerance. The relative water content and membrane injury index of a genotype measured during early phase was found to provide an indication of its relative membrane injury index during reproductive stage.

Berger *et al.* (2003) conducted a study over a 2-year period with a common set of 73 genotypes which showed that high yielding genotypes flowered early, podded early and had a relatively long flowering period at most, but not all, low yielding sites. Thus

drought escape was an important phenological characteristic at sites with terminal drought. However, these characteristics did not predominate at a site in which the drought was severs throughout the growth period.

Kushwaha *et al.* (2003) reported that relatively less damage to the assimilatory system of genotypes is due to high initial water content (IWC) along with the high relative water content resulting in production of relatively higher biomass. The significant correlation between DSI and RWC permitted to suggest that these parameters may be used as selection criteria for chickpea genotypes screening for drought-stressed environment.

Tejpal *et al.* (2004) reported that the mean relative water content decreased, whereas the mean membrane injury increased during the vegetative, flowering and pod formation stages of the crop with delay in sowing.

Ali and shivekumar (2005) reported that under rainfed condition, erect, tall main stem, parallel main and primary branches, open canopy, early flowering, large size and number of leaflets with low osmotic adjustment were found most desirable traits for higher grain in chickpea.

Sharma *et al.* (2007) studied six chickpea genotypes under soil moisture for morphological-physiological characteristics conferring resistance to drought. The increased moisture stress reduced the maturity duration by 15 and 19 days under mid and severe stress, respectively over irrigated control. The moisture stress significantly reduced the plant height, number of effective pods per plant, test weight, seed yield, biological yield and harvest index over irrigated control.

Gaur *et al*. (2008) reported that chickpea is photo as well as thermo-sensitive and its maturity duration ranges between 80-180 days depending on genotypes, soil moisture, temperature, latitude and altitude. In at last two third of chickpea growing are the available crop growing season is short (90-120 days) due to risk of drought or temperature extremities towards the end of crop season.

Gupta (2008) studied the relative water content in leaves under moisture stress condition at pod formation stage was maximum in phule G-5 (70%) followed by RSG 143-1 (66%). Thus these genotypes have better mechanism to maintain moisture status to

support normal metabolism. The study revealed that the genotype RSG 143-1 showed drought tolerance at par with Phule G 5 amongst the genotypes tested. These genotypes, RSG 143-1 and Phule G 5 showed drought tolerancedue to higher level of osmolytes in leaf cell sap, better water relation indices, lower membrane injury, higher root biomass and higher photosynthetic rate as compared to other genotypes. All these physiological parameters resulted in lower drought susceptibility index (DSI) value of these genotypes.

Krouma (2009) conducted a greenhouse experiment to assess the effects of drought stress on plant growth, photosynthesis, and water relations in three Tunisian chickpea genotypes. A close relationship between plant growth, and photosynthesis and leaf water status was observed. In comparison to Chetoui and Kesseb, Amdoun exhibited the greatest plant growth and photosynthetic activity, the lowest drought intensity index, and important osmotic adjustment under drought stress. Water use efficiency clearly differentiated in this studied genotypes.

Cauci and Tokes (2009) evaluated chickpea genotypes having resistance to drought / heat stress and to identify the most appropriated selection criteria for this. The desi chickpea (smaller dark seeds) were generally more drought and heat resistant than the kabuli chickpeas (larger, pole seeds).

Farooq *et al.* (2009) stated that increased chlorophyll and carotenoid content under drought stress may be related to a decrease in leaf area, it also can be a defensive response to reduce the harmful effects of drought stress.

Mafakheri *et al.* (2010) conducted an experiment using three chickpea varieties (drought tolerant Bivaniej and ILC482 and drought sensitive Pirouz). Drought stress imposed at vegetative and anthesis phases, showing a decreased chlorophyll *a*, chlorophyll *b* and total chlorophyll content. Proline accumulation was higher in 'ILC482' than in 'Pirouz' both under control and drought stress conditions. Under drought conditions the drought tolerant variety 'Bivaniej' gave the highest yield whereas the drought sensitive variety 'Pirouz' gave the lowest yield. Drought stress at anthesis phase reduced seed yield more severe than that on vegetative stage.

Rozrokh *et al.* (2012) studied twenty genotypes of chickpea in which three drought resistant (Azad, ILC.482 and ILC.1799) and three drought susceptible (Hashim, X96. TH62K2 and FLIP.97-219) were identified. The amounts of potassium, sodium, calcium,

proline, amino acid, soluble proteinsand soluble carbohydrate were measured in the grains and in comparison of rain-fed and irrigated conditions, proline concentration in the grains increased, while the others decreased.

Biradar *et al.* (2013) conducted an experiment by using sixteen chickpea genotypes under rainfed condition and found that BG-1092 recorded significantly higher yield (1599 kg/ha) which was followed by ICC-4958 (1279 kg/ha).

Golezani *et al*. (2013) resulted that Pods per plant, grains per plant, 100 grains weight, biological yield, grain yield and harvest index decreased with decreasing water supply. Azad was a superior cultivar in grains per pod, 100 grain weight, plant biomass, grain yield and harvest index, compared with Arman and Jam. The superiority of Azad in grain yield was more evident under normal irrigation conditions. Differences between Arman and Jam in grains per pod, 100 grains weight and biological yield were not significant. Therefore, yield and yield components of chickpea can be reduced under water stress, depending on the severity of stress and cultivar.

Talebi *et al*. (2013) evaluated thirty-five genotypes of chickpea, under optimum conditions (irrigated) or drought stress implemented at post-anthesis stage. And the chickpea genotypes tolerance to drought stress was variable because, drought-tolerant genotypes had higher relative water content, chlorophyll and carotenoid concentrations and larger K^+ accumulation compared to Na^+. Significant and well-defined relationships between drought susceptibility index and relative water content, chlorophyll and carotenoid concentration, Na and K uptake were found. And drought susceptibility index was used as a measure of drought tolerance.

Yaqoob *et al*. (2013) in this experiment using fourty chickpea lines including some approved varieties were assessed for drought tolerance under glass house condition. The crop was given an artificial drought stress at pre flowering stage for a period of 30 days, and then irrigated regularly till harvesting. Genotypes SL-05-30, NCS 950219 and F-97-112 remained superior. The plant recovery response revealed that more than 50% of studied lines could not properly recover after termination of moisture stress suggesting that moisture stress at pre-flowering has usually lethal effect on chickpea plants. Kabuli type chickpea lines were more sensitive to moisture stress and high temperature and produced lower yields as compared to desi type chickpea.

Rizvi *et al*. (2014) conducted an experiment and found that five chickpea genotypes in field under irrigated and rain fed conditions. Observations were recorded on relative water content (RWC), and the contents of chlorophyll, carotenoid, proline and protein in the five chickpea genotypes. RWC and contents of chlorophyll, carotenoid and protein decreased under moisture stress, whereas proline content increased with the increase in moisture stress. Pusa-1108, Pusa-362, Pusa-1103 were able to maintain relatively higher RWC, Chl, Car and protein content and greater proline accumulation, while Flip 90-166 and SBD377 showed comparatively greater decline in the RWC, Chl, Car and Protein and less accumulation of Pro under moisture stress.

2.3 Root characterstics of chickpea lines for drought tolerance

Saab *et al.* (1990) reported that under water stress condition, the ratio of root growth to shoot growth was much higher when ABA was present (i.e., in the wild type) than when it was absent (in the mutant) which, along with the effect of ABA on stomatal closure, helps the plant cope with water stress.

Assengi *et al.* (1998) conducted an experiment in wheat crop with early, mid water deficit and control are treatments, concluded that The early-, the mid-season water deficit treatments,and the control treatment had total root length of 27.4, 19.4 and 30.6 km m^{-2}. Evapotranspiration declined underwater deficit, but water uptake in deeper layers increased. This helpful in overcoming water deficit condition.

Smita and Nayyar (2005) observed that significant differences are present among chickpea genotypes for root length under normal and deficit moisture conditions. Plasmolysis, distortion and reduction in root-hair diameter were reported as possible reasons for reduction of root length under suboptimal moisture availability.

Kashiwagi *et al.* (2006) conducted an experiment using twelve chickpea genotypes in a pipe study with two different soil water treatments in 2000 and 2001. In field trials of both years shows the root length density (RLD) is showing positive correlation with seed yield. a more severe drought year, when the RLD in deeper soil layer, 30–60 cm depth, showed a significant positive relationship with seed yield. Also, the RLD at deeper soil layer, 30–60 cm depth, was higher in 2001/2002 than in 2000/2001, in particular in tolerant genotypes. This indicates the importance of roots in

coping with terminal drought in chickpea. The cylinder system offers a much easier procedure to screen chickpea genotypes with large RLD.

Macar *et al.* (2009) Shoot-to-root ratio is reduced in chickpea under drought conditions due to reduction in epicotyl elongation relative to root growth. Reduction in root growth is a good indicator of drought susceptibility of cultivars

Parameshwarappa *et al.* (2010) observed that genotypes of chick pea with deep and dense root system display better drought tolerance by extracting water from deeper layers. Increase in root length, root weight and root volume increased grain yield under terminal drought.

Franco *et al.* (2011) observed that deep rooting is a critical factor influencing the ability of the plant to absorb water from the deeper layers of the soil.

Lopes *et al. (*2011) postulated that deeper root system with greater root density is a great stress management tool as it not only facilitates better extraction of soil water but also helps the plant to sustain optimal growth and development under drought stress conditions.

Henry *et al.* (2012) conducted experiment to study the drought response of different rice genotypes in terms of root morphology, anatomy, gene expression, and hydraulics that are related to water uptake and field performance under drought and reported that there is an increase in lateral root formation and suberization of endodermis whereas root diameter, number of xylem vessel and aquaporin expression decreased under drought.

Renuka *et al.* (2013) conducted experiment on different genotypes of rice to identify drought tolerance on root characters and found that there was a positive correlation between high root volume and grain yield and dry matter production. Increased root thickness improved drought resistance as the roots are capable of increasing root length and water uptake by producing more and larger root branches. Root volume and root weight were positively associated with grain yield and dry matter production.

Purushottam *et al.* (2016) conducted an experiment using 12 genotypes of chickpea. In this they measured the surface water use and root distribution. Drought sensitivity can be explained by poor root growth and poor soil water utilization alone but drought tolerance scan be variable with variations in exploitation of moisture in various soil depths and growth stages. The water use at 15-30 cm soil depth ensured greater uptake from lower depths and the soil water use from 90-120 cm soil was critical for best drought adaptation. Root length density and the soil water uptake across soil depths were closely associated.

Ramamoorthy *et al.* (2017) conclude that under drought condition increase in root length density (RLD) below 30cm soil depth, deep root bio-mass (RDW)but decrease in root diameter (RD). And for the best combination of profuse RLD at surface soil depths, and RDW at deeper soil layers, was proposed to be the best selection strategy, for an efficient water use and an enhanced terminal drought tolerance in chickpea.

MATERIALS AND METHOD

III. MATERIALS AND METHOD

The present investigation entitled "Screening of chickpea (*Cicer arietinum* L.) lines for drought tolerance." includes assessment of chickpea genotypes under non irrigated (stress) and Irrigated (non stress) conditions and also root characterization was taken up by sowing the lines in polyvinyl chloride (PVC) pipes..

The details of the experimental materials used and techniques adopted during the course of investigation are described in this chapter.

3.1 Experimental site

The experiment was carried out in plot number H_{11} at Agricultural Research Station, Kalaburagi, University of Agricultural Sciences, Raichur, during the *rabi* 2017, which is situated at North Eastern Dry Zone of Karnataka at a latitude of 17^0 34' North, longitude of 76^0 79' East and an altitude of 478 meters above mean sea level.

3.2 Climatic conditions

The meteorological monthly data were recorded at meteorological observatory, Agricultural Research Station, Kalaburagi for the year 2017 and the mean data of climatic parameters like rainfall (mm), maximum and minimum temperatures (^oC) and relative humidity (%) are presented in Table 1 and Fig. 1.

3.3 Soil and its characteristics

The soil of the experimental site was medium black with clay loam texture. Composite soil sample was collected from experimental site up to 30 cm depth before initiation of the experiment. The soil was air-dried, powdered and allowed to pass through 2 mm sieve and was analysed for physical and chemical properties. The mean values obtained along with the methods adopted for their estimation are furnished in Table 2.

3.4 Previous crop grown on the experimental site

Pigeonpea was grown during *kharif* 2017 in the experimental site with normal agronomical practices.

Table 1. Monthly meteorological data for the experimental year 2017-18 and average annual rainfall at Meteorological Observatory, Agricultural Research Station, Kalaburagi, University of Agricultural Sciences, Raichur

Month	Temperature (°c)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Afternoon	
January -17	26.54	17.55	59.31	32.62	0.00
February -17	31.18	19.15	47.10	19.95	0.00
March -17	34.89	23.43	40.13	19.01	61.00
April -17	39.40	28.68	28.81	12.28	0.00
May -17	38.47	30.62	41.29	15.92	7.00
June-17	32.17	26.41	81.50	23.89	239.20
July -17	31.93	25.65	82.99	23.11	85.80
August -17	29.69	25.32	87.97	24.19	100.90
September-17	30.29	25.31	88.51	22.78	357.00
October-17	29.44	24.68	86.19	21.57	124.00
November-17	29.11	22.77	65.42	13.32	0.00
December -17	29.12	19.75	60.18	14.48	0.00
January -18	30.63	12.31	67.21	51.23	0.00
February -18	33.20	15.30	59.08	47.29	0.00
March -18	36.78	24.19	36.89	19.21	0.00
Total	-	-	-	-	974.9

Table 2. Physical and chemical properties of soil in the experimental site

Particulars	Value	Methods employed
I. Physical properties		
1. Particle size analysis		International pipette method (Piper, 1966)
a) Sand (%)	20.8	
b) Silt (%)	22.4	
c) Clay (%)	56.7	
2. Textural classes	Clay	
II. Chemical properties		
1. Soil pH 1:2.5	8.3	pH meter (Piper, 1966)
2. Electrical conductivity (ds m^{-1})	0.21	Conductivity bridge (Jackson, 1967)
3. Organic carbon (%)	0.5	Wet oxidation method (Jackson, 1967)
4. Available nitrogen (kg ha^{-1})	241	Alkaline permanganate method (Subbaiah and Asija, 1956)
5. Available phosphorus (kg ha^{-1})	14.9	Olsen‘s method (Olsen et al., 1954)
6. Available potash (kg ha^{-1})	284	Flame photometry method (Jackson, 1967)

3.5 EXPERIMENTAL DETAILS

3.5.1 Design, layout and replications

The experiment was laid out in a split plot design and treatments were replicated thrice. The plan of layout and randomization of treatment are depicted in Fig. 2

3.5.2 Details of Experiment

Experimental site **:** Agricultural Research Station, kalaburagi

Crop **:** Chickpea

Season **:** *Rabi*, 2017

Design **:** Split plot design

Spacing **:** 30 cm * 10 cm

Gross plot size **:** 3.6 m * 4.0 m

Net plot size **:** 3.0 m * 3.8 m

3.5.3 Treatments details

Main Plot: Irrigation

M_1- Non - Irrigated

M_2- irrigated

Sub plot: Genotypes

S_1: A-1	S_7: MABC-WR-SA-1
S_2: JG-11	S_8: MABC-WR-SA-2
S_3: BGD-103	S_9: JG-14
S_4: GBM-2	S_{10}: JAKI-9218
S_5: RKD-1	S_{11}: DIBG-204
S_6: RKD-4	S_{12}: RVSSG-52

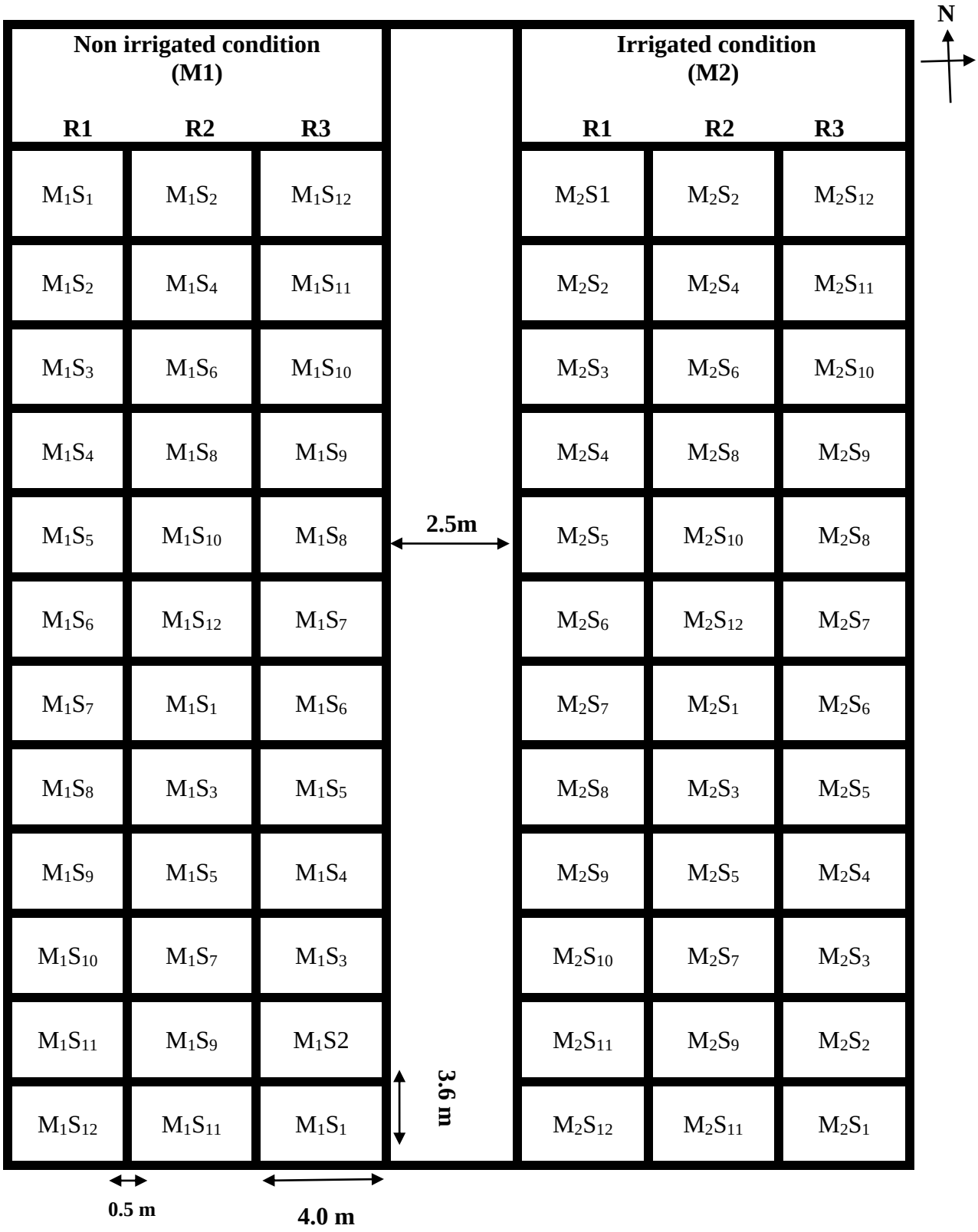

Fig. 2. Plan of layout of experiment

Table 3. Salient features of the lines used for study

Sl. no.	Variety	Days to maturity	Remarks
1	A-1	95-100	Selected variety as drought check,
2	JG-11	95-100	Resistant to wilt, bold seeded
3	BGD-103	95-100	Resistant to fusarium wilt, bold seeded
4	GBM-2	100-110	Tall and erect type suitable for Mechanical harvesting
5	RKD-1	95-100	Semi-erect, bold seeded
6	RKD-4	100-105	Semi-erect
7	MABC-WR-SA-1	95-100	Wilt resistant
8	MABC-WR-SA-2	95-100	Wilt resistant
9	JG-14	113	Moderate resistant to wilt, dry root and pod borer
10	JAKI-9218	95-123	Resistant to wilt, collar rot and root rot
11	DIBG-204	95-100	Small seeded
12	RVSSG-52	100-105	Semi-erect

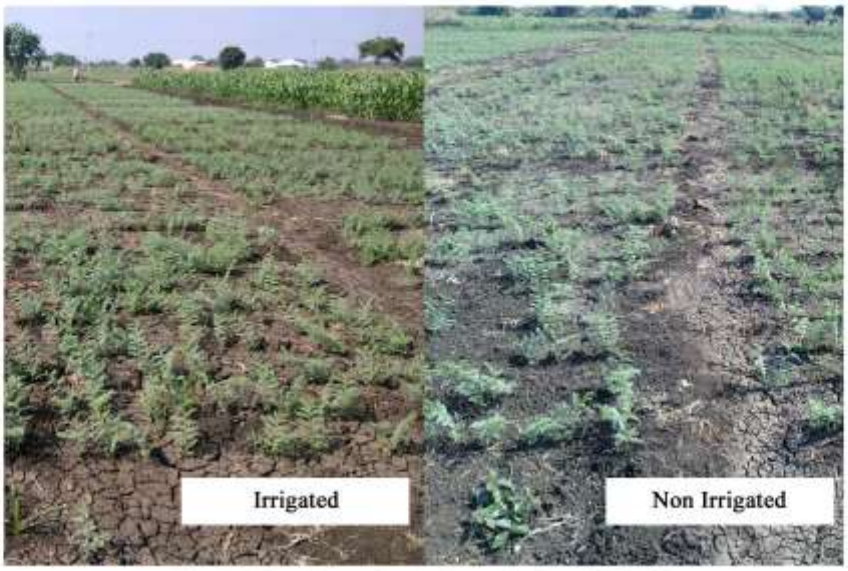

Plate 1. Overview of experimental plot at 20 DAS

Plate 2. Overview of experimental plot at 50 DAS

Plate 2a. Overview of non irrigated experimental plot at 50 DAS

Plate 2b. Overview of irrigated experimental plot at 50 DAS

3.5.4 Land preparation

The land was ploughed once and then harrowed twice to bring the soil to fine tilth. Then experiment was laid out as per the plan of layout. Small bunds were raised around each plot. Lines were marked both ways as per the treatments.

