

**Relative performance of Chickpea (*Cicer arietinum* L.)
genotypes under drought stress and non-stress situations**

THESIS



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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

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In

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PLANT BREEDING AND GENETICS

by

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2015

CERTIFICATE – 1

This is to certify that the thesis entitled **Relative performance of chickpea(*Cicer arietinum* L.) genotypes under drought stress and non-stress situations** submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE in Plant Breeding and Genetics** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior a record of the bona-side research work carried out by **MS. JYOTI KUMARI ID. No. RA/SH/303/08** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma or has been published. All the assistance and help received during the course of this investigations has been acknowledged by the scholar.

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This is to certify that the thesis entitled **Relative performance of chickpea (*Cicer arietinum* L.) genotypes under drought stress and non-stress situations** submitted by **MS. JYOTI KUMARI ID. No.RA/SH/303/08** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfillment of the requirements for the degree of Master of Science in **AGRICULTURE** in the Department of **Plant Breeding and Genetics**, has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination on the same.

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LIST OF ABBREVIATION

Symbol	Legend
BS	Broad sense.
C.D	Critical difference.
DAS	Day after sowing.
DI	Drought Index.
DMA	Dry matter accumulation.
DSI	Drought susceptibility Index.
DTE	Drought Tolerance efficiency.
DW	Dry weight.
<i>et al.</i>	And others.
FW	Fresh weight.
Fig.	Figure (s)
GA	Genetic advance.
GCV	Genotypic Coefficient of variation.
HI	Harvest Index
PCV	Phenotypic Coefficient of variation.
RWC	Relative water content.
S	Drought Stress.
S.Em.±	Standard error of mean
S.S.	Sum of Square
SMW	Standard Metrological week.
TW	Turgid weight.
WSD	Water saturation deficit.
NS	Non-stress.
NS	Non significant
NS	Non significant
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

CHAPTER - I

INTRODUCTION- I

Chickpea (*Cicer arietinum* L.) belongs to genus *Cicer*, tribe *cicerace*, family *Fabaceae* and subfamily *papilionaceae*. Vavilov (1949) suggested southeastern Turkey as a centre of origin of Chickpea. Chickpea has been recognized as a valuable source of protein (25.2-28.9%), vitamins (mainly C) and minerals (P and Ca) in the human diet and occupy a very important place in human nutrition in many developing countries. On an average, chickpea seed contains 23% protein, 64% total carbohydrate, 47% starch, 5% fat, 6% crude fibre, 6% soluble sugar & 3% ash. Being a leguminous crop, possessing root nodules, it maintains the soil fertility as it enriches the soil through symbiotic nitrogen fixation. The deep penetrating root systems of chickpea enable it to utilize the limited available moisture more efficiently and contribute substantially to the loosening up of soil. Based on size and colour of seed, chickpea is of two types *i.e.*, microspora and macrospora. Microspora are having small and angular in shape, seed colour varies from brown, black, yellow to green and on an average producing 1-2 seeds per pod. The plants are short with small leaflets having pink to purplish flower and contain anthocynin pigmentation. On the other hand, the seeds of macrospora are round or ram shaped and cream coloured. The plant is medium to tall in height with large leaflet having white flower and contain no anthocynin pigmentation.

As per estimates projected by Food and Agricultural organization chickpea production is about 12 million metric tons in 2011. India is the largest producer of chickpea with about 8 million tons accounting of about 70% of total world production. In India, it is being grown under 9.51 mha area, with production of 8.83 mt. and productivity 929 kg/ha (2012-13). Madhya Pradesh, Uttar Pradesh, Maharashtra and Rajasthan are the major chickpea growing states, sharing 85% area in India. Madhya Pradesh covers 3128.70 thousand ha area with 3551.20 thousand tones production and productivity 1135 kg/ha (2012-13). Madhya Pradesh is contributing 37% chickpea production of the country. (Singh 2014)

Self sufficiency on chickpea production has been achieved through developing high yielding chickpea cultivar with advanced production technologies and their adoption by the farmers. Quantum of genetic variability and the extent to

heritable and non-heritable variation are related to the characters determine the extent of genetics amelioration. Partitioning of phenotypic and genotypic variation, environmental variation, idea of heritability, association between characters and path analysis are essential features of breeding programmers.

Drought or moisture stress being the one of the most detrimental constraints causing its low production. Drought tolerance improvement is one of the most challenging objectives of plant breeding programme. Water resource is an important factor affecting partitioning of biomass and there by its seed yield, as the availability of water for agriculture is becoming limiting factor day by day. Thus, it becomes necessary to identify chickpea genotypes tolerant to drought stress. The chickpea genotypes with better biomass partitioning and mobilization efficiency will be suitable for cultivation in dry land areas.

In view of these facts, the present investigation planned with following objectives.

Objective:-

1. To estimate genetic variability existing in population under drought stress and non-stress conditions.
2. To study the relationship between yield and its components and amongst themselves under drought stress and non-stress conditions.
3. To estimate efficiency of screening criteria for drought tolerance in chickpea.

CHAPTER – II

REVIEW OF LITERATURE

The relevant literature related to the present investigation has been reviewed under the following heads:

2.1 Parameters of genetic variability

2.1.1 Genetic variation

2.1.2 Heritability and Expected Genetic Advance

2.2 Character association

2.2.1 Correlation

2.2.2 Path coefficient analysis

2.3 Drought tolerance

2.1 Parameters of genetic variability:

2.1.1. Genetic variation:

Related literature available for genetic variability on chickpea is as follows

Chauhan and Singh (2000) observed the highest variability for seeds/pod in chickpea.

Nimbalkar (2000) observed genotypic (48.84%) and phenotypic (49.02%) coefficients of variation were highest for 100-grain weight and lowest for days to maturity in chickpea.

Arora and Jeena (2001) studied forty genetically diverse genotypes of chickpea and reported that the highest genetic variability was expressed by 100 seed weight, followed by primary branches per plant and seeds per plant.

Jeena and Arora (2001) evaluated ninety six chickpea genotypes and observed high genotypic and phenotypic coefficient of variation for 100 seed weight.

Kumar *et al.*, (2001a) studied twenty six genetically