3.5.5 Fertilizer application

Recommended dose of fertilizers (25:50:0 kg ha^{-1}) were applied as per the recommendation. Urea, Di-ammonium phosphate (DAP) and were used to supply N, and P respectively.

3.5.6 Sowing

Sowing was taken up on 5th November, 2017 by hand dibbling with spacing of 30 cm between rows and 10 cm between plants. Sowing was done at a depth of 4 to 5 cm with 2-3 seeds per spot. For the root characterization study, PVC pipe of 17 cm diameter with a length of 100 cm were filled with soil and sand, sowing of all twelve genotypes was taken on 7th December, 2017. And the overview of experimental plot at 20 DAS and 50 DAS has been shown in plate 1 and plate 2 respectively, and plate 2a and 2b shows the overview of both non irrigated and irrigated experimental plot at 50DAS.

3.5.7 Irrigation management

After the sowing, on 07th November, 2017 irrigation was provided for the proper germination of seedlings in both the main plots and on 1st December, 2017 only for Irrigated main plot irrigation is provided.

3.5.8 Harvesting and threshing

The crop was harvested on 27thFebruary, 2018 at maturity, it includes both short and long duration varieties (plate 3). Hand threshing and winnowing was done to separate the grains after thorough sun drying. Treatment wise for grain and straw yield was recorded separately and finally expressed in kg ha^{-1}. For root characteristics study, pipes are harvested at 45 DAS and the root length, root mass and root to shoot ratio were measured (plate 4 and plate 5).

Plate 3. Overview of experimental plot at Harvest

Plate 4. Overview of root length of chickpea lines

Plate 5. Overview of PVC pipe root study at 20 DAS

3.6 COLLECTION OF EXPERIMENTAL DATA

In the experiment three plants in net plot area were selected at random and tagged for the purpose of recording various observations. Observations on growth parameters were recorded at regular intervals of crop growth and yield components at harvest were recorded on observation plants. Based on observations recorded on five tagged plants, average per plant was calculated.

3.6.1 Morphological parameters

Three plants were tagged at random in net plot area for recording various observations on growth parameters at 35, 55 and 75 days after sowing and at harvest.

3.6.1.1 Plant height (cm)

Plant height was measured for five plants from base of the plant to the tip of main shoot and mean of plant height was worked out and expressed in centimetres.

3.6.1.2 Number of branches

The number of branches per plant was counted at each sampling and mean values of five plants was expressed as number of branches per plant.

3.6.2 Physiological parameters

3.6.2.1 Growth parameters

Five plants in each treatment were uprooted randomly at 35, 55, 75 days after sowing and at harvest and used for recording dry matter distribution, leaf area and other growth characteristics as described below

3.6.2.2 Dry matter production and its partitioning

Five plants were uprooted at random in each plot and partitioned into their component parts *viz.,* stem, leaf and reproductive parts and were air dried and then transferred to hot air oven at 80 ^{o}C until a constant weight was obtained and their dry weight was recorded. The dry weight of different plant parts and total dry weight was recorded at 35, 55, 75 days after sowing and at harvest and expressed on per plant basis.

3.6.2.3 Leaf area (dm^2 $plant^{-1}$)

The leaf area per plant was worked out by disc method on dry weight basis as per Vivekanandan *et al.* (1972). It was expressed as dm^2 per plant.

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (dm^2)

Wa = Oven dry weight of all leaves (inclusive of 20 disc weight, mg)

W_d = Oven dry weight of 20 disc (mg)

A = Area of the 20 discs (dm^2)

3.6.2.4 Leaf area index (LAI)

Leaf area index (LAI) is defined as leaf area per unit land area. It was worked out by dividing the leaf area per plant by land area occupied by the plant as per Sestak *et al.* (1971)

$$\text{Leaf area index} = \frac{\text{leaf area}}{\text{land area}}$$

3.6.2.5 Absolute growth rate (AGR, g day^{-1})

Absolute growth rate (AGR) is the dry matter production per unit time (g day^{-1}), which was calculated by using formula given by Radford (1967).

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 = Dry matter of the plant (g) at time t_1

W_2 = Dry matter of the plant (g) at time t_2

3.6.2.6 Crop growth rate (CGR, g dm^{-2} day^{-1})

Crop growth rate is the rate of dry matter produced per unit ground area per unit time. It was calculated by using the following formula as per Watson, (1952) and expressed as g dm^{-2} per day.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

t_1& t_2 = Time interval (days)

A = Unit land area (dm^2)

3.6.3 Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})

Infrared gas analyzers (IRGAs) measure the reduction in transmission of IR wavebands caused by the presence of CO_2 between the radiation source and a detector. The reduction in transmission is a function of the concentration of CO_2. The only gas normally present in the air with an absorption spectrum overlapping that of CO_2 is water vapour. General parts of a gas exchange system:

1. Leaf chamber
2. Flow meter
3. Means of generating and controlling air flow over the leaf

IRGA, model TPS-2 was used for the instantaneous measurements, the TPS-2 passes a measured flow of air over a leaf sealed into a chamber called the leaf cuvette, using a valve, the TPR-2 first samples the CO_2 and H_2O in the air going to the cuvette and then in the air leaving the flow rate and the changing in the CO_2 and H_2O concentration , the assimilation rate of CO_2 and the transpiration rate of water can be

determined, this is commonly referred to as the “ open system method of measurement ” , this is the method used by the TPS-2 for photosynthetic rate measurements.

3.6.5 Chlorophyll content

Chlorophyll was estimated following the standard procedure (Hiscox and Israelstam, 1979) at 35, 55 and 75 days after sowing. The third fresh leaves from top of the plants were collected. A known fresh weight of leaf sample were cut in to small pieces and suspended in test tubes containing seven ml of dimethyl sulphoxide (DMSO). Test tubes were incubated at 65 °C for 30 min in a water bath. The supernatant was decanted and another three ml of DMSO was added to the residue and incubated at 65° C for 30 min. The supernatants were pooled and the volume was made up to 10 ml by adding DMSO. The chlorophyll extract was transferred to a cuvette and the absorbance was read in a systronic spectrophotometer-169 at 645 and 663 nm against DMSO blank. Chlorophyll a, b, and total chlorophyll were calculated by the following formulae and the data on the chlorophyll content was recorded in mg g^{-1} fresh weight.

Chl. a (mg/g) = [12.7(OD663)-2.69(OD645)] x V/1000 x W x a

Chl. b (mg/g) = [22.9(OD645) - 4.68(OD663)] x V/1000 x W x a

Total Chl. (mg/g) = [20.2(OD645) + 8.02 (OD663)] x V/1000 x W x a

Where,

V = Volume of the DMSO used in extract (ml)

W = Weight of fresh leaf tissue (g)

a = Path length of light (cm)

A = Absorbance at specific wave length (645 & 663nm)

3.6.7 Relative water content (Barr and Weatherley 1962)

Relative water content was analysed from 4th leaf at different stages of growth and development.

Fresh weight (FW) at excision was taken and then leaves were left to rehydrate in distilled water for 24hrs at 25°C in darkness to obtain the weight at full turgor (TW). The weight of turgid leaves was recorded and was later on dried for 24h at 80°C and the dry weight (DW) was recorded. The relative leaf water content was calculated as mentioned below:

RWC = (FW-DW/ TW-DW) x 100

Where,

FW- Fresh weight (mg)

TW- Turgid weight (mg)

DW- Dry weight (mg).

3.6.8 Proline content in leaves (Bates *et al* .,1973)

Reagents

A: Methanol:Chloroform:Water (12:5:1v/v)

B: Acid Ninhydrin : 1.25 g of ninhydrin in 30 ml 0f glacial acetic acid and 20 ml of 6M orthophospharic acid and keep it in cool and we can only use within 24 hrs.

C:Glacial Acetic acid

D: Toulene

E: Sulphosalicylic acid (3%)

F: Orthophospharic acid (6M)

Extraction

The sample of 0.5g weighed and extracted in 6ml of Methanol:Chloroform:Water (12:5:1) by volume at room temperature. It was then centrifuged for 10 minutes and the supernatant was collected. Again the contents were centrifuged after adding 4ml of Methanol:Chloroform:Water. Supernatant was pooled and final volume was made up to 10ml with same solvent. To this 6ml of chloroform and 4ml of distilled water was added.

After stirring it was allowed to stand for 15 minutes in separating funnel till the two layers get separated. Lower layer containing pigments was rejected and upper layer was collected *i.e* pink layer. The final volume of upper layer was made to 10 ml by adding distilled water and take OD @ 520 nm, calculated by using formula

Preparation of acid Ninhydrin

125 mg of Ninhydrin mixed in 3ml of acetic acid and 2ml of orthophosphoric acid, and then kept in oven at 70^0C till a clear solution was formed. This solution is kept for a 24 hrs.

Estimation

5.0 ml of this solution was taken and added with 2.0 ml of acid Ninhydrin, the mixture was boiled for 45 minutes in boiling water bath till pink colour is formed. On cooling, add 4 ml of toulene. Again allow it to stand in separating funnel for another 30 minutes till the two layers get separated. Lower layer was discarded and upper pink layer was collected. OD was recorded at 520 nm by using toluene as blank. Proline is used as standard to make standard curve.

3.6.9 Membrane injury Index

The membrane injury index (MII) was determined according to the method of Premchandra *et al*. (1990). Shoot portion (0.1 g) of different treatments and control were thoroughly washed in running tap water and double distilled water and thereafter placed in10 ml of double distilled water at 40°C for 30 minutes. After the end of this period their electrical conductivity was recorded by EC meter (C_1). Subsequently the same samples were placed on boiling water bath (100°C) for 10 min and their electrical conductivity was recorded as above (C_2). The membrane injury index (MII) was calculated as:

$$MII = (C_1/C_2) \times 100$$

Where,

C_1= EC at 40°C C_2= EC at 100°C

3.6.10 Leaf water potential

The soil water potential were estimated according to Saxon et al (1986), as a function of soil water content and soil textural properties. Root water potential and leaf water potentials were determined using scholander type of pressure chambers of different sizes. The small one (industrial product) was used for determining leaf water potential, in case of leaf water potential, the leaves are sealed in the pressure chamber with some few centimetres of mid rib protruding out. And saw the reading on pressure chamber.

3.6.11 Phenology

3.6.11.1 Days to flower initiation

Number of days from the date of sowing to the date of the first flower bud initiation was recorded.

3.6.11.2 Days to pod initiation

Number of days from the date of sowing to the date of the first pod initiation was recorded.

3.6.11.3 Days to physiological maturity

The number of days required from sowing to physiological maturity (*i.e.*75-80% pods mature) was recorded.

3.6.12Yield parameters

3.6.12.1 Number of pods per plant

It was recorded by counting the total number of pods borne on each plant.

3.6.12.2 100 seed weight (g)

Two samples of 100 seeds were drawn randomly from bulked seed of the five plants and were weighed in g up to second decimal place with the help of an electronic balance and mean of the samples recorded as 100 seed weight.

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

Pods from net plot were threshed, cleaned and the seed weight was recorded. From this, seed yield per hectare was computed.

3.6.12.4 Straw yield (kg ha^{-1})

The total biological portion from yield of above ground portion from net plot at harvest was recorded after complete sun drying, straw yield per hectare was worked out by deducting the grain yield.

3.6.12.5 Harvest index

The ratio of seed yield to biological yield of each selected plant was calculated and then average value were obtained and expressed in Percentage. Harvest index was estimated as per the formula suggested by Donald (1962).

3.6.13 Root characteristics study

3.6.13.1 Root length (cm)

The plants were removed carefully from the polyvinyl chloride (PVC) pipes without much damage to the roots by using digging fork to disturb the soil and jetting water to separate soil particles and the root length for each plant was measured from the base to the tip of longest root and expressed in cm.

3.6.13.2 Root dry weight (g)

After measuring root volume the roots were dried in shade and then oven dried at 70° C to constant weight and dry weight was recorded and expressed in g.

3.6.13.3 Shoot length (cm)

The plants were removed carefully from the polyvinyl chloride (PVC) pipes and the shoot length for each plant was measured from the base to the tip of longest shoot and expressed in cm.

3.7 Statistical analysis and interpretation of data

The analysis and interpretation of data were done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967). The level of significance used in "F" and "t" test was at 5 % probability level and wherever "F" test was found significant, the "t" test was performed to estimate critical differences among various treatments

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the field experiment entitled "Screening of chickpea lines for drought tolerance" conducted during *rabi* 2017 at Agricultural Research Station, Kalaburagi are presented in this chapter.

4.1 Morphological parameters:

4.1.1 Plant height (cm)

The data pertaining to plant height (cm) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.4

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher plant height (26.45, 49.27, 64.56 and 66.00 cm) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (23.31, 47.02, 56.79 and 59.63 cm, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher plant height was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (29.91, 54.49, 71.26 and 74.13 cm) when compared to rest of genotypes. But it was followed by plant height of JG-11(26.05, 52.23, 66.80 and 68.25 cm). Significantly lower plant height was recorded in RVSSG-52 at all the stages of plant growth (22.70, 41.26, 53.53 and 55.97 cm at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher plant height of chickpea was recorded in the irrigated conditions with RKD-1 (32.03, 56.13, 76.56 and 78.51 cm) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower plant height was observed in non irrigated condition with RVSSG-52 genotype (21.60, 40.27, 52.10 and 54.27 cm) at all the growth stages.

4.1.2 Number of branches per plant

The data pertaining to number of branches per plant of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.5

Table 4. Plant height (cm) of chickpea genotypes as influenced by non-irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	21.80	24.27	**23.03**	40.91	42.85	**41.88**	52.69	55.42	**54.06**	55.26	57.78	**56.52**
JG-11	24.18	27.93	**26.05**	51.18	53.28	**52.23**	58.68	74.93	**66.80**	61.24	75.27	**68.25**
BGD-103	23.37	27.10	**25.24**	51.35	52.79	**52.07**	58.22	70.29	**64.25**	60.84	71.71	**66.28**
GBM-2	25.83	31.35	**28.59**	51.65	54.56	**53.11**	61.69	73.81	**67.75**	64.35	75.44	**69.89**
RKD-1	27.79	32.04	**29.91**	52.85	56.13	**54.49**	65.76	76.56	**71.26**	70.26	78.51	**74.13**
RKD-4	23.17	26.08	**24.62**	50.17	52.08	**51.13**	57.51	69.93	**63.72**	60.26	71.09	**65.67**
MABC-WR-SA-1	22.08	24.57	**23.33**	42.09	44.31	**43.20**	54.05	56.80	**55.42**	57.16	58.61	**57.88**
MABC-WR-SA-2	22.08	24.57	**23.33**	42.09	44.34	**43.21**	53.72	56.63	**55.18**	55.83	58.33	**57.08**
JG-14	22.53	25.20	**23.87**	47.34	49.87	**48.60**	55.64	58.76	**57.20**	58.31	60.04	**59.17**
JAKI-9218	22.36	24.81	**23.58**	44.82	46.71	**45.76**	54.82	57.15	**55.98**	57.83	58.22	**58.02**
DIBG-204	22.97	25.66	**24.31**	49.49	52.05	**50.77**	56.65	69.24	**62.94**	59.13	70.65	**64.89**
RVSSG-52	21.60	23.79	**22.70**	40.27	42.25	**41.26**	52.10	54.96	**53.53**	55.27	56.84	**55.97**
Mean	**23.31**	**26.45**		**47.02**	**49.27**		**56.79**	**64.56**		**59.63**	**66.00**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.18	0.78	0.40	1.70	0.44	1.89	0.81	3.48
Genotypes(G)	0.04	0.07	0.08	0.16	0.12	0.24	0.13	0.26
IXG	0.05	0.10	0.12	0.23	0.17	0.33	0.18	0.37

Table 5. Number of branches per plant of chickpea genotypes as influenced by non-irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	4.09	4.68	**4.38**	6.42	7.01	**6.71**	8.16	11.14	**9.65**	8.29	11.59	**9.94**
JG-11	6.07	6.57	**6.32**	9.12	10.15	**9.59**	10.10	12.93	**11.52**	10.42	13.23	**11.83**
BGD-103	5.56	5.69	**5.62**	8.01	10.07	**9.08**	10.00	12.77	**11.39**	10.17	13.11	**11.64**
GBM-2	4.46	4.96	**4.71**	7.41	6.07	**6.74**	8.68	11.20	**9.94**	8.83	11.47	**10.15**
RKD-1	6.18	6.97	**6.58**	10.17	12.14	**11.15**	10.66	13.76	**12.21**	11.08	14.07	**12.58**
RKD-4	5.62	5.85	**5.73**	7.51	9.10	**8.31**	9.71	12.23	**10.97**	10.04	12.43	**11.24**
MABC-WR-SA-1	4.19	4.73	**4.46**	5.99	6.36	**6.18**	8.26	11.25	**9.76**	8.43	11.77	**10.10**
MABC-WR-SA-2	4.19	4.73	**4.46**	6.58	7.58	**7.08**	9.38	11.78	**10.58**	9.61	12.12	**10.86**
JG-14	5.10	5.65	**5.38**	6.22	7.08	**6.65**	9.02	11.46	**10.24**	9.16	11.84	**10.50**
JAKI-9218	5.06	5.59	**5.33**	6.85	7.80	**7.32**	9.47	12.03	**10.75**	9.71	12.38	**11.04**
DIBG-204	5.40	6.00	**5.70**	7.21	8.09	**7.65**	9.64	12.18	**10.91**	9.85	12.53	**11.19**
RVSSG-52	4.09	4.68	**4.38**	5.76	6.26	**6.01**	8.03	10.56	**9.29**	8.20	10.80	**9.50**
Mean	**5.00**	**5.51**		**7.27**	**8.14**		**9.26**	**11.94**		**9.48**	**12.28**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.040	0.173	0.10	0.42	0.14	0.60	0.14	0.61
Genotypes(G)	0.013	0.027	0.04	0.08	0.02	0.03	0.02	0.04
IXG	0.019	0.038	0.05	0.11	0.02	0.05	0.03	0.05

All chickpea genotypes grown under irrigated conditions (non-stress) recorded significantly higher number of branches per plant (5.51, 8.14, 11.94 and 12.28) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (5.00, 7.27, 9.26 and 9.48, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher number of branches per plant was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (6.58, 11.15, 12.21 and 12.58) when compared to rest of genotypes. But it was followed by number of branches per plant of JG-11(6.32, 9.59, 11.52 and 11.83). Significantly lower number of branches per plant was recorded in RVSSG-52 at all the stages of plant growth (4.38, 6.01, 9.29 and 9.50 at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher number of branches per plant of chickpea was recorded in the irrigated conditions with RKD-1 (6.97, 12.14, 13.76 and 14.07) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower number of branches per plant was observed in non-irrigated condition with RVSSG-52 genotype (4.09, 5.76, 8.03 and 8.20) at all the growth stages.

4.2 Growth parameters

4.2.1 Absolute growth rate (g day $^{-1}$)

The data pertaining to absolute growth rate (g day^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.6

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher absolute growth rate (0.35, 1.42 and 0.81 g day^{-1}) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (0.15, 0.93 and 0.20 g day^{-1}, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher absolute growth rate was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.36, 1.42 and 0.68 g day^{-1}) when compared to rest of genotypes. But it was followed by absolute growth rate of JG-11(0.34, 1.27 and 0.65 gday^{-1}). Significantly lower absolute growth rate was recorded in RVSSG-52 at all

Table 6. Absolute growth rate (g day^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35 -55			55 -75			75 –Harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	0.09	0.30	**0.20**	0.87	1.28	**1.08**	0.16	0.58	**0.37**
JG-11	0.20	0.49	**0.34**	0.94	1.61	**1.27**	0.14	1.15	**0.65**
BGD-103	0.19	0.41	**0.30**	0.98	1.50	**1.24**	0.18	1.01	**0.59**
GBM-2	0.11	0.26	**0.18**	0.91	1.32	**1.11**	0.21	0.64	**0.43**
RKD-1	0.15	0.58	**0.36**	1.04	1.80	**1.42**	0.17	1.20	**0.68**
RKD-4	0.18	0.39	**0.29**	0.95	1.49	**1.22**	0.19	0.94	**0.56**
MABC-WR-SA-1	0.11	0.25	**0.18**	0.92	1.30	**1.11**	0.19	0.59	**0.39**
MABC-WR-SA-2	0.16	0.30	**0.23**	0.86	1.34	**1.10**	0.26	0.82	**0.54**
JG-14	0.13	0.28	**0.21**	0.85	1.34	**1.10**	0.26	0.77	**0.52**
JAKI-9218	0.17	0.29	**0.23**	1.03	1.42	**1.22**	0.22	0.70	**0.46**
DIBG-204	0.18	0.30	**0.24**	1.03	1.44	**1.23**	0.24	0.74	**0.49**
RVSSG-52	0.09	0.29	**0.19**	0.86	1.24	**1.05**	0.18	0.54	**0.36**
Mean	**0.15**	**0.35**		**0.93**	**1.42**		**0.20**	**0.81**	
For comparing means of	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
Irrigation(I)	0.004		0.018	0.020		0.085	0.011		0.046
Genotypes(G)	0.001		0.003	0.003		0.005	0.003		0.006
IXG	0.002		0.004	0.004		0.007	0.004		0.009

the stages of plant growth (0.19, 1.05 and 0.36 g day^{-1}at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher absolute growth rate of chickpea was recorded in the irrigated conditions with RKD-1 (0.58, 1.80, 1.20 g day^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower absolute growth rate was observed in non irrigated condition with RVSSG-52 genotype (0.09, 0.86 and 0.18 g day^{-1}) at all the growth stages.

4.2.2 Crop growth rate (g dm^{-2} day^{-1})

The data pertaining to crop growth rate (g dm^{-2} day^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.7

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher crop growth rate (0.12, 0.47 and 0.27 g dm^{-2} day^{-1}) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (0.05, 0.31 and 0.07 g dm^{-2} day^{-1}, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher crop growth rate was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.12, 0.47 and 0.23 g dm^{-2} day^{-1}) when compared to rest of genotypes. But it was followed by crop growth rate of JG-11(0.11, 0.42 and 0.21 g dm^{-2}day^{-1}). Significantly lower crop growth rate was recorded in RVSSG-52 at all the stages of plant growth (0.06, 0.35 and 0.12 g dm^{-2} day^{-1}at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher crop growth rate of chickpea was recorded in the irrigated conditions with RKD-1 (0.19, 0.60 and 0.40 g dm^{-2} day^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower crop growth rate was observed in non irrigated condition with RVSSG-52 genotype (0.03, .29 and 0.06 g dm^{-2} day^{-1}) at all the growth stages.

Table 7. Crop growth rate (g dm^{-2} day^{-1}) of chickpea genotypes as influenced by Non irrigated and irrigated condition

Genotype	Days after sowing								
	35 -55			55 -75			75 –Harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	0.031	0.100	**0.066**	0.29	0.43	**0.36**	0.05	0.19	**0.12**
JG-11	0.066	0.171	**0.118**	0.31	0.54	**0.42**	0.05	0.38	**0.21**
BGD-103	0.063	0.138	**0.100**	0.33	0.50	**0.41**	0.06	0.34	**0.20**
GBM-2	0.037	0.086	**0.062**	0.30	0.44	**0.37**	0.07	0.21	**0.14**
RKD-1	0.049	0.193	**0.121**	0.35	0.60	**0.47**	0.06	0.40	**0.23**
RKD-4	0.061	0.131	**0.096**	0.32	0.50	**0.41**	0.06	0.31	**0.19**
MABC-WR-SA-1	0.037	0.085	**0.061**	0.31	0.43	**0.37**	0.06	0.20	**0.13**
MABC-WR-SA-2	0.053	0.100	**0.076**	0.29	0.45	**0.37**	0.09	0.27	**0.18**
JG-14	0.043	0.094	**0.068**	0.28	0.45	**0.37**	0.09	0.26	**0.17**
JAKI-9218	0.058	0.098	**0.078**	0.34	0.47	**0.41**	0.07	0.23	**0.15**
DIBG-204	0.060	0.101	**0.081**	0.34	0.48	**0.41**	0.08	0.25	**0.16**
RVSSG-52	0.032	0.097	**0.064**	0.29	0.41	**0.35**	0.06	0.18	**0.12**
Mean	**0.049**	**0.116**		**0.31**	**0.47**		**0.07**	**0.27**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.0014	0.0059	0.0066	0.0285	0.0039	0.0166
Genotypes(G)	0.0005	0.0009	0.0008	0.0017	0.0011	0.0023
IXG	0.0007	0.0013	0.0012	0.0024	0.0016	0.0032

4.2.3 Leaf area (dm^2 $plant^{-1}$)

The data pertaining to leaf area (dm^2 $plant^{-1}$) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.8

All chickpea genotypes grown under irrigated conditions (non-stress) recorded significantly higher leaf area (1.89, 3.88, 7.61 and 4.03 dm^2 $plant^{-1}$) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (1.23, 2.35, 4.92 and 2.59 dm^2 $plant^{-1}$, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher leaf area was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (2.03, 3.78, 7.40 and 4.01 dm^2 $plant^{-1}$) when compared to rest of genotypes. But it was followed by leaf area of JG-11(1.77, 3.41, 7.16 and 3.58 dm^2 $plant^{-1}$). Significantly lower leaf area was recorded in RVSSG-52 at all the stages of plant growth (1.27, 2.57, 5.13 and 2.77 dm^2 $plant^{-1}$ at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher leaf area of chickpea was recorded in the irrigated conditions with RKD-1 (2.39, 4.61, 9.12 and 4.85 dm^2 $plant^{-1}$) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower leaf area was observed in non irrigated condition with RVSSG-52 genotype (1.02, 1.99, 4.06 and 2.21 dm^2 $plant^{-1}$) at all the growth stages.

4.2.4 Leaf area index

The data pertaining to leaf area index of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.9

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher leaf area index (0.63, 1.29, 2.54 and 1.34) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (0.41, 0.78, 1.64 and 0.86, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher leaf area index was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.68, 1.26, 2.47 and 1.34) when compared to rest of genotypes, it was followed by leaf area index of JG-11(0.59, 1.14, 2.39 and 1.19).

Table 8. Leaf area (dm^2 $plant^{-1}$) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	1.08	1.63	**1.35**	2.12	3.31	**2.72**	4.26	6.54	**5.40**	2.36	3.51	**2.94**
JG-11	1.40	2.15	**1.77**	2.63	4.19	**3.41**	5.66	8.66	**7.16**	2.84	4.32	**3.58**
BGD-103	1.32	2.08	**1.67**	2.57	4.18	**3.37**	5.36	8.37	**6.87**	2.79	4.30	**3.54**
GBM-2	1.13	1.67	**1.40**	2.19	3.71	**2.95**	4.68	7.03	**5.85**	2.44	3.88	**3.16**
RKD-1	1.67	2.39	**2.03**	2.95	4.61	**3.78**	5.69	9.12	**7.40**	3.17	4.85	**4.01**
RKD-4	1.25	2.02	**1.67**	2.45	4.17	**3.31**	5.15	8.21	**6.68**	2.64	4.28	**3.46**
MABC-WR-SA-1	1.12	1.65	**1.39**	2.16	3.65	**2.90**	4.39	6.86	**5.63**	2.40	3.79	**3.10**
MABC-WR-SA-2	1.17	1.89	**1.56**	2.25	3.87	**3.06**	4.96	7.60	**6.28**	2.54	3.98	**3.26**
JG-14	1.16	1.82	**1.50**	2.23	3.82	**3.02**	4.78	7.43	**6.10**	2.51	3.93	**3.22**
JAKI-9218	1.19	1.92	**1.92**	2.25	3.92	**3.08**	4.98	7.62	**6.30**	2.53	4.03	**3.28**
DIBG-204	1.23	1.97	**1.58**	2.40	4.05	**3.23**	5.12	7.64	**6.38**	2.60	4.16	**3.38**
RVSSG-52	1.02	1.53	**1.27**	1.99	3.15	**2.57**	4.06	6.20	**5.13**	2.21	3.33	**2.77**
Mean	**1.23**	**1.89**		**2.35**	**3.88**		**4.92**	**7.61**		**2.59**	**4.03**	

For comparing means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Irrigation(I)	0.009	0.038	0.04	0.18	0.08	0.36	0.045	0.192
Genotypes(G)	0.003	0.007	0.01	0.01	0.01	0.03	0.007	0.013
IXG	0.005	0.010	0.01	0.02	0.02	0.04	0.009	0.019

Table 9. Leaf area index of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	0.36	0.54	**0.45**	0.71	1.10	**0.91**	1.42	2.18	**1.80**	0.79	1.17	**0.98**
JG-11	0.47	0.72	**0.59**	0.88	1.40	**1.14**	1.89	2.89	**2.39**	0.95	1.44	**1.19**
BGD-103	0.44	0.69	**0.57**	0.86	1.39	**1.12**	1.79	2.79	**2.29**	0.93	1.43	**1.18**
GBM-2	0.38	0.56	**0.47**	0.73	1.24	**0.98**	1.56	2.34	**1.95**	0.81	1.29	**1.05**
RKD-1	0.56	0.80	**0.68**	0.98	1.54	**1.26**	1.90	3.04	**2.47**	1.06	1.62	**1.34**
RKD-4	0.42	0.67	**0.55**	0.82	1.39	**1.10**	1.72	2.74	**2.23**	0.88	1.43	**1.15**
MABC-WR-SA-1	0.37	0.55	**0.46**	0.72	1.22	**0.97**	1.46	2.29	**1.88**	0.80	1.26	**1.03**
MABC-WR-SA-2	0.39	0.63	**0.51**	0.75	1.29	**1.02**	1.65	2.53	**2.09**	0.85	1.33	**1.09**
JG-14	0.39	0.61	**0.50**	0.74	1.27	**1.01**	1.59	2.48	**2.03**	0.84	1.31	**1.07**
JAKI-9218	0.40	0.64	**0.52**	0.75	1.31	**1.03**	1.66	2.54	**2.10**	0.84	1.34	**1.09**
DIBG-204	0.41	0.66	**0.53**	0.80	1.35	**1.08**	1.71	2.55	**2.13**	0.87	1.39	**1.13**
RVSSG-52	0.34	0.51	**0.43**	0.66	1.05	**0.86**	1.35	2.07	**1.71**	0.74	1.11	**0.92**
Mean	**0.41**	**0.63**		**0.78**	**1.29**		**1.64**	**2.54**		**0.86**	**1.34**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.0076	0.0328	0.0139	0.0600	0.0282	0.1212	0.0150	0.0645
Genotypes(G)	0.0017	0.0034	0.0029	0.0059	0.0046	0.0094	0.0021	0.0043
IXG	0.0024	0.0048	0.0042	0.0084	0.0066	0.0132	0.0030	0.0060

Significantly lower leaf area index was recorded in RVSSG-52 at all the stages of plant growth (0.43, 0.86, 1.71 and 0.92 at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher leaf area index of chickpea was recorded in the irrigated conditions with RKD-1 (0.80, 1.54, 3.04 and 1.62) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower leaf area index was observed in non-irrigated condition with RVSSG-52 genotype (0.34, 0.66, 1.35 and 0.74) at all the growth stages.

4.3 Dry matter accumulation and its partitioning

4.3.1 Leaf dry weight (g plant^{-1})

The data pertaining to leaf dry weight (g plant^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.10

All chickpea genotypes grown under irrigated conditions (non-stress) recorded significantly higher leaf dry weight (4.65, 7.20, 8.33 and 7.39 g plant^{-1}) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (2.55, 5.15, 6.35 and 5.59 g plant^{-1}, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher leaf dry weight was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (4.61, 8.44, 9.32 and 8.54 g plant^{-1}) when compared to rest of genotypes. But it was followed by leaf dry weight of JG-11(4.34, 7.34, 8.49 and 7.68 g plant^{-1}). Significantly lower leaf dry weight was recorded in RVSSG-52 at all the stages of plant growth (2.60, 5.12, 6.15 and 5.41g plant^{-1} at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher leaf dry weight of chickpea was recorded in the irrigated conditions with RKD-1 (5.46, 9.67, 10.23 and 9.21 g plant^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower leaf dry weight was observed in non irrigated condition with RVSSG-52 genotype (2.02, 3.93, 5.05 and 4.35 g plant^{-1}) at all the growth stages.

Table 10. Leaf dry weight (g plant^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	2.07	3.43	**2.75**	4.05	6.18	**5.12**	5.10	7.19	**6.15**	4.48	6.34	**5.41**
JG-11	3.34	5.34	**4.34**	6.88	7.80	**7.34**	7.63	9.36	**8.49**	7.22	8.13	**7.68**
BGD-103	2.74	5.32	**4.03**	6.29	7.57	**6.93**	7.23	9.13	**8.18**	6.82	7.99	**7.41**
GBM-2	2.19	4.34	**3.26**	4.43	6.58	**5.51**	5.73	7.85	**6.79**	4.74	6.98	**5.86**
RKD-1	3.77	5.46	**4.61**	7.22	9.67	**8.44**	8.40	10.23	**9.32**	7.87	9.21	**8.54**
RKD-4	2.63	5.30	**3.96**	5.56	7.54	**6.69**	6.79	8.71	**7.75**	5.97	7.72	**6.85**
MABC-WR-SA-1	2.11	4.16	**3.13**	4.16	6.26	**5.21**	5.24	7.32	**6.28**	4.61	6.58	**5.59**
MABC-WR-SA-2	2.39	4.72	**3.56**	4.81	7.02	**5.91**	6.11	8.12	**7.12**	5.17	7.32	**6.25**
JG-14	2.32	4.39	**3.36**	4.55	6.95	**5.75**	6.01	8.06	**7.04**	5.02	7.20	**6.11**
JAKI-9218	2.50	5.02	**3.76**	4.88	7.16	**6.02**	6.38	8.36	**7.37**	5.24	7.43	**6.34**
DIBG-204	2.55	5.16	**3.85**	5.06	7.36	**6.21**	6.53	8.58	**7.56**	5.53	7.52	**6.53**
RVSSG-52	2.02	3.18	**2.60**	3.93	6.02	**5.12**	5.05	7.06	**6.15**	4.35	6.22	**5.41**
Means	**2.55**	**4.65**		**5.15**	**7.20**		**6.35**	**8.33**		**5.59**	**7.39**	

For comparing means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Irrigation(I)	0.06	0.24	0.08	0.34	0.094	0.405	0.084	0.363
Genotypes(G)	0.01	0.03	0.02	0.04	0.020	0.040	0.020	0.039
IXG	0.02	0.04	0.03	0.06	0.028	0.057	0.028	0.056

4.3.2 Stem dry weight (g plant^{-1})

The data pertaining to stem dry weight (g plant^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.11

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher stem dry weight (7.59, 9.33, 22.83 and 23.16 g plant^{-1}) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (6.73, 8.65, 14.63 and 14.94 g plant^{-1}, respectively at 35, 55, 75, and at harvest).

Among the genotypes, significantly higher stem dry weight was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (8.05, 10.66, 25.43, 25.74 g plant^{-1}) when compared to rest of genotypes. But it was followed by stem dry weight of JG-11(7.63, 10.14, 24.65 and 24.96 g plant^{-1}). Significantly lower stem dry weight was recorded in RVSSG-52 at all the stages of plant growth (6.54, 7.90, 14.62 and 14.89 g plant^{-1} at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher stem dry weight of chickpea was recorded in the irrigated conditions with RKD-1 (8.53, 11.21, 32.62 and 32.94 g plant^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower stem dry weight was observed in non irrigated condition with RVSSG-52 genotype (6.07, 7.78, 11.70 and 12.04 g plant^{-1}) at all the growth stages.

4.3.3 Total dry matter accumulation (g plant^{-1})

The data pertaining to total dry matter accumulation (g plant^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.12

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher total dry matter accumulation (12.24, 16.53, 37.58 and 53.70 g plant^{-1}) at 35, 55, 75 DAS and at harvest, respectively as compared to the chickpea genotypes grown under stress condition (9.28, 13.80 and 44.68 g plant^{-1}, respectively at 35, 55 and at harvest). . But at 75 DAS under non irrigated condition 40.69 g plant^{-1} recorded

Table 11. Stem dry weight (g plant^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	6.31	7.22	**6.77**	7.92	8.32	**8.12**	12.20	17.93	**15.07**	12.49	18.18	**15.34**
JG-11	7.22	8.04	**7.63**	9.85	10.43	**10.14**	17.69	31.62	**24.65**	18.02	31.90	**24.96**
BGD-103	7.12	7.85	**7.49**	9.61	9.95	**9.78**	16.44	26.48	**21.46**	16.85	27.73	**22.29**
GBM-2	6.37	7.38	**6.88**	8.01	8.75	**8.38**	13.74	18.55	**16.14**	14.06	18.79	**16.43**
RKD-1	7.58	8.53	**8.05**	10.11	11.21	**10.66**	18.23	32.62	**25.43**	18.53	32.94	**25.74**
RKD-4	7.00	7.69	**7.35**	9.06	9.85	**9.45**	15.81	25.73	**20.77**	16.13	25.93	**21.03**
MABC-WR-SA-1	6.36	7.32	**6.84**	7.97	8.66	**8.32**	12.97	18.08	**15.52**	13.25	18.34	**15.80**
MABC-WR-SA-2	6.46	7.48	**6.97**	8.35	9.07	**8.71**	13.89	21.31	**17.60**	14.19	21.62	**17.90**
JG-14	6.47	7.44	**6.96**	8.04	8.92	**8.48**	13.76	19.75	**16.75**	14.03	19.97	**17.00**
JAKI-9218	6.80	7.49	**7.14**	8.40	9.17	**8.78**	14.23	21.82	**18.02**	14.50	22.01	**18.26**
DIBG-204	6.94	7.63	**7.29**	8.67	9.64	**9.15**	14.91	22.49	**18.70**	15.21	22.71	**18.96**
RVSSG-52	6.07	7.00	**6.54**	7.78	8.02	**7.90**	11.70	17.54	**14.62**	12.04	17.78	**14.89**
Means	**6.73**	**7.59**		**8.65**	**9.33**		**14.63**	**22.83**		**14.94**	**23.16**	
For comparing means of	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
Irrigation(I)	0.09		0.39	0.12		0.50	0.25		1.09	0.25		1.09
Genotypes(G)	0.01		0.02	0.02		0.04	0.07		0.14	0.07		0.15
IXG	0.02		0.03	0.03		0.05	0.10		0.20	0.10		0.21

Table 12. Total dry matter accumulation (g plant^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing											
	35			55			75			At harvest		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	8.38	10.65	**9.52**	11.97	14.51	**13.24**	35.90	33.60	**34.75**	39.10	45.21	**42.16**
JG-11	10.56	13.38	**11.97**	16.73	18.23	**17.48**	46.38	42.34	**44.36**	49.23	66.27	**57.75**
BGD-103	9.86	13.17	**11.51**	15.90	17.52	**16.71**	43.62	40.98	**42.30**	47.17	61.22	**54.19**
GBM-2	8.56	11.72	**10.14**	12.44	15.34	**13.89**	37.47	34.84	**36.15**	41.66	47.66	**44.66**
RKD-1	11.34	13.99	**12.67**	17.33	20.87	**19.10**	50.37	46.30	**48.33**	53.74	69.37	**61.55**
RKD-4	9.63	12.99	**11.31**	14.60	17.69	**16.15**	43.02	39.94	**41.48**	46.75	58.65	**52.70**
MABC-WR-SA-1	8.47	11.48	**9.98**	12.13	14.92	**13.53**	36.76	33.97	**35.37**	40.61	45.84	**43.22**
MABC-WR-SA-2	8.86	12.20	**10.53**	13.16	16.09	**14.62**	38.98	34.73	**36.85**	44.16	51.07	**47.62**
JG-14	8.80	11.83	**10.31**	12.58	15.88	**14.23**	38.31	34.21	**36.26**	43.54	49.59	**46.57**
JAKI-9218	9.30	12.51	**10.91**	13.28	16.33	**14.80**	41.08	38.32	**39.70**	45.51	52.25	**48.88**
DIBG-204	9.48	12.79	**11.14**	13.73	17.00	**15.36**	41.52	38.80	**40.16**	46.35	53.53	**49.94**
RVSSG-52	8.09	10.18	**9.13**	11.71	14.04	**12.87**	34.87	32.90	**33.88**	38.40	43.77	**41.09**
Mean	**9.28**	**12.24**		**13.80**	**16.53**		**40.69**	**37.58**		**44.68**	**53.70**	

For comparing means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Irrigation(I)	0.14	0.58	0.21	0.89	0.53	2.29	0.62	2.68
Genotypes(G)	0.02	0.05	0.05	0.10	0.09	0.18	0.13	0.27
IXG	0.03	0.07	0.07	0.14	0.13	0.26	0.19	0.38

significantly higher total dry matter accumulation (pods) than irrigated condition

Among the genotypes, significantly higher total dry matter accumulation was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (12.67, 19.10, 48.33 and 61.55 g plant^{-1}) when compared to rest of genotypes. But it was followed by total dry matter accumulation of JG-11(11.97, 17.48, 44.36 and 57.75 g plant^{-1}). Significantly lower total dry matter accumulation was recorded in RVSSG-52 at all the stages of plant growth (9.13, 12.87, 33.88 and 41.09 g plant^{-1} at 35, 55, 75 and at harvest, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher total dry matter accumulation of chickpea was recorded in the irrigated conditions with RKD-1 (13.99, 20.87 and 69.37 g plant^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower total dry matter accumulation was observed in non irrigated condition with RVSSG-52 genotype (8.09, 11.71 and 38.40 g plant^{-1}) at all the growth stages. But at 75 DAS under non irrigated condition RKD-1 shows significantly higher total dry matter accumulation (50.37 g plant^{-1}) and lower total dry matter accumulation under irrigated condition RVSSG-52 (32.90 g plant^{-1})

4.4 Physiological parameters

4.4.1 Membrane injury index (%) (MII)

The data pertaining membrane injury index (%) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.13

All chickpea genotypes grown under irrigated conditions (non-stress) observed significantly lower membrane injury index (15.28, 21.72 and 28.51 %) at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (22.42, 35.31 and 46.23 %, respectively at 35, 55 and 75).

Among the genotypes, significantly lower membrane injury index was noticed in RKD-1 at 35, 55 and 75 DAS (15.37, 24.35 and 31.73 %) when compared to rest of genotypes. But it was followed by membrane injury index of JG-11(16.02, 25.17 and 33.47 %). Significantly higher membrane injury index was recorded in RVSSG-52 at all the stages of plant growth (23.92, 33.32 and 43.35 % at 35, 55 and 75, respectively).

Table 13. Membrane injury index (%) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	28.80	18.25	**23.52**	40.15	23.49	**31.82**	51.65	31.82	**41.74**
JG-11	19.40	12.63	**16.02**	31.20	19.14	**25.17**	41.77	25.17	**33.47**
BGD-103	20.25	13.01	**16.63**	31.89	20.60	**26.24**	42.94	26.24	**34.59**
GBM-2	28.26	17.24	**22.75**	38.27	22.82	**30.54**	48.63	30.54	**39.59**
RKD-1	18.76	11.99	**15.37**	30.14	18.57	**24.35**	39.11	24.35	**31.73**
RKD-4	20.34	13.20	**16.77**	32.26	20.92	**26.59**	43.62	26.59	**35.11**
MABC-WR-SA-1	28.67	17.48	**23.08**	39.17	23.01	**31.09**	49.58	31.09	**40.33**
MABC-WR-SA-2	26.19	15.56	**20.87**	34.51	22.09	**28.30**	46.18	28.30	**37.24**
JG-14	26.44	15.84	**21.14**	36.84	22.42	**29.63**	46.51	29.63	**38.07**
JAKI-9218	23.72	14.91	**19.32**	33.78	22.02	**27.90**	45.80	27.90	**36.85**
DIBG-204	22.97	14.61	**18.79**	32.71	21.67	**27.19**	45.53	27.19	**36.36**
RVSSG-52	29.25	18.59	**23.92**	42.79	23.84	**33.32**	53.39	33.32	**43.35**
Mean	**24.42**	**15.28**		**35.31**	**21.72**		**46.23**	**28.51**	

For comparing means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Irrigation(I)	0.34	1.46	0.50	2.16	0.63	2.70
Genotypes(G)	0.06	0.13	0.06	0.12	0.07	0.14
IXG	0.09	0.18	0.09	0.18	0.10	0.20

The interaction effects between irrigation and genotypes were found significant. Significantly lower membrane injury index of chickpea was recorded in the irrigated conditions with RKD-1 (11.99, 18.57 and 24.35 %) at all the growth stages when compared to the rest of the treatments combinations. Significantly higher membrane injury index was observed in non irrigated condition with RVSSG-52 genotype (29.25, 42.79 and 53.39 %) at all the growth stages.

4.4.2 Relative water content (%)

The data pertaining relative water content (%) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.14

All chickpea genotypes grown under irrigated conditions (non-stress) noticed significantly higher relative water content (83.03. 80.81 and 72.90 %) at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (75.46, 70.24 and 65.67 %, respectively at 35, 55 and 75).

Among the genotypes, significantly higher relative water content was noticed in RKD-1 at 35, 55 and 75 DAS (86.20, 82.07 and 75.72 %) when compared to rest of genotypes. But it was followed by relative water content of JG-11(83.47, 79.70 and 72.9 %). Significantly lower relative water content was recorded in RVSSG-52 at all the stages of plant growth (74.87, 71.48 and 64.26 % at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher relative water content of chickpea was recorded in the irrigated conditions with RKD-1 (89.98, 87.06 and 79.76 %) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower relative water content was observed in non irrigated condition with RVSSG-52 genotype (71.34, 66.60 and 59.94 %) at all the growth stages.

4.4.3 Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})

The data pertaining to photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.15

Table 14. Relative water content (%) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	72.53	78.88	**75.71**	67.48	76.59	**72.03**	61.12	69.96	**65.54**
JG-11	79.18	87.75	**83.47**	73.84	85.55	**79.70**	69.13	76.67	**72.90**
BGD-103	77.72	86.50	**82.11**	72.56	84.39	**78.48**	68.24	75.18	**71.71**
GBM-2	73.44	80.35	**76.89**	68.18	78.39	**73.28**	63.87	70.94	**67.41**
RKD-1	82.42	89.98	**86.20**	77.08	87.06	**82.07**	71.28	79.76	**75.72**
RKD-4	77.49	85.10	**81.29**	72.24	82.63	**77.43**	67.42	74.95	**71.18**
MABC-WR-SA-1	73.06	79.62	**76.34**	67.92	77.82	**72.87**	63.81	70.50	**67.15**
MABC-WR-SA-2	73.06	79.62	**76.34**	67.92	77.71	**72.82**	63.79	70.50	**67.14**
JG-14	74.73	83.15	**78.94**	69.48	80.57	**75.02**	66.54	72.09	**69.32**
JAKI-9218	73.73	82.16	**77.94**	67.77	79.51	**73.64**	65.69	71.17	**68.43**
DIBG-204	76.77	84.89	**80.83**	71.76	83.16	**77.46**	67.20	74.47	**70.83**
RVSSG-52	71.34	78.41	**74.87**	66.60	76.35	**71.48**	59.94	68.58	**64.26**
Mean	**75.46**	**83.03**		**70.24**	**80.81**		**65.67**	**72.90**	
For comparing means of	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
Irrigation(I)	0.61		2.61	0.54		2.34	0.52		2.25
Genotypes(G)	0.06		0.12	0.06		0.12	0.06		0.11
IXG	0.08		0.17	0.08		0.16	0.08		0.16

Table 15. Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	4.71	6.72	**5.71**	6.65	8.93	**7.79**	13.72	17.39	**15.55**
JG-11	6.17	7.84	**7.01**	9.37	12.01	**10.69**	17.05	22.25	**19.65**
BGD-103	5.47	7.73	**6.60**	8.93	11.42	**10.17**	16.77	21.40	**19.08**
GBM-2	4.95	7.04	**6.00**	7.39	9.33	**8.36**	14.32	17.86	**16.09**
RKD-1	6.34	8.49	**7.42**	10.15	13.09	**11.62**	17.94	22.95	**20.44**
RKD-4	5.40	7.64	**6.52**	8.41	11.36	**9.89**	16.27	19.39	**17.83**
MABC-WR-SA-1	4.80	6.90	**5.85**	7.29	9.00	**8.15**	14.12	17.43	**15.77**
MABC-WR-SA-2	5.33	7.34	**6.34**	8.00	9.72	**8.86**	14.49	18.14	**16.32**
JG-14	5.23	7.32	**6.28**	7.60	9.63	**8.61**	14.35	17.96	**16.16**
JAKI-9218	5.34	7.48	**6.41**	8.31	10.33	**9.32**	15.43	18.18	**16.81**
DIBG-204	5.39	7.55	**6.47**	8.40	10.40	**9.40**	16.03	18.88	**17.46**
RVSSG-52	4.66	6.59	**5.62**	6.37	8.27	**7.32**	12.85	17.01	**14.93**
Mean	**5.32**	**7.39**		**8.07**	**10.29**		**15.28**	**19.07**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.082	0.355	0.12	0.51	0.22	0.94
Genotypes(G)	0.012	0.023	0.02	0.05	0.04	0.08
IXG	0.016	0.033	0.03	0.07	0.05	0.11

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher photosynthetic rate (7.39, 10.29 and 19.07 µ mol CO_2 m^{-2} s^{-1} at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (5.32, 8.07 and 15.28 µ mol CO_2 m^{-2} s^{-1}, respectively at 35, 55 and 75).

Among the genotypes, significantly higher photosynthetic rate was noticed in RKD-1 at 35, 55 and 75 DAS (7.42, 11.6 and 20.44 µ mol CO_2 m^{-2} s^{-1}) when compared to rest of genotypes. But it was followed by photosynthetic rate of JG-11(7.01, 10.69 and 19.65 µ mol CO_2 m^{-2} s^{-1}). Significantly lower photosynthetic rate was recorded in RVSSG-52 at all the stages of plant growth (5.62, 7.32 and 14.93 µ mol CO_2 m^{-2} s^{-1} at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher photosynthetic rate of chickpea was recorded in the irrigated conditions with RKD-1 (8.49, 13.09 and 22.95 µ mol CO_2 m^{-2} s^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower photosynthetic rate was observed in non-irrigated condition with RVSSG-52 genotype (4.66, 6.37 and 12.85 µ mol CO_2 m^{-2} s^{-1}) at all the growth stages.

4.4.4 Leaf water potential (ψ_w) (-MPa)

The data pertaining to leaf water potential (-MPa) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.16

All chickpea genotypes grown under irrigated conditions (non-stress) recoded significantly lower leaf water potential (-0.70, -0.80 and -1.01 –Mpa at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (-1.13, -1.28 and -1.43 -MPa, respectively at 35, 55 and 75).

Among the genotypes, significantly lower leaf water potential was noticed in RKD-1 at 35, 55 and 75 DAS (-0.81, -0.92 and -1.09 -MPa) when compared to rest of genotypes. But it was followed by leaf water potential of JG-11(-0.84, 0.96 and -1.11 -MPa). Significantly higher leaf water potential was recorded in RVSSG-52 at all the stages of plant growth (-1.00, -1.13 and -1.35 -MPa at 35, 55 and 75, respectively).

Table 16 Leaf water potential (-MPa) of chickpea genotypes as influenced by non irrigated (moisture stress) and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	-1.19	-0.76	**-0.98**	-1.37	-0.86	**-1.12**	1.56	-1.11	**-1.33**
JG-11	-1.05	-0.64	**-0.84**	-1.18	-0.74	**-0.96**	-1.30	-0.93	**-1.11**
BGD-103	-1.08	-0.65	**-0.86**	-1.20	-0.76	**-0.98**	-1.32	-0.94	**-1.13**
GBM-2	-1.17	-0.74	**-0.95**	1.33	-0.83	**-1.08**	-1.52	-1.04	**-1.28**
RKD-1	-1.01	-0.62	**-0.81**	-1.12	-0.72	**-0.92**	-1.28	-0.90	**-1.09**
RKD-4	-1.09	-0.66	**-0.87**	-1.21	-0.77	**-0.99**	-1.33	-0.96	**-1.14**
MABC-WR-SA-1	-1.17	-0.75	**-0.96**	-1.32	-0.84	**-1.08**	-1.53	-1.07	**-1.30**
MABC-WR-SA-2	-1.13	-0.71	**-0.92**	-1.35	-0.81	**-1.08**	-1.48	-1.01	**-1.25**
JG-14	-1.15	-0.72	**-0.93**	-1.32	-0.82	**-1.07**	-1.50	-1.03	**-1.27**
JAKI-9218	-1.12	-0.69	**-0.90**	-1.28	-0.80	**-1.04**	-1.45	-0.99	**-1.22**
DIBG-204	-1.11	-0.67	**-0.89**	-1.23	-0.79	**-1.01**	-1.34	-0.98	**-1.16**
RVSSG-52	-1.21	-0.79	**-1.00**	-1.38	-0.88	**-1.13**	-1.57	-1.14	**-1.35**
Mean	**-1.13**	**-0.70**		**-1.28**	**-0.80**		**-1.43**	**-1.01**	
For comparing mean of	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
Irrigation(I)	0.013		0.054	0.016		0.067	0.017		0.072
Genotypes(G)	0.001		0.002	0.001		0.002	0.002		0.003
IXG	0.001		0.003	0.002		0.003	0.002		0.005

The interaction effects between irrigation and genotypes were found significant. Significantly lower leaf water potential of chickpea was recorded in the irrigated conditions with RKD-1 (-0.62, -0.71 and -0.90 -MPa) at all the growth stages when compared to the rest of the treatments combinations. Significantly higherleaf water potential was observed in non irrigated condition with RVSSG-52 genotype (-1.21, -1.38 and -1.57 -MPa) at all the growth stages.

4.5 Biochemical parameters

4.5.1 Chlorophyll 'a' content (mg g^{-1} fresh wt.)

The data pertaining to chlorophyll 'a' content (mg g^{-1} fresh wt.) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.17

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher chlorophyll a content (1.98, 2.17 and 1.45 mg g^{-1} fresh wt. at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (1.86, 1.99 and 1.25 mg g^{-1} fresh wt., respectively at 35, 55 and 75).

Among the genotypes, significantly higher chlorophyll a content was noticed in RKD-1 at 35, 55 and 75 DAS (2.05, 2.24 and 1.47mg g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by chlorophyll a content of JG-11(2.02, 2.20 and 1.44 mg g^{-1} fresh wt). Significantly lower chlorophyll a content was recorded in RVSSG-52 at all the stages of plant growth (1.79, 1.95 and 1.24 mg g^{-1} fresh wt. at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher chlorophyll a content of chickpea was recorded in the irrigated conditions with RKD-1 (2.12, 2.33 and 1.58mg g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower chlorophyll a content was observed in non-irrigated condition with RVSSG-52 genotype (1.73, 1.84 and 1.11 mg g^{-1} fresh wt.) at all the growth stages.

Table 17. Chlorophyll a content (mg g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	1.78	1.88	**1.83**	1.89	2.07	**1.98**	1.16	1.37	**1.27**
JG-11	1.95	2.09	**2.02**	2.11	2.29	**2.20**	1.33	1.54	**1.44**
BGD-103	1.93	2.07	**2.00**	2.09	2.24	**2.17**	1.32	1.52	**1.42**
GBM-2	1.81	1.92	**1.87**	1.93	2.10	**2.02**	1.19	1.40	**1.30**
RKD-1	1.98	2.12	**2.05**	2.15	2.33	**2.24**	1.35	1.58	**1.47**
RKD-4	1.90	2.03	**1.97**	2.06	2.21	**2.14**	1.30	1.51	**1.41**
MABC-WR-SA-1	1.79	1.90	**1.85**	1.90	2.09	**2.00**	1.18	1.38	**1.28**
MABC-WR-SA-2	1.84	1.94	**1.89**	1.97	2.15	**2.06**	1.26	1.45	**1.36**
JG-14	1.82	1.93	**1.88**	1.95	2.12	**2.04**	1.22	1.42	**1.32**
JAKI-9218	1.86	1.97	**1.92**	1.98	2.18	**2.08**	1.28	1.47	**1.38**
DIBG-204	1.87	2.00	**1.94**	2.01	2.20	**2.11**	1.29	1.49	**1.39**
RVSSG-52	1.73	1.85	**1.79**	1.84	2.06	**1.95**	1.11	1.36	**1.24**
Mean	**1.86**	**1.98**		**1.99**	**2.17**		**1.25**	**1.46**	
For comparing means of	**S.Em±**	**CD at 5%**		**S.Em±**	**CD at 5%**		**S.Em±**	**CD at 5%**	
Irrigation(I)	0.0265	0.1139		0.024	0.105		0.015	0.064	
Genotypes(G)	0.0037	0.0075		0.002	0.004		0.001	0.003	
IXG	0.0053	0.0106		0.003	0.006		0.002	0.004	

4.5.2 Chlorophyll 'b' content (mg g^{-1} fresh wt.)

The data pertaining to chlorophyll 'b' content (mg g^{-1} fresh wt.)of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.18

All chickpea genotypes grown under irrigated conditions (non-stress) recorded significantly higher chlorophyll b content (0.65, 0.70 and 0.45 mg g^{-1} fresh wt. at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (0.61, 0.64 and 0.39 mg g^{-1} fresh wt., respectively at 35, 55 and 75).

Among the genotypes, significantly higher chlorophyll b content was noticed in RKD-1 at 35, 55 and 75 DAS (0.68, 0.72 and 0.46 mg g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by chlorophyll b content of JG-11(0.67, 0.71 and 0.45 mg g^{-1} fresh wt). Significantly lower chlorophyll b content was recorded in RVSSG-52 at all the stages of plant growth (0.59, 0.63 and 0.38 mg g^{-1} fresh wt. at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher chlorophyll b content of chickpea was recorded in the irrigated conditions with RKD-1 (0.70, 0.75 and 0.49mg g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower chlorophyll b content was observed in non-irrigated condition with RVSSG-52 genotype (0.57, 0.59 and 0.35 mg g^{-1} fresh wt.) at all the growth stages.

4.5.3 Total chlorophyll content (mg g^{-1} fresh wt.)

The data pertaining to total chlorophyll content (mg g^{-1} fresh wt.) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.19

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher total chlorophyll content (2.63, 2.87 and 1.91 mg g^{-1} fresh wt. at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (2.47, 2.63 and 1.64 mg g^{-1} fresh wt. , respectively at 35, 55 and 75).

Table 18. Chlorophyll b content (mg g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	0.59	0.62	**0.61**	0.61	0.66	**0.63**	0.36	0.43	**0.39**
JG-11	0.65	0.69	**0.67**	0.68	0.73	**0.71**	0.41	0.48	**0.45**
BGD-103	0.64	0.69	**0.66**	0.67	0.72	**0.69**	0.41	0.47	**0.44**
GBM-2	0.60	0.64	**0.62**	0.62	0.67	**0.65**	0.37	0.44	**0.40**
RKD-1	0.66	0.70	**0.68**	0.69	0.75	**0.72**	0.42	0.49	**0.46**
RKD-4	0.63	0.67	**0.65**	0.66	0.71	**0.68**	0.40	0.47	**0.44**
MABC-WR-SA-1	0.59	0.63	**0.61**	0.61	0.67	**0.64**	0.37	0.43	**0.40**
MABC-WR-SA-2	0.61	0.64	**0.63**	0.63	0.69	**0.66**	0.39	0.45	**0.42**
JG-14	0.60	0.64	**0.62**	0.63	0.68	**0.65**	0.38	0.44	**0.41**
JAKI-9218	0.62	0.65	**0.63**	0.63	0.70	**0.67**	0.40	0.46	**0.43**
DIBG-204	0.62	0.66	**0.64**	0.64	0.71	**0.67**	0.40	0.46	**0.43**
RVSSG-52	0.57	0.61	**0.59**	0.59	0.66	**0.63**	0.35	0.42	**0.38**
Mean	**0.61**	**0.65**		**0.64**	**0.70**		**0.39**	**0.45**	

For comparing mean of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.008	0.036	0.0073	0.0312	0.0045	0.0194
Genotypes(G)	0.001	0.002	0.0018	0.0035	0.0005	0.0010
IXG	0.002	0.003	0.0025	0.0049	0.0007	0.0014

Table 19. Total chlorophyll content (mg g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	2.37	2.50	**2.44**	2.50	2.73	**2.61**	1.52	1.80	**1.66**
JG-11	2.60	2.78	**2.69**	2.79	3.02	**2.91**	1.74	2.02	**1.88**
BGD-103	2.57	2.76	**2.66**	2.76	2.96	**2.86**	1.73	1.99	**1.86**
GBM-2	2.41	2.56	**2.48**	2.55	2.77	**2.66**	1.56	1.84	**1.70**
RKD-1	2.64	2.82	**2.73**	2.84	3.08	**2.96**	1.77	2.07	**1.92**
RKD-4	2.53	2.70	**2.62**	2.72	2.92	**2.82**	1.70	1.98	**1.84**
MABC-WR-SA-1	2.38	2.53	**2.46**	2.51	2.76	**2.63**	1.55	1.81	**1.68**
MABC-WR-SA-2	2.45	2.58	**2.52**	2.60	2.84	**2.72**	1.65	1.90	**1.78**
JG-14	2.42	2.57	**2.50**	2.58	2.80	**2.69**	1.60	1.86	**1.73**
JAKI-9218	2.48	2.62	**2.55**	2.61	2.88	**2.75**	1.68	1.93	**1.80**
DIBG-204	2.49	2.66	**2.58**	2.65	2.91	**2.78**	1.69	1.95	**1.82**
RVSSG-52	2.30	2.46	**2.38**	2.43	2.72	**2.57**	1.46	1.78	**1.62**
Mean	**2.47**	**2.63**		**2.63**	**2.87**		**1.64**	**1.91**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.0188	0.0809	0.032	0.138	0.019	0.082
Genotypes(G)	0.0167	0.0337	0.003	0.007	0.003	0.006
IXG	0.0237	0.0477	0.005	0.010	0.004	0.009

Among the genotypes, significantly higher total chlorophyll content was noticed in RKD-1 at 35, 55 and 75 DAS (2.73, 2.96 and 1.92mg g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by total chlorophyll content of JG-11(2.69, 2.91 and 1.88 mg g^{-1} fresh wt). Significantly lower total chlorophyll content was recorded in RVSSG-52 at all the stages of plant growth (2.38, 2.57 and 1.62 mg g^{-1} fresh wt. at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher total chlorophyll content of chickpea was recorded in the irrigated conditions with RKD-1 (2.82, 3.08 and 2.07mg g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower total chlorophyll content was observed in non irrigated condition with RVSSG-52 genotype (cc) at all the growth stages.

4.5.4 Proline content (µ mole g^{-1} fresh wt.)

The data pertaining to proline content (µ mole g^{-1} fresh wt.) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition are presented in Table.20

All chickpea genotypes grown under irrigated conditions (non-stress) observed significantly lower proline content (0.72, 1.21 and 1.99 µ mole $g^{-}1$ fresh wt. at 35, 55 and 75 DAS, respectively as compared to the chickpea genotypes grown under stress condition (1.57, 3.83 and 7.46 µ mole g^{-1} fresh wt. respectively at 35, 55 and 75).

Among the genotypes, significantly higher proline content was noticed in RKD-1 at 35, 55 and 75 DAS at harvest (1.46, 3.06 and 5.53µ mole g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by proline content of JG-11(1.26, 2.71 and 5.12 µ mole g^{-1} fresh wt.). Significantly lower proline content was recorded in RVSSG-52 at all the stages of plant growth (0.91, 2.22 and 4.08 µ mole g^{-1} fresh wt. at 35, 55 and 75, respectively).

The interaction effects between irrigation and genotypes were found significant. Significantly higher proline content of chickpea was recorded in the non irrigated conditions with RKD-1 (2.01, 4.64 and 8.64 µ mole g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower proline

Table 20. Proline content (µmole g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days after sowing								
	35			55			75		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	1.35	0.63	**0.99**	3.59	1.07	**2.33**	6.70	1.79	**4.24**
JG-11	1.87	0.85	**1.36**	4.09	1.33	**2.71**	8.05	2.19	**5.12**
BGD-103	1.68	0.84	**1.26**	3.91	1.25	**2.58**	8.03	2.15	**5.09**
GBM-2	1.41	0.68	**1.04**	3.70	1.16	**2.43**	6.90	1.90	**4.40**
RKD-1	2.01	0.91	**1.46**	4.64	1.47	**3.06**	8.66	2.40	**5.53**
RKD-4	1.65	0.75	**1.20**	3.88	1.23	**2.55**	7.75	2.09	**4.92**
MABC-WR-SA-1	1.40	0.66	**1.03**	3.62	1.14	**2.38**	6.83	1.83	**4.33**
MABC-WR-SA-2	1.54	0.70	**1.12**	3.77	1.20	**2.48**	7.64	1.93	**4.79**
JG-14	1.48	0.69	**1.08**	3.72	1.17	**2.44**	7.14	1.91	**4.53**
JAKI-9218	1.59	0.71	**1.15**	3.81	1.21	**2.51**	7.65	1.95	**4.80**
DIBG-204	1.60	0.73	**1.16**	3.86	1.22	**2.54**	7.73	1.99	**4.86**
RVSSG-52	1.25	0.58	**0.91**	3.46	0.99	**2.22**	6.46	1.71	**4.08**
Mean	**1.57**	**0.72**		**3.83**	**1.21**		**7.46**	**1.99**	

For comparing means of	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
Irrigation(I)	0.018	0.078	0.049	0.210	0.099	0.425
Genotypes(G)	0.003	0.006	0.005	0.011	0.011	0.022
IXG	0.004	0.009	0.007	0.015	0.015	0.031

content was observed in irrigated condition with RVSSG-52 genotype (0.58, 0.99 and 1.71 µ mole g^{-1} fresh wt.) at all the growth stages.

4.6 Phenology

4.6.1 Days to 50% flowering

The data pertaining to days to 50% floweringof chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.21

All chickpea genotypes grown under irrigated conditions (non-stress) noticed significantly higher days to 50% flowering (50.34) as compared to the chickpea genotypes grown under stress condition (47.48).

Among the genotypes, significantly lower days to 50% flowering were noticed in MABC-WR-SA-2 (44.17) when compared to rest of genotypes. But it was followed by JAKI-9218(44.18). Significantly higher days to 50% flowering were recorded in RVSSG-52 (57.02).

The interaction effects between irrigation and genotypes were found significant. Significantly higher days to 50% flowering of chickpea were recorded in the irrigated conditions with RVSSG-52 (58.55), when compared to the rest of the treatments combinations. Significantly lower days to 50% floweringwere observed in non irrigated condition with JAKI-9218 genotype (43.03).

4.6.2 Days to pod initiation

The data pertaining to days to pod initiation of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.21

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher days to pod initiation (67.27) as compared to the chickpea genotypes grown under stress condition (62.28).

Among the genotypes, significantly lower days to pod initiation were noticed in JG-14 (60.3) when compared to rest of genotypes. But it was followed by MABC-WR-SA-2(61.82). Significantly higher days to pod initiation were recorded in GBM-2 (69.42).

Table 21. Days to phenology of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Days to 50% flowering			Days to pod initiation			Days to maturity		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	46.75	49.47	**48.11**	61.61	67.10	**64.36**	101.2	105.71	**103.4**
JG-11	47.71	49.97	**48.84**	63.63	69.13	**66.38**	98.2	101.00	**99.6**
BGD-103	46.32	49.30	**47.81**	62.62	68.12	**65.37**	99.0	102.68	**100.8**
GBM-2	55.14	57.53	**56.33**	67.67	71.17	**69.42**	106.2	112.05	**109.1**
RKD-1	46.05	49.36	**47.71**	61.61	66.08	**63.85**	99.2	102.00	**100.6**
RKD-4	47.08	50.28	**48.68**	63.63	69.13	**66.38**	101.6	104.03	**102.8**
MABC-WR-SA-1	43.07	46.46	**44.77**	58.75	65.25	**62.11**	101.2	105.05	**103.1**
MABC-WR-SA-2	43.07	45.26	**44.17**	58.58	65.07	**61.82**	96.1	99.99	**98.1**
JG-14	49.99	52.97	**51.48**	57.57	63.03	**60.30**	106.0	109.80	**107.9**
JAKI-9218	43.03	45.33	**44.18**	65.65	69.13	**67.39**	102.2	106.05	**104.1**
DIBG-204	46.08	49.65	**47.86**	61.61	66.08	**63.85**	100.2	103.03	**101.6**
RVSSG-52	55.48	58.55	**57.02**	64.64	68.12	**66.38**	99.3	102.10	**100.7**
Mean	**47.48**	**50.34**		**62.28**	**67.27**		**100.5**	**103.96**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.11	0.46	0.51	2.19	0.12	0.51
Genotypes(G)	0.21	0.43	0.05	0.10	0.26	0.52
IXG	0.30	0.61	0.07	0.14	0.36	0.73

The interaction effects between irrigation and genotypes were found significant. Significantly higher days to pod initiation of chickpea were recorded in the irrigated conditions with GBM-2 (71.17), when compared to the rest of the treatments combinations. Significantly lower days to pod initiation were observed in non irrigated condition with JG-14 genotype (57.5).

4.6.3 Days to maturity

The data pertaining to days to maturity of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.21

All chickpea genotypes grown under irrigated conditions (non-stress) recorded significantly higher days to maturity (103.96) as compared to the chickpea genotypes grown under stress condition (100.5).

Among the genotypes, significantly lower days to maturity were noticed in MABC-WR-SA-2 (98.1) when compared to rest of genotypes. But it was followed by JG-11(99.6). Significantly higher days to maturity were recorded in GBM-2 (109.4).

The interaction effects between irrigation and genotypes were found significant. Significantly higher days to maturity of chickpea were recorded in the irrigated conditions with GBM-2 (109.2), when compared to the rest of the treatments combinations. Significantly lower days to maturity were observed in non irrigated condition with MABC-WR-SA-2genotype (96.1).

4.7. Yield and yield attributes (kg ha^{-1})

4.7.1 Number of pods per plant

The data pertaining to number of pods per plant of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.22 a

All chickpea genotypes grown under irrigated conditions (non-stress) observed significantly higher number of pods per plant (52.13) as compared to the chickpea genotypes grown under stress condition (33.41).

Table 22 a. Yield attributes of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Number of pods plant^{-1}			100 seed weight		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	30.48	49.19	**39.83**	18.12	20.25	**19.19**
JG-11	37.36	56.23	**46.80**	21.84	23.75	**22.79**
BGD-103	36.29	54.95	**45.62**	23.51	30.85	**27.18**
GBM-2	32.24	50.56	**41.40**	20.33	22.88	**21.61**
RKD-1	37.83	60.00	**48.92**	33.16	36.11	**34.63**
RKD-4	34.46	53.91	**44.19**	31.05	33.53	**32.29**
MABC-WR-SA-1	31.42	49.53	**40.48**	19.83	22.27	**21.05**
MABC-WR-SA-2	31.42	49.53	**40.48**	16.23	19.20	**17.71**
JG-14	32.70	51.65	**42.18**	25.78	28.80	**27.29**
JAKI-9218	32.51	51.37	**41.94**	24.14	26.47	**25.31**
DIBG-204	34.26	52.30	**43.28**	30.55	32.33	**31.44**
RVSSG-52	29.94	46.30	**38.12**	26.34	28.80	**27.57**
Mean	**33.41**	**52.13**		**24.24**	**27.10**	

For comparing means of	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
Irrigation(I)	0.245	1.052	0.36	1.56
Genotypes(G)	0.051	0.103	0.10	0.20
IXG	0.072	0.145	0.14	0.29

Among the genotypes, significantly higher number of pods per plant was noticed in RKD-1 (48.92) when compared to rest of genotypes. But it was followed by number of pods per plant of JG-11(46.80). Significantly lower number of pods per plant was recorded in RVSSG-52 (38.12).

The interaction effects between irrigation and genotypes were found significant. Significantly higher number of pods per plant of chickpea was recorded in the irrigated conditions with RKD-1 (60.00), when compared to the rest of the treatments combinations. Significantly lower days to maturity were observed in non irrigated condition with RVSSG-52 genotype (29.94).

4.7.2 Test weight (grams)

The data pertaining to test weight (g) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.22 a

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher number of pods per plant (27.1 g) as compared to the chickpea genotypes grown under stress condition (24.2 g).

Among the genotypes, significantly higher test weight was noticed in RKD-1 (34.63 g) when compared to rest of genotypes. But it was followed by test weight of RKD-4(32.29 g). Significantly lower test weight was recorded in MABC-WR-SA-2 (17.71 g).

The interaction effects between irrigation and genotypes were found significant. Significantly higher test weight of chickpea was recorded in the irrigated conditions with RKD-1 (36.11 g), when compared to the rest of the treatments combinations. Significantly lower test weight was observed in non irrigated condition with MABC-WR-SA-2 genotype (16.23 g).

4.7.3 Harvest index (%)

The data pertaining to harvest index (%) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.22

Table 22 a. Yield attributes of chickpea genotypes as influenced by non irrigated and irrigated condition

Genotype	Number of pods plant^{-1}			100 seed weight		
	Non Irrigated	Irrigated	Mean	Non Irrigated	Irrigated	Mean
A-1	30.48	49.19	**39.83**	18.12	20.25	**19.19**
JG-11	37.36	56.23	**46.80**	21.84	23.75	**22.79**
BGD-103	36.29	54.95	**45.62**	23.51	30.85	**27.18**
GBM-2	32.24	50.56	**41.40**	20.33	22.88	**21.61**
RKD-1	37.83	60.00	**48.92**	33.16	36.11	**34.63**
RKD-4	34.46	53.91	**44.19**	31.05	33.53	**32.29**
MABC-WR-SA-1	31.42	49.53	**40.48**	19.83	22.27	**21.05**
MABC-WR-SA-2	31.42	49.53	**40.48**	16.23	19.20	**17.71**
JG-14	32.70	51.65	**42.18**	25.78	28.80	**27.29**
JAKI-9218	32.51	51.37	**41.94**	24.14	26.47	**25.31**
DIBG-204	34.26	52.30	**43.28**	30.55	32.33	**31.44**
RVSSG-52	29.94	46.30	**38.12**	26.34	28.80	**27.57**
Mean	**33.41**	**52.13**		**24.24**	**27.10**	
For comparing means of	**S.Em±**	**CD at 5%**		**S.Em±**	**CD at 5%**	
Irrigation(I)	0.245	1.052		0.36	1.56	
Genotypes(G)	0.051	0.103		0.10	0.20	
IXG	0.072	0.145		0.14	0.29	

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher harvest index (39.43%) as compared to the chickpea genotypes grown under stress condition (37.51%).

Among the genotypes, significantly higher harvest indexwas noticed in RKD-1 (43.34%) when compared to rest of genotypes. But it was followed by seed yield and harvest index of JG-11(41.32%). Significantly lower harvest index was recorded in RVSSG-52 (35.59%).

The interaction effects between irrigation and genotypes were found significant. Significantly higher harvest index of chickpea was recorded in the irrigated conditions with RKD-1 (44.47%), when compared to the rest of the treatments combinations. Significantly lower harvest index was observed in non irrigated condition with RVSSG-52 genotype (34.55%).

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

The data pertaining to seed yield (kg ha^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.22b

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher seed yield (2055 kgha^{-1}) as compared to the chickpea genotypes grown under stress condition (1660 kg ha^{-1}).

Among the genotypes, significantly higher seed yield was noticed in RKD-1 (1991kg ha^{-1}) when compared to rest of genotypes. But it was followed by seed yield of JG-11(1954 kg ha^{-1}). Significantly lower seed yield was recorded in RVSSG-52(1726 kgha^{-1}).

The interaction effects between irrigation and genotypes were found significant. Significantly higher seed yield of chickpea was recorded in the irrigated conditions with RKD-1 (2213 kg ha^{-1}), when compared to the rest of the treatments combinations. Significantly lower seed yield was observed in non irrigated condition with RVSSG-52 genotype (1528 kg ha^{-1}).

4.7.5 Straw yield (kg ha^{-1})

The data pertaining to straw yield (kg ha^{-1}) of chickpea at different stages as influenced by non irrigated (moisture stress) and irrigated condition presented in Table.22b

All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher straw yield (5396 kg ha^{-1}) as compared to the chickpea genotypes grown under stress condition (4446 kg ha^{-1}).

Among the genotypes, significantly higher straw yield and was noticed in JG-14 (5081 kg ha^{-1}) when compared to rest of genotypes. But it was followed by straw yield of GBM-2(5054 kg ha^{-1}). Significantly lower straw yield was recorded in RKD-4 (4700 $kgha^{-1}$).

The interaction effects between irrigation and genotypes were found significant. Significantly higher straw yield of chickpea was recorded in the irrigated conditions with JG-14 (5577 kg ha^{-1}), when compared to the rest of the treatments combinations. Significantly lower straw yield was observed in non irrigated condition with RKD-4genotype (4312 kg ha^{-1}).

4.8 Results of root characterization studies

4.8.1 Root length (cm) and root weight (g)

The data pertaining to root length (cm) and root weight (g) indicated significant difference at 45 days after sowing (DAS) of chickpea (Table 23) as influenced by non irrigated (moisture stress) condition.

Among genotypes, RKD-1 shows significantly higher Root length (cm) and root weight (g) (101.2 cm and 2.28 gm**)** followed by JG-11(98.70cm and 2.09 g) over all other genotypes. RVSSG-52 genotype recorded significantly lower Root length (cm) and root weight (g) (83.10 cm and 1.28 gm**)** at 45 days after harvesting, respectively.

Table 23. Root characterization of chickpea genotypes under non irrigated condition

Genotype	Root characteristics			
	Root length (cm)	Root weight (g)	Shoot length (cm)	Root to shoot ratio
A-1	90.00	1.29	29.80	3.02
JG-11	98.70	2.09	27.34	3.61
BGD-103	98.30	2.06	27.69	3.55
GBM-2	93.00	1.68	29.81	3.12
RKD-1	101.02	2.28	27.45	3.68
RKD-4	97.00	1.98	28.45	3.41
MABC-WR-SA-1	92.50	1.66	30.33	3.05
MABC-WR-SA-2	93.70	1.85	28.83	3.25
JG-14	93.20	1.81	29.31	3.18
JAKI-9218	95.50	1.88	29.03	3.29
DIBG-204	96.30	1.97	28.58	3.37
RVSSG-52	83.10	1.28	28.07	2.96
Mean	**94.36**	**1.82**	**28.72**	**3.29**
S.Em±	1.23	0.11	0.20	0.08
CD at 5%	4.12	0.33	0.53	0.24

DISCUSSION

V. DISCUSSION

Results of the field experiment entitled "Screening of chickpea (*cicer arietinum* L.) lines for drought tolerance" was conducted during *rabi* season of 2017-18 at Agricultural Research Station Kalaburgi, are discussed in this chapter justifying the variations among parameters with scientific reasoning and logic and in comparison with the results of research carried out by the past research workers elsewhere in the field of irrigation and genotypes in agriculture.

5.1 Weather and crop growth

Crop growth is mainly dependent on environmental factors, soil and climate, the associated crops and the management. In general, the soil characteristics and weather conditions (Mwale *et al.,* 2007) greatly influence the growth and development and yield potential of crops. In particular, the research station where the present investigation was carried out falls in Northern Dry Zone of Karnataka is characterized as dry climate with uncertain and erratic rainfall. The rain received during third week of October helped for preparation of seedbed. Sowing of crop was taken up on 7th Nov, 2017. The germination and establishment was good due to irrigation provided after sowing. The treatments under non stress condition did not experience moisture stress as they were supplemented with irrigation during dry spells for irrigated main plot but the non-irrigated main plots (stress) were not supplemented with irrigation hence the treatments suffer moisture stress. The crop was free from major pest and diseases as necessary plant protection measures were taken. The temperature and relative humidity were near normal during the growing period. During crop growth period Mean monthly maximum temperature ranged from 33.2 °C (February) to 30.63 °C (January) while, the mean minimum temperature ranged from 12.31 °C (January) to 15.30 °C (February). Mean monthly maximum relative humidity ranged from 67.25 % (January) to 60.18 % (December) while, the mean minimum relative humidity ranged from 13.42 % (November) to 14.48% (December) (Table 1).

5.2 Morphological characteristics as influenced by non irrigated and irrigated condition

In the present study plant height (cm) (Fig. 3) and number of branches per plant of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher plant height and number of branches per plant was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (29.91, 54.49, 71.26 and 73.4 cm) and (6.58, 11.15, 12.21 and 12.58) when compared to rest of genotypes. The plant height and number of branches per plant was followed by JG-11. Significantly lower plant height and number of branches per plant was recorded in RVSSG-52 at all the stages of plant growth (22.70, 41.26, 53.53 and 55.64 cm) and (4.38, 6.01, 9.29 and 9.50) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher plant height (cm) and number of branches per plant of chickpea was recorded in the irrigated conditions with RKD-1 (32.03, 56.13, 76.56 and 78.51 cm) and (6.97, 12.14, 13.76 and 14.07) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower plant height (cm) and number of branches per plant was observed in non irrigated condition with RVSSG-52 genotype (21.60, 40.27, 52.10 and 54.27 cm) and (4.09, 5.76, 8.03 and 8.20) at all the growth stages. These results are in continuity with the findings of Ulemale *et al* (2013) in chickpea where drought conditions resulted in decreased plant height. Ghiabi *et al* (2013) postulated that drought decreases the cell expansion properties which ultimately lead to lower plant height. Slower cell division and inhibition of growth occurs as a result of reduced cyclin dependent kinase activity under drought conditions as reported in wheat (Schuppler *et al* 1998). Number of primary and secondary branches also had significant and positive association with seed yield. So these were the most important characters contributing to seed yield (Joshi *et al*., 1992; Ramani *et al*., 1995; Yadave & Singh., 1996). Tripathi *et al.* (1995) noted significantly positive association of yield per plant with the number of primary branches and pods per plant.

5.3 Growth parameters as influenced by non irrigated and irrigated condition

5.3.1 Absolute growth rate (g day^{-1})

In the present study absolute growth rate (g day^{-1}) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher absolute

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

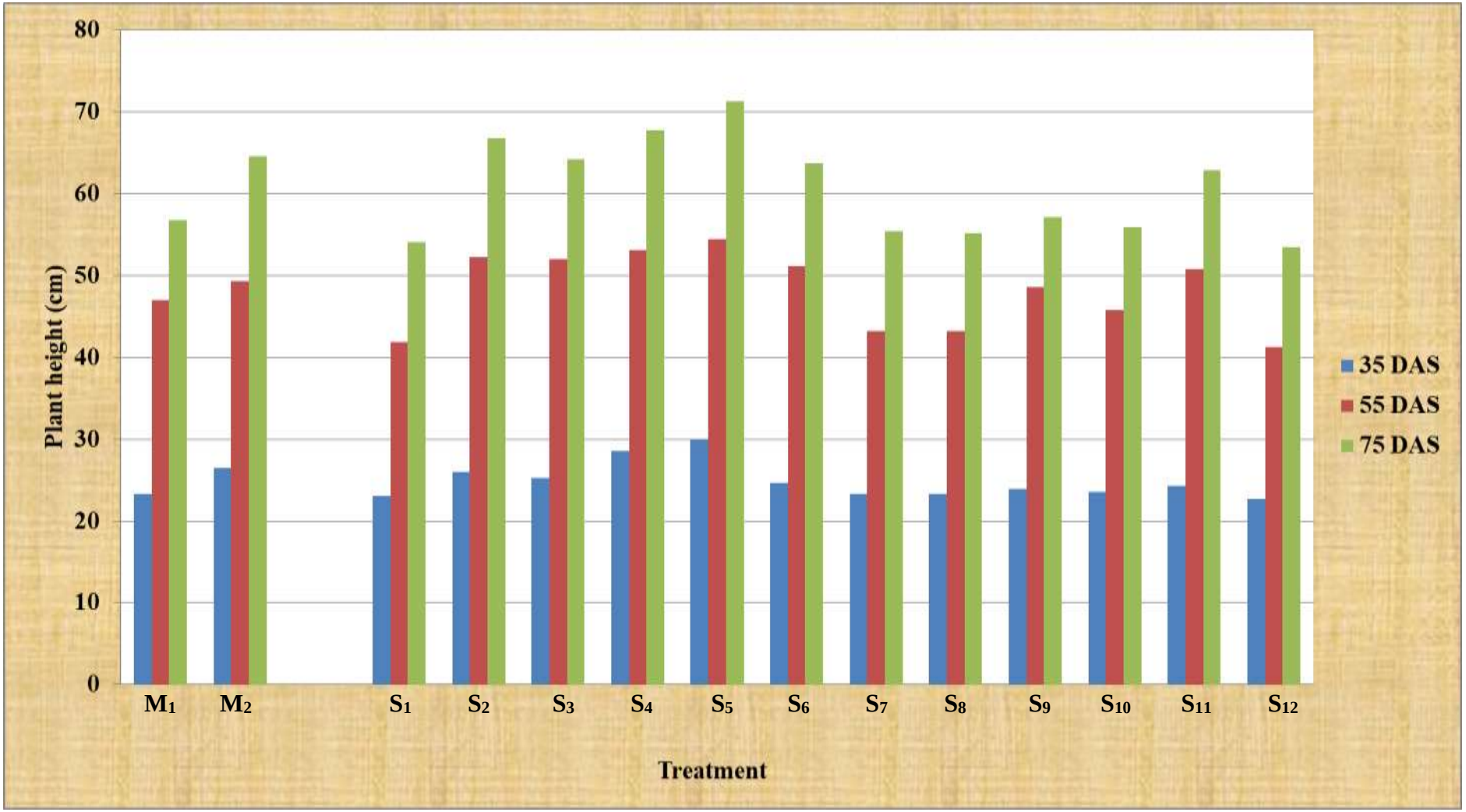

Fig. 3. Plant height (cm) of chickpea genotypes as influenced by non irrigated and irrigated condition

growth rate was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.36, 1.42 and 0.68 g day^{-1}) when compared to rest of genotypes, it was followed by absolute growth rate of JG-11. Significantly lower absolute growth rate was recorded in RVSSG-52 at all the stages of plant growth (0.19, 1.05 and 0.36 g day^{-1}) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher absolute growth rate of chickpea was recorded in the irrigated conditions with RKD-1 (0.58, 1.80, 1.20 g day^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower absolute growth rate was observed in non irrigated condition with RVSSG-52 genotype (0.09, 0.86 and 0.18 g day^{-1}) at all the growth stages. The results are in continuity with the findings of Damatta, (2004) the lower supply of water provided to the plants under water deficit, possibly resulted in a reduction in the photosynthetic rate, resulting in less absolute growth.

5.3.2 Crop growth rate (g dm^{-2} day^{-1})

In the present study crop growth rate (g dm^{-2} day^{-1}) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher crop growth rate was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.12, 0.47 and 0.23 g dm^{-2} day^{-1}) when compared to rest of genotypes, it was followed by crop growth rate of JG-11. Significantly lower crop growth rate was recorded in RVSSG-52 at all the stages of plant growth (0.06, 0.35 and 0.12 g dm^{-2} day^{-1}) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher crop growth rate of chickpea was recorded in the irrigated conditions with RKD-1 (0.19, 0.60 and 0.40 g dm^{-2} day^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower crop growth rate was observed in non irrigated condition with RVSSG-52 genotype (0.03, .29 and 0.06 g dm^{-2} day^{-1}) at all the growth stages. Similar to the findings of Akram (2011) observed that moisture stress at different crop growth stages affected CGR differently. Fully irrigated crops indicated significantly greater CGR than other crops throughout the season.

5.3.3 Leaf area (dm^2 plant^{-1}) (LA)

In the present study leaf area (dm^2 plant^{-1}) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher leaf area was noticed in

RKD-1 at 35, 55, 75 DAS and at harvest (2.03, 3.78, 7.40 and 4.01 dm^2 $plant^{-1}$) when compared to rest of genotypes, it was followed by leaf area of JG-11. Significantly lower leaf area was recorded in RVSSG-52 at all the stages of plant growth (1.27, 2.57, 5.13 and 2.77 dm^2 $plant^{-1}$) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher leaf area of chickpea was recorded in the irrigated conditions with RKD-1 (2.39, 4.61, 9.12 and 4.85 dm^2 $plant^{-1}$) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower leaf area was observed in non irrigated condition with RVSSG-52 genotype (1.02, 1.99, 4.06 and 2.21 dm^2 $plant^{-1}$) at all the growth stages. These results are in continuity with the findings of Rucker *et al* (1995) wherein number of leaves and the size of individual leaf are also reduced under the drought conditions. The expansion of the leaf normally depends upon the turgor pressure and the supply of assimilates. Reduced turgor pressure and slow rate of photosynthesis under drought conditions mainly limit the leaf expansion. One of the first responses of the plants to water deficit is a reduction in leaf area, producing smaller leaves, or even reducing the emission of new leaves (Damatta, 2004).

5.3.4 Leaf area index (LAI)

In the present study leaf area index of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher leaf area index was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (0.68, 1.26, 2.47 and 1.34) when compared to rest of genotypes, it was followed by leaf area index of JG-11. Significantly lower leaf area index was recorded in RVSSG-52 at all the stages of plant growth (0.43, 0.86, 1.71 and 1.11) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher leaf area index of chickpea was recorded in the irrigated conditions with RKD-1 (0.80, 1.54, 3.04 and 1.62) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower leaf area index was observed in non irrigated condition with RVSSG-52 genotype (0.34, 0.66, 1.35 and 0.74) at all the growth stages. Similar results were also observed in Souza *et al* (2016). The larger leaf area with the larger number of leaves at 100% irrigation, favored the greater leaf area index.

5.4 Dry matter accumulation and its partitioning as influenced by non irrigated and irrigated condition

5.4.1 Total dry matter accumulation (g plant^{-1})

In the present study total dry matter accumulation (g plant^{-1}) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher total dry matter accumulation (g plant^{-1}) was noticed in RKD-1 at 35, 55, 75 DAS and at harvest (12.67, 19.10, 48.33 and 61.55 g plant^{-1}) when compared to rest of genotypes, it was followed by total dry matter accumulation (g plant^{-1}) of JG-11. Significantly lower total dry matter accumulation (g plant^{-1}) was recorded in RVSSG-52 at all the stages of plant growth (9.13, 12.87, 33.88 and 41.09 g plant^{-1}) at 35, 55, 75 and at harvest, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher total dry matter accumulation (g plant^{-1}) of chickpea was recorded in the irrigated conditions with RKD-1 (13.99, 20.87 and 69.37 g plant^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower total dry matter accumulation (g plant^{-1}) was observed in non irrigated condition with RVSSG-52 genotype (8.09, 11.71 and 38.40 g plant^{-1}) at all the growth stages (Fig. 4). Similar results were also observed by Thomas *et al* (2004), Ashraf and Iram (2005) who stated that shoot dry weight of two leguminous plants, *Phaseolus vulgaris* and *Sesbania aculeate* decreased significantly due to water deficit. Under water stress conditions, decrease in plant height alludes to decline in biomass (Labidi *et al* 2009) which is positively notified to studies of Ulemale *et al* (2013) wherein biomass accumulation declined with the water reduction. According to Schuppler *et al* (1998) reduction in vegetative growth of chickpea plants under drought in particular biomass accumulation is due to slower cell division and inhibition of growth.

5.5 Bio physical parameters as influenced by non irrigated and irrigated condition

5.5.1 Membrane injury index (MII) (%)

In the present study membrane injury index (%) of chickpea differed significantly due to stress condition. Among the genotypes, significantly lower membrane injury index was noticed in RKD-1 at 35, 55 and 75 DAS (15.37, 24.35 and 31.73 %) when compared to rest of genotypes, it was followed by membrane injury index of JG-11. Significantly higher membrane injury index was recorded in RVSSG-52 at all the stages of plant

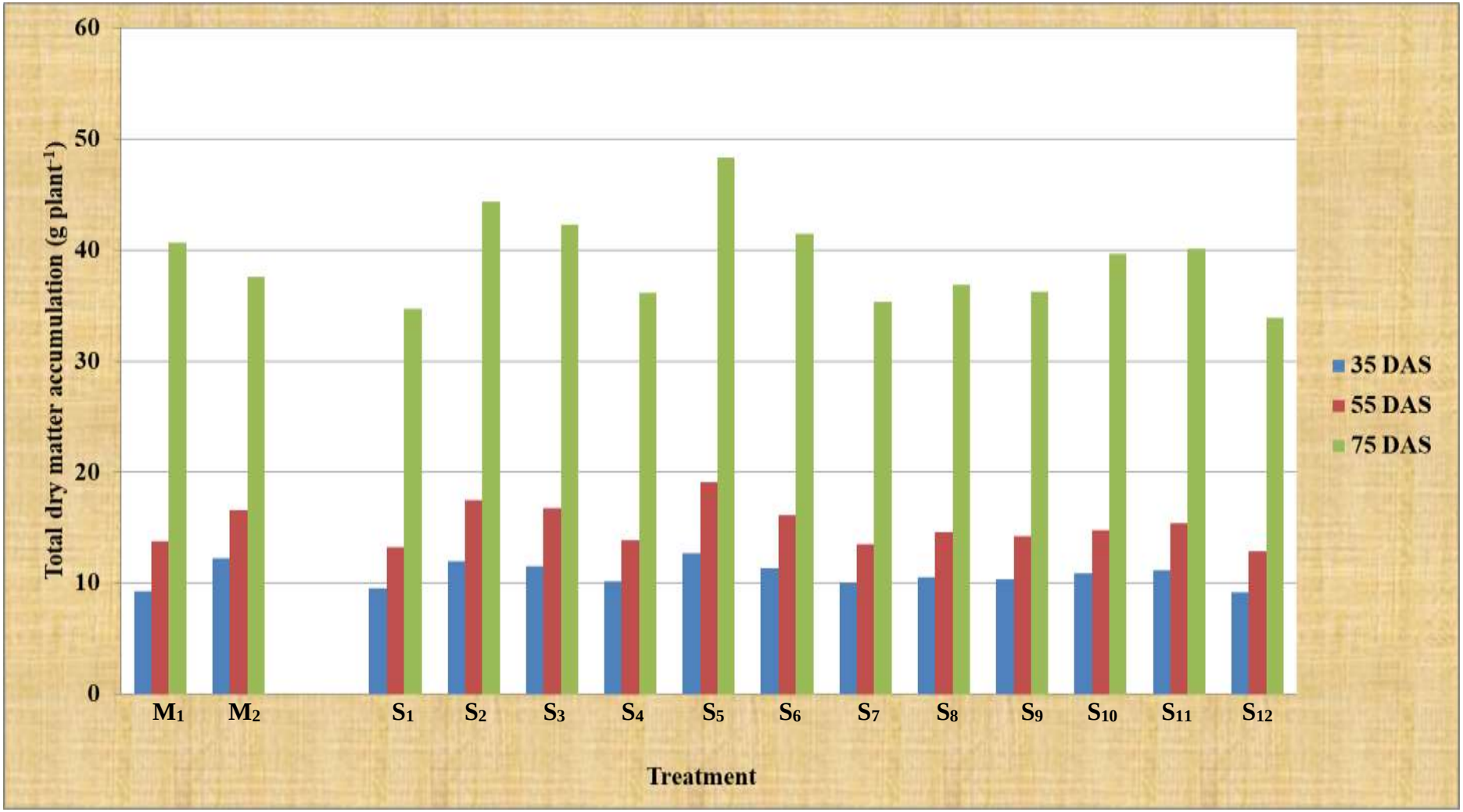

Fig. 4. Total dry matter accumulation (g plant^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

growth (23.92, 33.32 and 43.35 %) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly lower membrane injury index of chickpea was recorded in the irrigated conditions with RKD-1 (11.99, 18.57 and 24.35 %) at all the growth stages when compared to the rest of the treatments combinations. Significantly higher membrane injury index was observed in non irrigated condition with RVSSG-52 genotype (29.25, 42.79 and 53.39 %) at all the growth stages (Fig. 5). Studies showed that membrane stability index (MSI) was positively and significantly correlated with seed yield and biomass. The strong and linear relationship of membrane stability index with biological yield indicates the dependence of biomass production on the membrane stability index. The close association between membrane stability index (MSI) and biomass and seed yield has also been observed by Kushwaha *et al.* (2011)

5.5.2 Relative water content (RWC) (%)

In the present study relative leaf water content (%) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher relative leaf water content was noticed in RKD-1 at 35, 55 and 75 DAS (86.20, 82.07 and 75.72 %) when compared to rest of genotypes, it was followed by relative leaf water content of JG-11. Significantly lower relative water content was recorded in RVSSG-52 at all the stages of plant growth (74.87, 71.48 and 64.26 %) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher relative water content of chickpea was recorded in the irrigated conditions with RKD-1 (89.98, 87.06 and 79.76 %) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower relative water content was observed in non irrigated condition with RVSSG-52 genotype (71.34, 66.60 and 59.94 %) at all the growth stages (Fig. 6). Similar results were also replicated by Siddique *et al* (1999) and Bahadur (2008) reported that there is significant reduction in relative leaf water content of plant subjected to water shortage. Significant differences in relative water content in tolerant and sensitive genotypes of maize crop (Pastori and Trippi 1993) and wheat crop (Sairam and Srivastava 2001) have also been reported. High relative water content may result from osmoregulation by osmoprotectants, as ions or sugars are often accumulated in plants subjected to drought (Gunes *et al* 2008). Patel *et al* (2011) observed that high

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

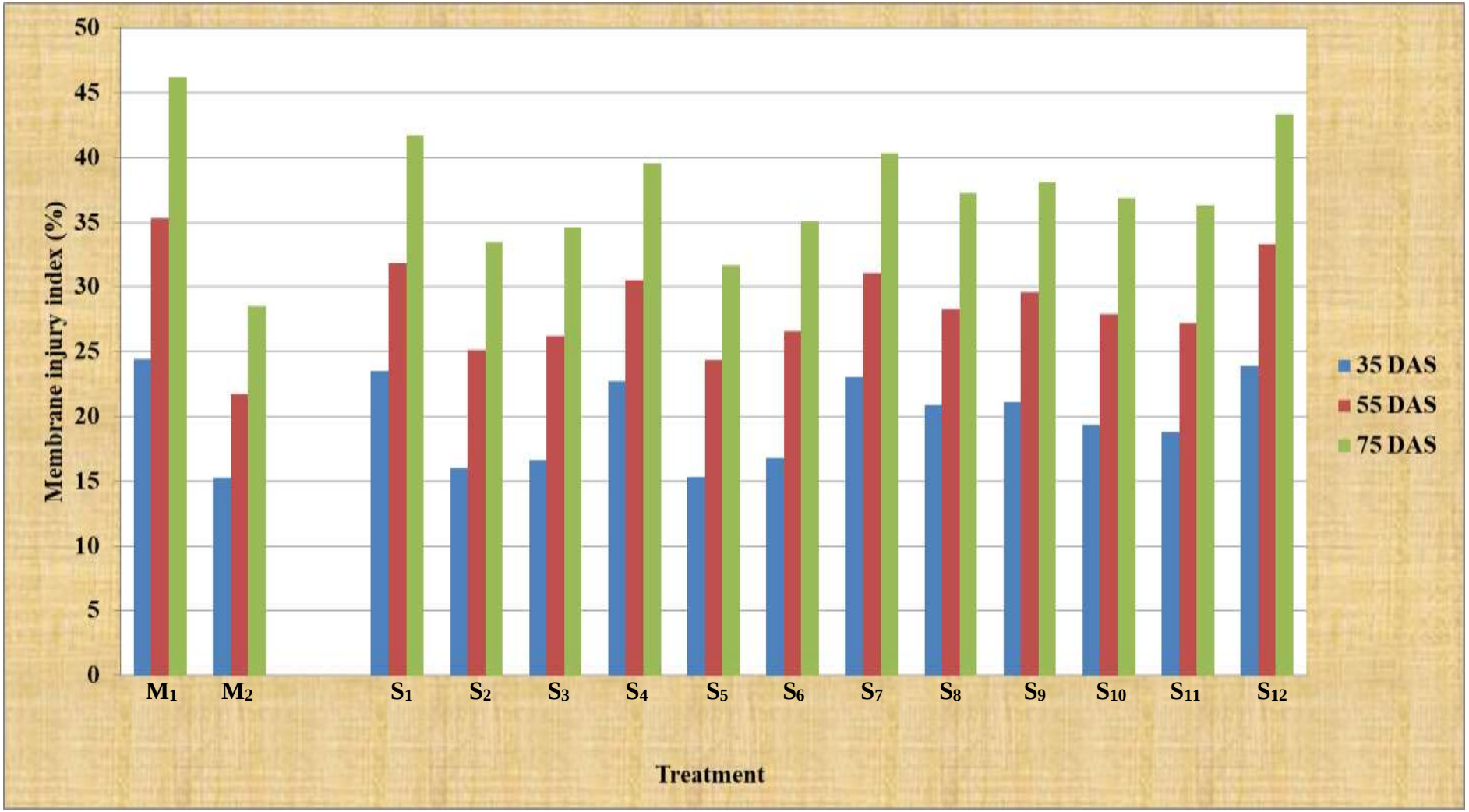

Fig. 5. Membrane injury index (%) of chickpea genotypes as influenced by non irrigated and irrigated condition

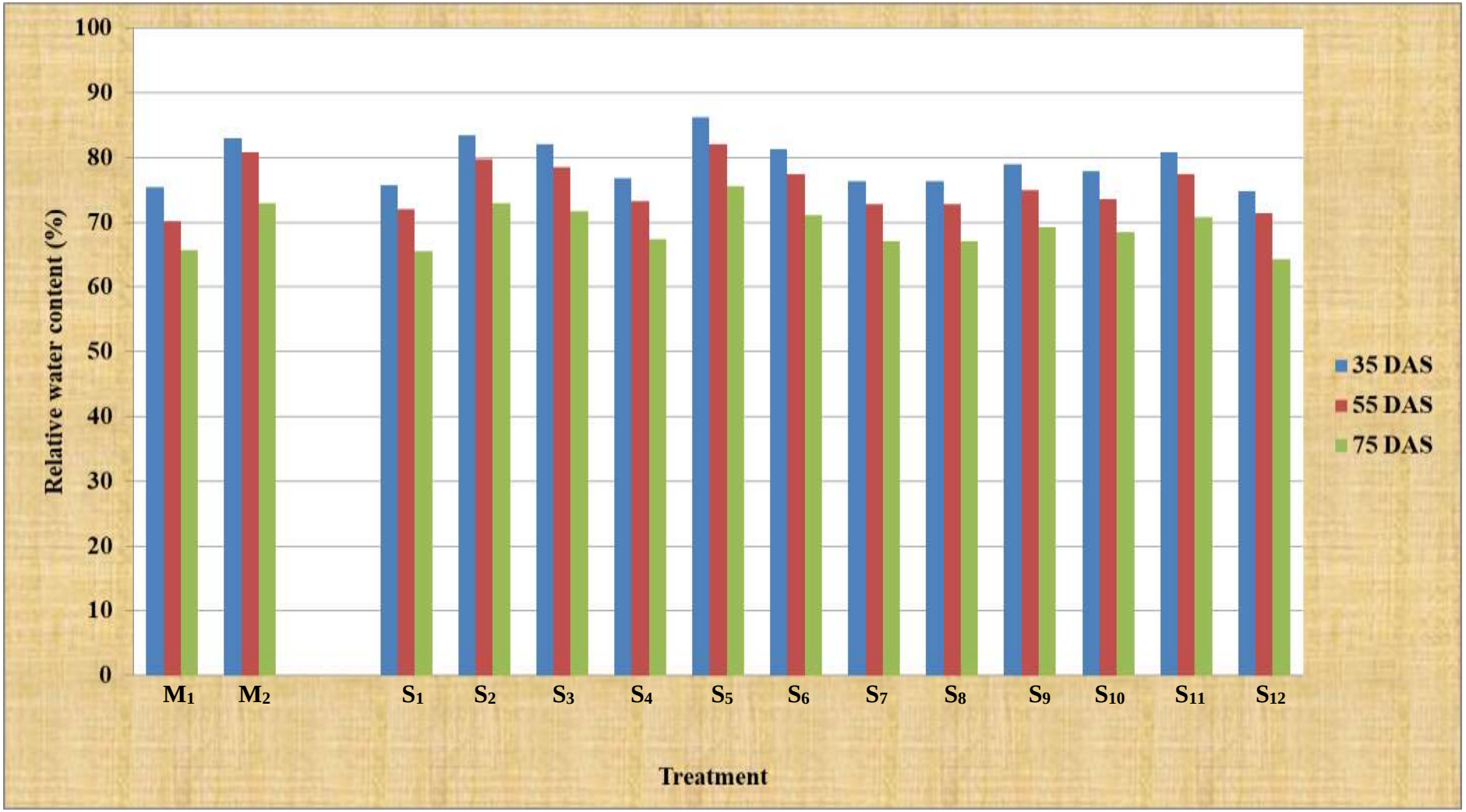

Fig. 6. Relative water content (%) of chickpea genotypes as influenced by non irrigated and irrigated condition

RWC could help the tolerant genotypes to perform physio-biochemical processes more efficiently under stress conditions than susceptible genotypes of chickpea.

5.5.3 Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})

In the present study photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher photosynthetic rate was noticed in RKD-1 at 35, 55 and 75 DAS (7.42, 11.6 and 20.44 µ mol CO_2 m^{-2} s^{-1}) when compared to rest of genotypes. But it was followed by photosynthetic rate of JG-11. Significantly lower photosynthetic rate was recorded in RVSSG-52 at all the stages of plant growth (5.62, 7.32 and 14.93 µ mol CO_2 m^{-2} s^{-1}) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher photosynthetic rate of chickpea was recorded in the irrigated conditions with RKD-1 (8.49, 13.09 and 22.95 µ mol CO_2 m^{-2} s^{-1}) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower photosynthetic rate was observed in non irrigated condition with RVSSG-52 genotype (4.66, 6.37 and 12.85 µ mol CO_2 m^{-2} s^{-1}) at all the growth stages (Fig. 7). These results are in line with the findings of Kumar *et al* (2010) who also observed the reduction in photosynthetic activity in different chickpea genotypes under water deficit condition. Flexas and Medrano (2002) concluded that decreased photosynthetic rate is due to the stomatal closure which resulted into CO_2 scarcity in the chloroplasts. But lawlor (2002) and Tang *et al* (2002) claimed that impaired ATP is a likely reason for decreased photosynthetic rate under water stress conditions. Later Basu *et al* (2004) also concluded that under moisture stress condition, limited photosynthesis occurs due to the stomatal closure.

5.5.4 Leaf water potential (ψ_w) (-MPa)

In the present study leaf water potential (-MPa) of chickpea differed significantly due to stress condition. Among the genotypes, significantly lower leaf water potentialwas noticed in RKD-1 at 35, 55 and 75 DAS (-0.81, -0.92 and -1.09 -MPa) when compared to rest of genotypes. But it was followed by leaf water potential of JG-11. Significantly higher leaf water potential was recorded in RVSSG-52 at all the stages of plant growth (-1.00, -1.13 and -1.35 -MPa) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly lower leaf water potential of

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

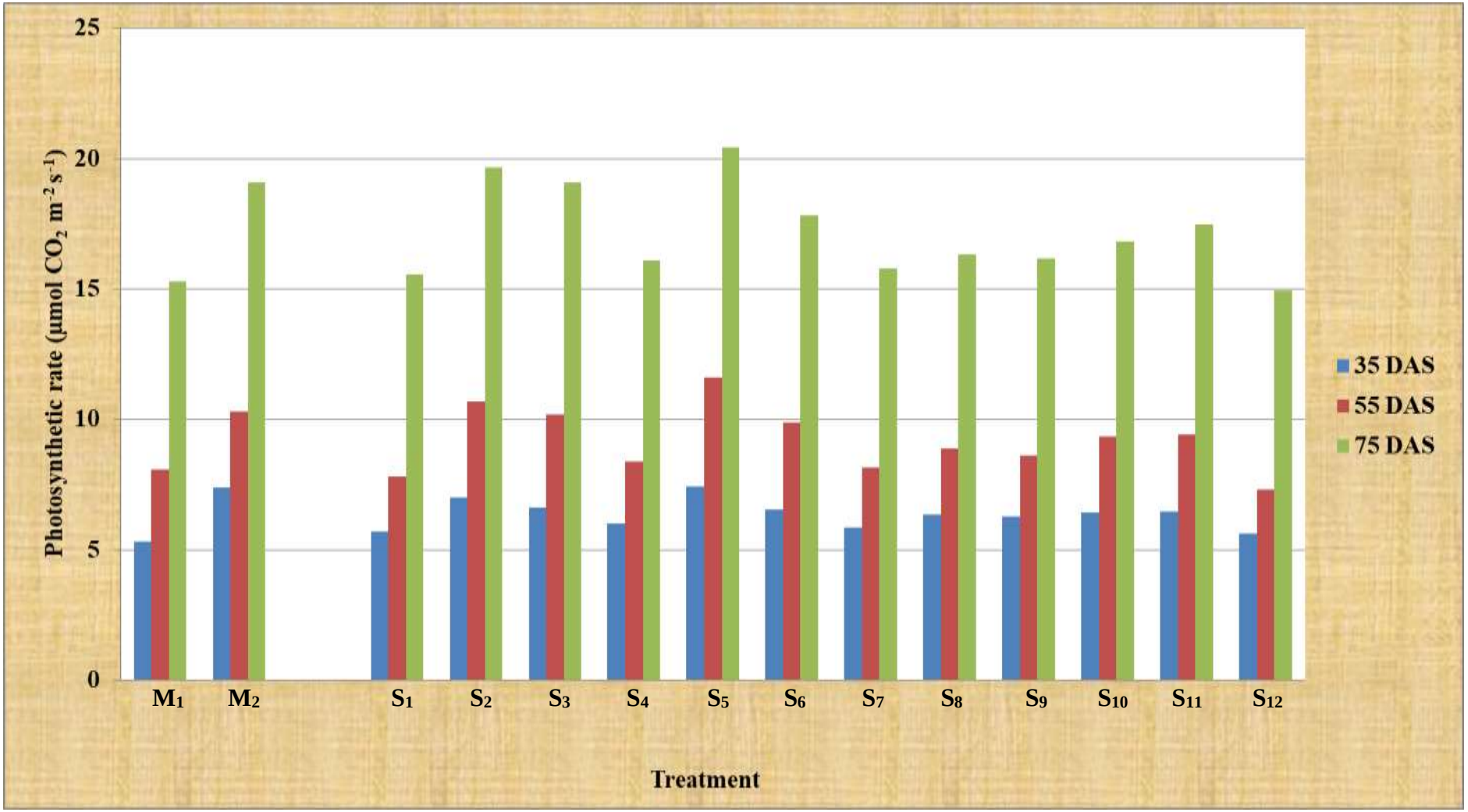

Fig. 7. Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}) of chickpea genotypes as influenced by non irrigated and irrigated condition

chickpea was recorded in the irrigated conditions with RKD-1 (-0.62, -0.71 and -0.93 -MPa) at all the growth stages when compared to the rest of the treatments combinations. Significantly higher leaf water potential was observed in non irrigated condition with RVSSG-52 genotype (-1.21, -1.38 and -1.57 MPa) at all the growth stages (Fig. 8). These results are in line with the findings of decrease in solute potential (ψ_s) and water potential (ψ_w) under stress conditions has been proposed to play an important role in turgor adjustment and survival of plants under dry conditions (Siddique *et al*., 2000; Sairam *et al*., 2000). Decline in ψs can be a result of either simple passive concentration of solute or net solute accumulation eg. amino acids like proline, betaine, total soluble sugars and ion accumulation (Scalabrelli *et al*., 2007).

5.6 Bio-chemical parameters as influenced by non irrigated and irrigated condition

5.6.1 Chlorophyll 'a' and 'b' content (mg g^{-1} fresh wt.)

In the present studychlorophyll a and b content (mg g^{-1} fresh wt.) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher chlorophyll a and b content was noticed in RKD-1 at 35, 55 and 75 DAS (2.05, 2.24 and 1.47 mg g^{-1} fresh wt.) and (0.68, 0.72 and 0.46 mg g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by chlorophyll a and b content of JG-11. Significantly lower chlorophyll a and b content was recorded in RVSSG-52 at all the stages of plant growth (1.79, 1.95 and 1.24 mg g^{-1} fresh wt.) and (0.59, 0.63 and 0.38 mg g^{-1} fresh wt.) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher chlorophyll a and b content of chickpea was recorded in the irrigated conditions with RKD-1 (2.12, 2.33 and 1.58mg g^{-1} fresh wt.) and (0.70, 0.75 and 0.49mg g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower chlorophyll a and b content was observed in non irrigated condition with RVSSG-52 genotype (1.73, 1.84 and 1.11 mg g^{-1} fresh wt.) and (0.57, 0.59 and 0.35 mg g^{-1} fresh wt.) at all the growth stages. Similar results were also replicated by Tehranifar *et al*. (2009) investigated the native and imported *Festuca arundinacea* and *Lolium perenne* and reported the reduction in chlorophyll a, b and total because of drought stress. In the plants under drought stress or other stresses, the water inside the cytosol decreased, so the osmotic pressure has to be increased to absorb water during drought stress period. A decrease in the chlorophyll a/b ratio was reported in Brassica species under drought conditions (Ashraf and Mehmood, 1990)

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

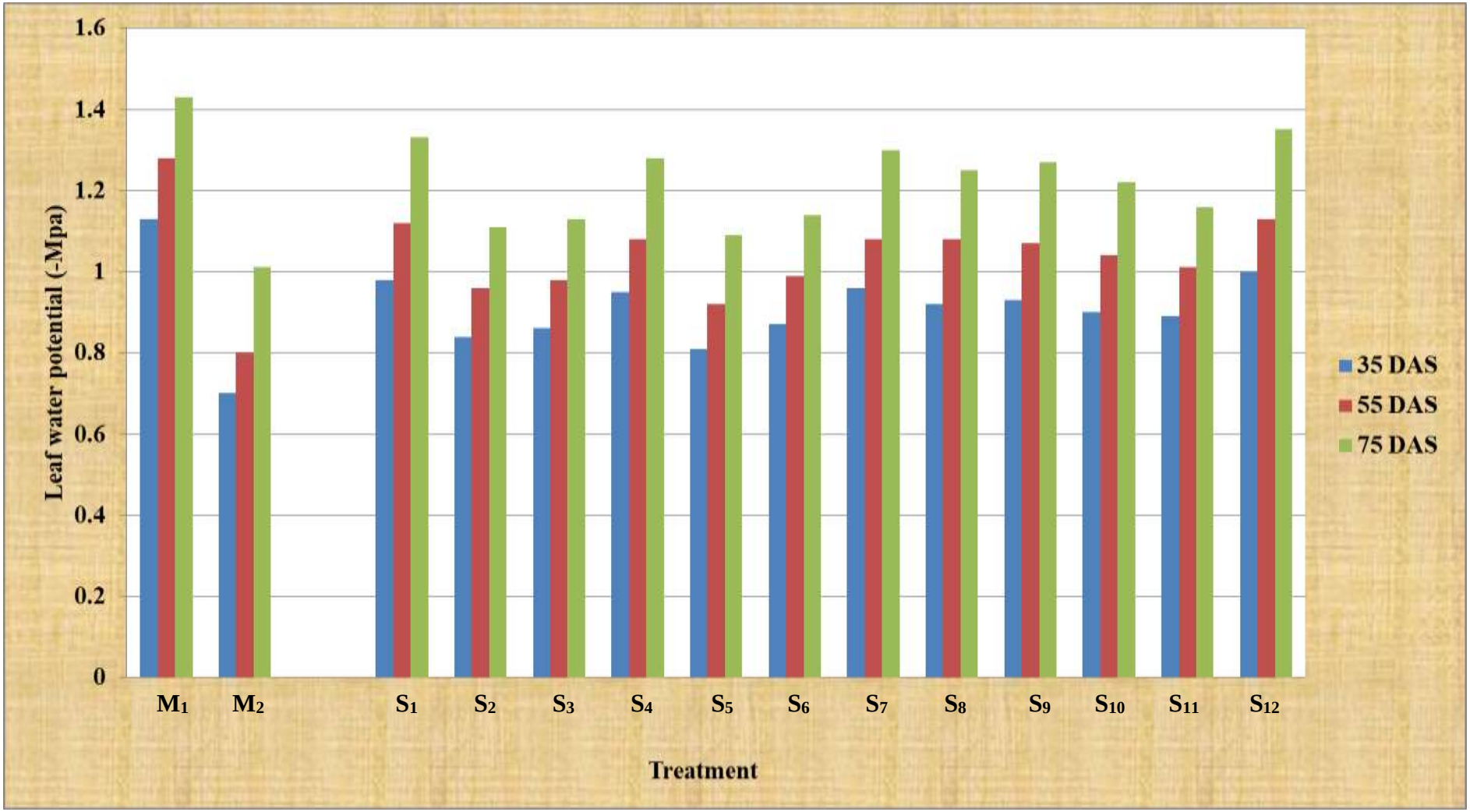

Fig. 8. Leaf water potential (-MPa) of chickpea genotypes as influenced by non irrigated and irrigated condition

5.6.2 Total chlorophyll content (mg g^{-1} fresh wt.)

In the present study total chlorophyll content (mg g^{-1} fresh wt.) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher total chlorophyll content was noticed in RKD-1 at 35, 55 and 75 DAS (2.73, 2.96 and 1.92mg g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by total chlorophyll content of JG-11. Significantly lower total chlorophyll content was recorded in RVSSG-52 at all the stages of plant growth (2.38, 2.57 and 1.62 mg g^{-1} fresh wt.) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher total chlorophyll content of chickpea was recorded in the irrigated conditions with RKD-1 (2.82, 3.08 and 2.07 mg g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower total chlorophyll content was observed in non irrigated condition with RVSSG-52 genotype (2.30, 2.43 and 1.46 mg g^{-1} fresh wt.) at all the growth stages (Fig. 9). Similar results were also replicated by Ghiabi *et al*., 2013 reported that total chlorophyll content decreased in Kabuli chickpea accessions grown under rainfed conditions against irrigated conditions. While increased chlorophyll and carotenoid content under drought stress may be related to a decrease in leaf area, it also can be a defensive response to reduce the harmful effects of drought stress (Farooq *et al*., 2009).

5.6.3 Proline content (µ mole g^{-1} fresh wt.)

In the present study proline content (µ mole g^{-1} fresh wt.) of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher proline content was noticed in RKD-1 at 35, 55 and 75 DAS (1.46, 3.06 and 5.53 µ mole g^{-1} fresh wt.) when compared to rest of genotypes. But it was followed by proline content of JG-11. Significantly lower proline content was recorded in RVSSG-52 at all the stages of plant growth (0.91, 2.22 and 4.08 µ mole g^{-1} fresh wt.) at 35, 55 and 75, respectively. Interaction effect between irrigation and genotypes was found significant. Significantly higher proline content of chickpea was recorded in the non irrigated conditions with RKD-1 (2.01, 4.64 and 8.64 µ mole g^{-1} fresh wt.) at all the growth stages when compared to the rest of the treatments combinations. Significantly lower proline content was observed in irrigated condition with RVSSG-52 genotype (0.58, 0.99 and 1.71 µ mole g^{-1} fresh wt.) at all the growth stages (Fig. 10). Several investigations indicated positive relationship between free proline content of leaves with drought tolerance in chickpea

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

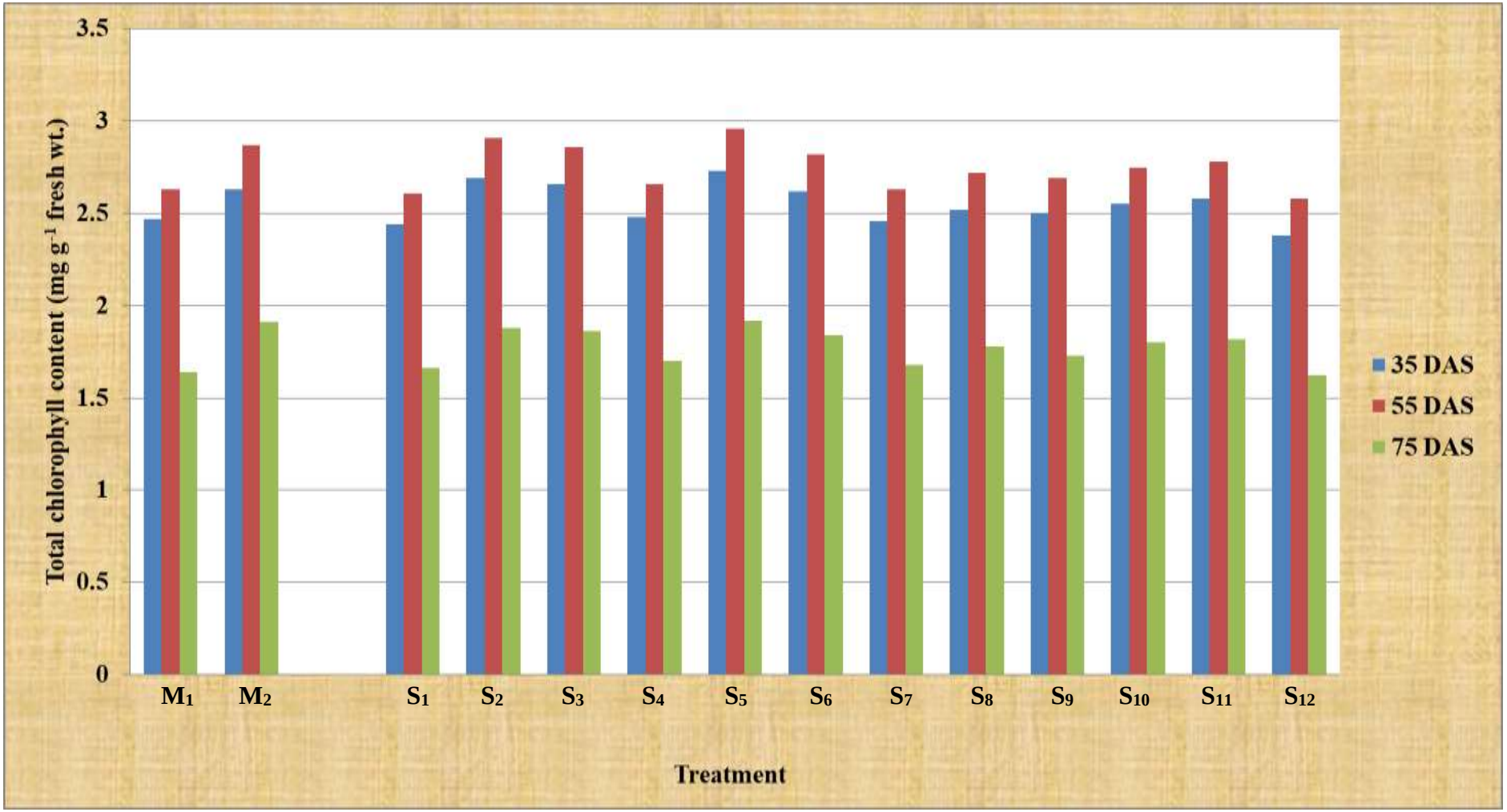

Fig. 9. Total chlorophyll content (mg g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated condition

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

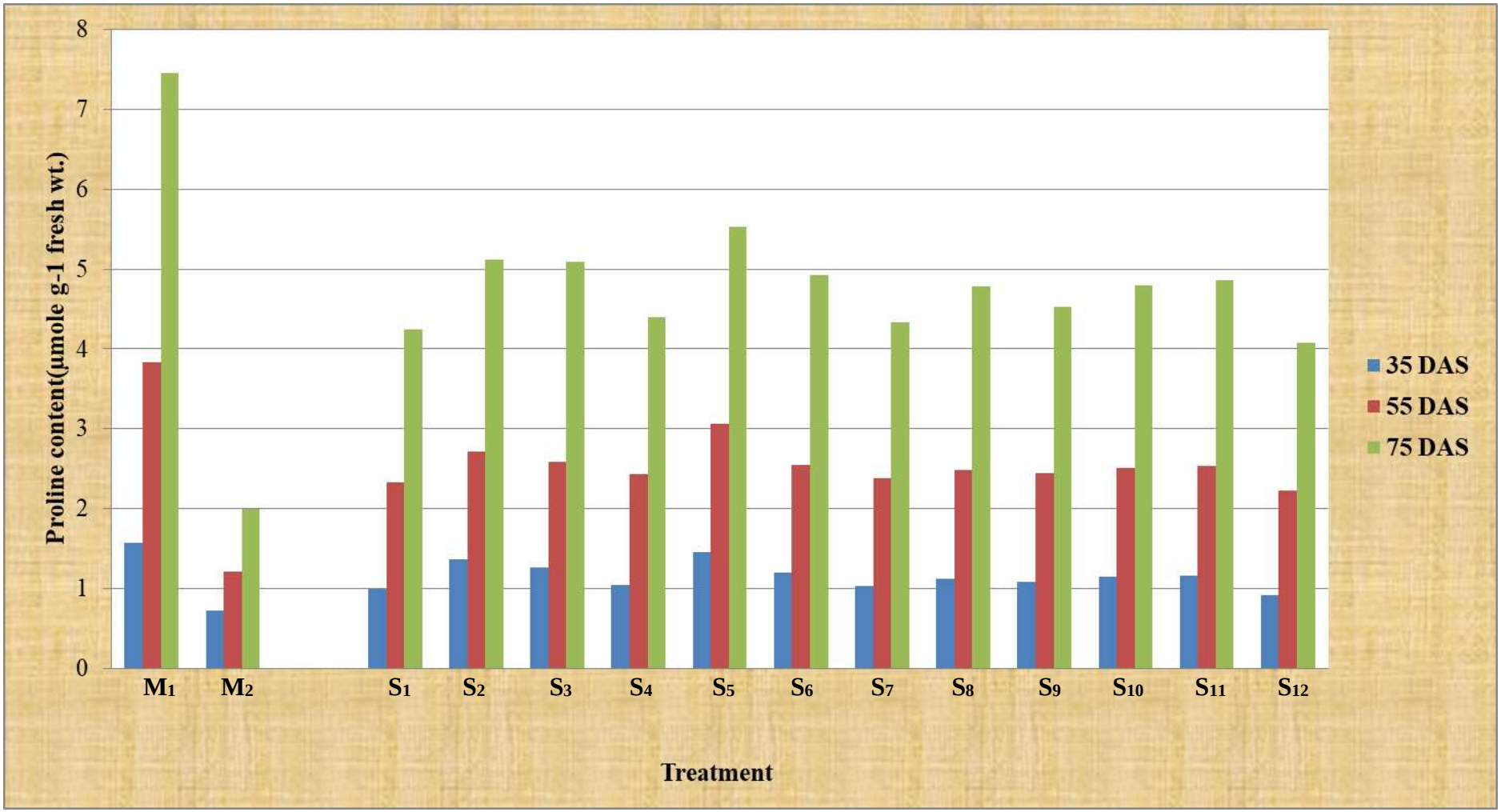

Fig. 10. Proline content (µ mole g^{-1} fresh wt.) of chickpea genotypes as influenced by non irrigated and irrigated conditio

(Singh and Singh 1999), pigeonpea (Mukane *et al* 1996) and soybean (Heerden *et al* 2002). Proline influences protein recovery and preserves the quaternary structure of complex proteins, maintains membrane integrity under dehydration stress and reduces oxidation of lipid membranes or photo inhibition as noticed in rice (Demiral and Turkan 2004). Proline accumulation is believed to play an adaptive role in plant stress tolerance (Verbruggen and Hermans 2008) and has been advocated as a parameter of selection for stress tolerance (Jaleel *et al* 2007).

5.7 Phenology as influenced by non irrigated and irrigated condition

5.7.1 Days to 50% flowering

In the present study days to 50% flowering of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher days to 50% flowering were noticed in RVSSG-52 (57.02) when compared to rest of genotypes. But it was followed by days to 50% flowering of JAKI-9218. Significantly lower days to 50% flowering were recorded in MABC-WR-SA-2 (44.17). Interaction effect between irrigation and genotypes was found significant. Significantly higher days to 50% flowering of chickpea were recorded in the irrigated conditions with RVSSG-52 (58.55) when compared to the rest of the treatments combinations. Significantly lower days to 50% flowering were observed in non irrigated condition with JAKI-9218 genotype (43.03). These results are in conformity with the findings of Ulemale *et al* (2013) demonstrated that yield potential and early flowering are two major components of drought escape in lentil and chickpea.

5.7.2 Days to pod initiation and days to physiological maturity

In the present study days to pod initiation and days to maturity of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher days to pod initiation and days to maturity were noticed in GBM-2 (69.42 and 109.4) when compared to rest of genotypes. But it was followed by days to pod initiation and days to maturity of JAKI-9218 and JG-14. Significantly lower days to pod initiation and days to maturity were recorded in JG-14 (63.03) and MABC-WR-SA-2 (96.1). Interaction effect between irrigation and genotypes was found significant. Significantly higher days to pod initiation and days to maturity of chickpea were recorded in the irrigated conditions with GBM-2 (71.17 and 109.2) when compared to the rest of the treatments

combinations. Significantly lower days to pod initiation and days to maturity were observed in non irrigated condition with JG-14 genotype (57.5) and MABC-WR-SA-2 (96.1). These results are in conformity with the findings of Salim and Saxena (1993) who stated that under severe moisture stress condition early flowering was associated with high HI, maximum number of pods and seed index. Sharma *et al* (2007) also noted that under increased moisture stress condition the maturity duration reduced by 15-19 days. This longer duration has significant positive correlation with seed yield.

5.8. Yield and yield attributes (kg ha^{-1}) as influenced by non irrigated and irrigated condition

5.8.1 Number of pods per plant

In the present study of number of pods per plant chickpea differed significantly due to stress condition. Among the genotypes, significantly higher number of pods per plant was noticed RKD-1 (48.92) when compared to rest of genotypes, it was followed by number of pods per plant of JG-11. Significantly lower number of pods per plant was recorded in RVSSG-52 (38.12). Interaction effect between irrigation and genotypes was found significant. Significantly higher number of pods per plant of chickpea was recorded in the irrigated conditions with RKD-1 (60.00) when compared to the rest of the treatments combinations. Significantly lower number of pods per plant was observed in non irrigated condition with RVSSG-52 (29.94). Similar results were also reported by Pilbeam *et al.* (1992) reported that decrease in yield of grain legumes grown under drought conditions is largely due to the reduction in number of pods per plant which also observed in present study than rainfed condition. This finding is in conformity with the results of Sharma *et al*. (2007).

5.8.2 Test weight (g)

In the present study test weight of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher test weight was noticed RKD-1 (34.63 g) when compared to rest of genotypes. But it was followed by test weight of RKD-4. Significantly lower test weight was recorded in MABC-WR-SA-2 (17.7 g). Interaction effect between irrigation and genotypes was found significant. Significantly higher test weight of chickpea was recorded in the irrigated conditions with RKD-1 (36.11 g) when compared to the rest of the treatments combinations. Significantly lower

test weight was observed in non irrigated condition with MABC-WR-SA-2 (16.23 g). These results are in line with the findings of Sadeghipour and Aghaei, (2011) Results showed that the longer growing period of autumn sown chickpeas affected positively characters contributing to yield such as biomass, pods per plant, and seeds per pod, 100-seeds weight and harvest index, which in turn contributed to increased seed yield.

5.8.3 Seed yield (kg ha^{-1}) and harvest index (%)

In the present study seed yield and harvest index of chickpea differed significantly due to stress condition. Among the genotypes, significantly higher seed yield and harvest index was noticed RKD-1 (1991kg ha^{-1} and 43.34%) when compared to rest of genotypes. But it was followed by seed yield and harvest index of JG-11. Significantly lower seed yield and harvest index was recorded in RVSSG-52 (1726 kgha^{-1} and 35.59%). Interaction effect between irrigation and genotypes was found significant. Significantly higher seed yield and harvest index of chickpea was recorded in the irrigated conditions with RKD-1 (2213 kg ha^{-1} and 44.47%) when compared to the rest of the treatments combinations. Significantly lower seed yield and harvest index was observed in non irrigated condition with RVSSG-52 (1528 kg ha^{-1} and 34.55%) (Fig.11). These results are in conformity with the findings of Rahangadale *et al*. (1994) in the field experiment on chickpea genotypes under soil moisture deficit reported tolerance efficiency, under water stressed condition; there was decrease in net assimilation rate (40.4%), dry matter production sources of (31.8%), pod number (26.2%) and seed yield (15.2%) compared to irrigated conditions. Singh *et al*. (1985) reported that seed per pod had direct effect on grain yield while most of other characters had indirect effect. Similarly, he concluded that grain yield per plant was significantly associated with pods per plant, harvest index, primary and secondary branches per plant.

5.8.4 Straw yield (kg ha^{-1})

In the present study straw yieldof chickpea differed significantly due to stress condition. Among the genotypes, significantly higher straw yield was noticed JG-14 (5081 kg ha^{-1}) when compared to rest of genotypes. But it was followed by straw yield of GBM-2. Significantly lower straw yield was recorded in RKD-4 (4700 kg ha^{-1}). Interaction effect between irrigation and genotypes was found significant. Significantly higher straw yield of chickpea was recorded in the irrigated conditions with RKD-1 (5577

LEGENDS

M_1	:	Non irrigated
M_2	:	Irrigated
S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

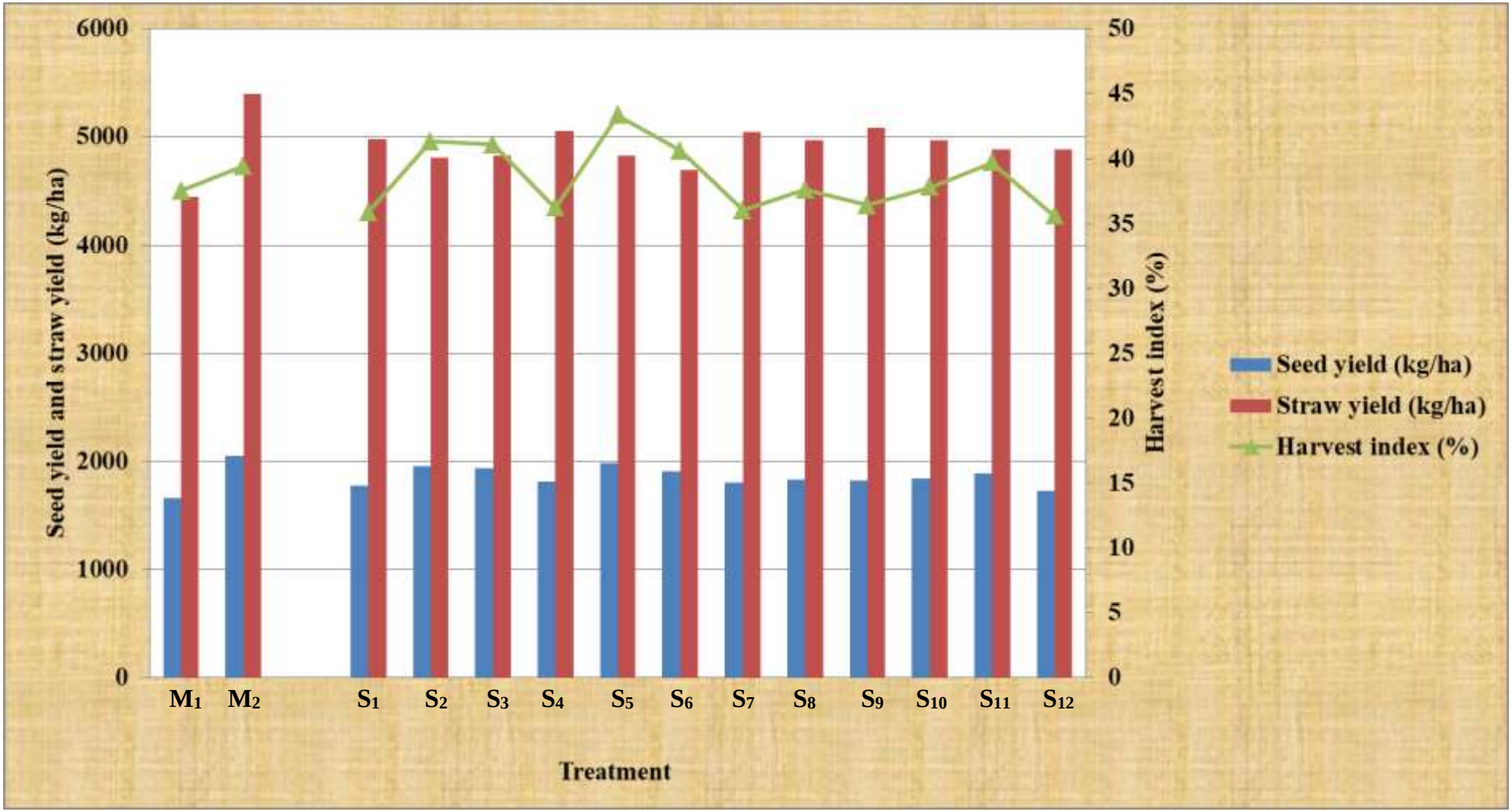

Fig. 11. Yield components of chickpea genotypes as influenced by non irrigated and irrigated condition

kg ha^{-1}) when compared to the rest of the treatments combinations. Significantly lower straw yield was observed in non irrigated condition with (4312 $kgha^{-1}$) (Fig. 11). Singh *et al.* (2005) observed higher biomass production which is a pre-requisite for any successful genotype under rain fed environment. Kumar *et al.* (2001) observed that biomass production reduced under rain fed condition in all the genotypes (22.71 to 28.35%) as compared to tolerant genotypes (9.01 to 19.56%). However the reduction in seed yield was 2.97 to 5.73%in tolerant genotypes compared to 9.2 to 24.66% in susceptible genotypes.

5.9 Root characteristics

5.9.1 Root length (cm) and root weight (g)

Among genotypes, RKD-1 shows significantly higher Root length and root weight (101.2 cm and 2.28 g**)** followed by JG-11over all other genotypes. RVSSG-52 genotype recorded significantly lower Root length (cm) and root weight (g) (83.10 cm and 1.28 g**)** at 45 days after harvesting, respectively (Fig. 12). Similar results were also reported by Oweis and Hachum (2009) demonstrated that the cultivars with deep root system can extract water at the greatest depths both under drought and irrigated conditions. Smita and Nayyar (2005) observed that significant differences have been observed among chickpea genotypes for root length under normal and deficit moisture conditions. Plasmolysis, distortion and reduction in root hair diameter were reported as possible reasons for reduction of root length under suboptimal moisture availability. Franco *et al.* (2011) observed that deep rooting is a critical factor that influences the ability of the plant to absorb water from the deeper layers of the soil.

LEGENDS

S_1	:	A-1
S_2	:	JG-11
S_3	:	BGD-103
S_4	:	GBM-2
S_5	:	RKD-1
S_6	:	RKD-4
S_7	:	MABC-WR-SA-1
S_8	:	MABC-WR-SA-2
S_9	:	JG-14
S_{10}	:	JAKI-9218
S_{11}	:	DIBG-204
S_{12}	:	RVSSG-52
DAS	:	Days after sowing

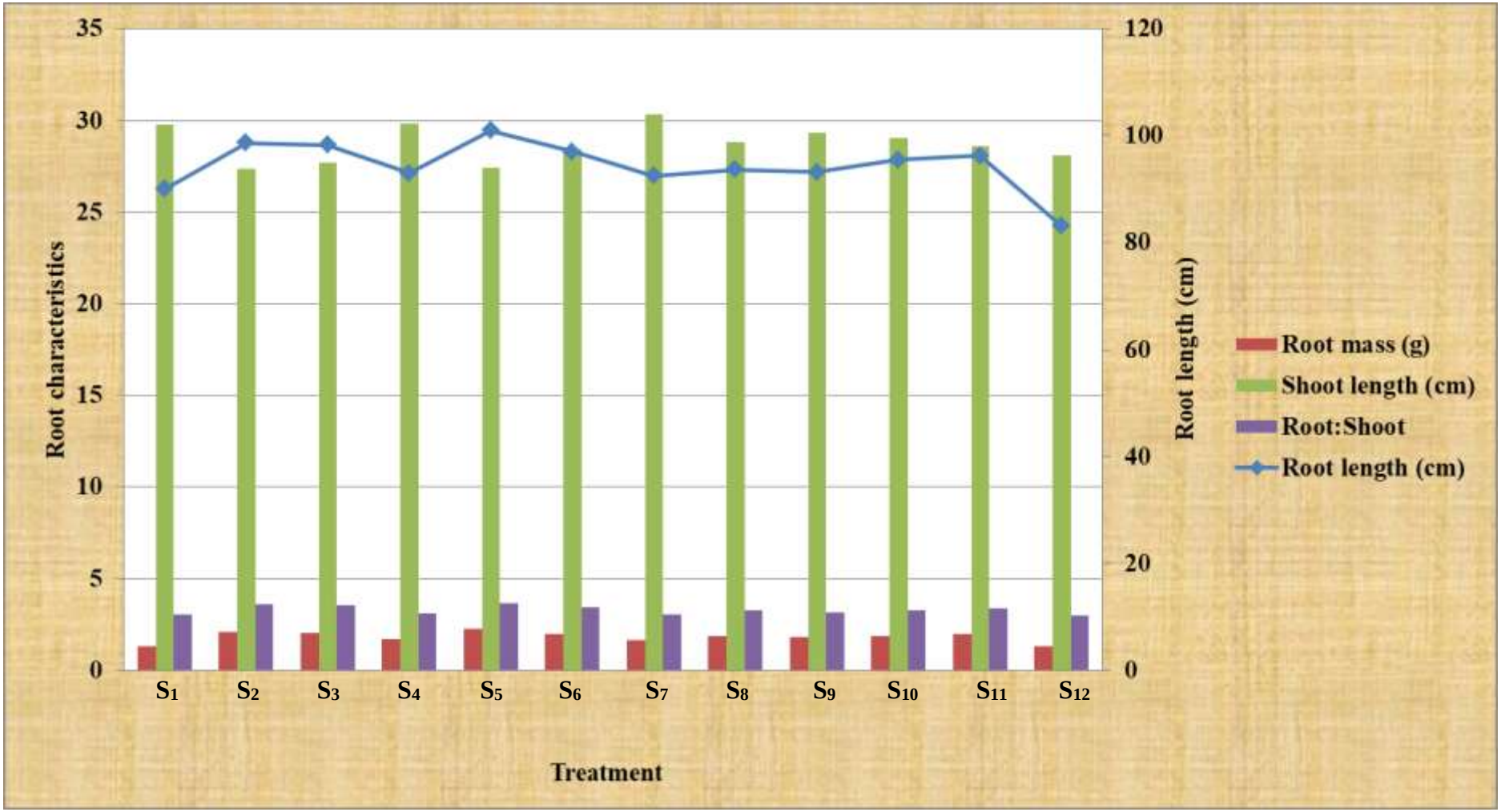

Fig. 12. Root characterization of chickpea genotypes under non irrigated condition

SUMMARY AND CONCLUSIONS

VI. SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Agricultural Research Station, Kalaburgi on medium black soil during *rabi* 2017-18 for "Screening of chickpea (*cicer arietinum* L.) lines for drought tolerance" under Northern Dry Zone of Karnataka. The experiment was laid out in split plot design with two main plots as non irrigated (stress) and irrigated conditions, and sub plots with twelve genotypes (A-1, JG-11, BGD-103, GBM-2, RKD-1, RKD-4, MABC-WR-SA-1, MABC-WR-SA-2, JG-14, JAKI-9218, DIBG-204 and RVSSg-52) with three replications. The results obtained are summarized in this chapter.

The genotypes showed a significantly variability among themselves in relation to their phenological development, physiological attributes and growth determinants, biochemical estimation morphological trait, yield attributing components and seed yield of chickpea under non irrigated (stress) and irrigated conditions. The moisture stress had a strong influence on almost all the parameters of yield in chickpea genotypes under investigation.

6.1 Irrigation (I)

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher morphological characteristics (plant height, number of branches per plant), respectively as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher absolute growth rate, crop growth rate, leaf area, leaf area index and dry matter accumulation as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher photosynthetic rate, chlorophyll content, relative water content as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly lower membrane injury index as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly lower leaf water potential as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly lower proline content as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher values of phenological parameters as compared to the chickpea genotypes grown under stress condition.

- All chickpea genotypes grown under irrigated conditions (non-stress) registered significantly higher seed yield, number of pods per plant, harvest index as compared to the chickpea genotypes grown under stress condition.

6.2 Genotypes (G)

- Among the genotypes, RKD-1 shows significantly higher morphological characteristics (plant height, number of branches per plant) when compared to rest of genotypes, significantly lower morphological characteristics (plant height, number of branches per plant) were recorded in RVSSG-52.

- Among the genotypes, RKD-1 shows significantly higher absolute growth rate, crop growth rate, leaf area, leaf area index and dry matter accumulation when compared to rest of genotypes, significantly lower absolute growth rate, crop growth rate, leaf area, leaf area index and dry matter accumulation was recorded in RVSSG-52.

- Among the genotypes, RKD-1 shows significantly higher photosynthetic rate, chlorophyll content, relative water content when compared to rest of genotypes, whereas significantly lower photosynthetic rate, chlorophyll content, relative water content was recorded in RVSSG-52.

- Among the genotypes, RKD-1 shows significantly lower membrane injury index& leaf water potential when compared to rest of genotypes, significantly higher membrane injury index& leaf water potential was recorded in RVSSG-52.

- Among the genotypes, RKD-1 shows significantly higher proline content when compared to rest of genotypes, significantly lower proline content was recorded in RVSSG-52.

- Among the genotypes, GBM-2 significantly higher values of phenological parameters when compared to rest of genotypes, significantly lower values of phenological parameters were recorded in MABC-WR-SA-2.

- Among the genotypes, RKD-1 shows significantly higher seed yield, number of pods per plant, harvest index when compared to rest of genotypes, significantly lower seed yield, number of pods per plant, harvest index was recorded in RVSSG-52.

- Among the genotypes, RKD-1 shows significantly higher root length and root mass which in turn showed positive effect on drought tolerance at both field and PVC pipes studies.

6.3 Irrigation x Genotypes

- The interaction effects between irrigation and genotypes were found significant. Significantly higher morphological characteristics, growth parameters, and biochemical parameters of chickpea was recorded in the irrigated conditions with RKD-1 when compared to the rest of the treatments combinations. Significantly lower seed yield and harvest index was observed in non irrigated condition with RVSSG-52 genotype.

- The interaction effects between irrigation and genotypes were found significant. Significantly higher proline content of chickpea was recorded in the non irrigated conditions with RKD-1 when compared to the rest of the treatments combinations. Significantly lower proline content was observed in irrigated condition with RVSSG-52 genotype.

- The interaction effects between irrigation and genotypes were found significant. Significantly lower leaf water potential of chickpea was recorded in the irrigated conditions with RKD-1 when compared to the rest of the treatments combinations.

Significantly higher leaf water potential was observed in non irrigated condition with RVSSG-52 genotype.

- The interaction effects between irrigation and genotypes were found significant. Significantly higher seed yield, number of pods per plant and harvest index of chickpea was recorded in the irrigated conditions with RKD-1, when compared to the rest of the treatments combinations. Significantly lower seed yield and harvest index was observed in non irrigated condition with RVSSG-52 genotype.

CONCLUSION

- There was percent reduction in yield due to stress in chickpea
- Among the genotypes RKD-1 has given higher yield under both irrigated (2213 kg ha^{-1}) and non-irrigated(1769 kg ha^{-1}) conditions indicating the ability of this genotype to perform well under both stress and non stress conditions hence this can be used as trait for screening drought tolerance lines in Chickpea.
- The results of the current studies indicate that genotypes should have higher amount of proline content, relative leaf water content, and lower leaf water potential and membrane injury index and deeper root length for the drought tolerance.

Future line of work

- Identification of molecular marker for drought tolerance should be studied.
- Enzymatic studies under drought condition can be carried out.
- Studies on root characterization for better uptake of water under drought condition can be carried out.

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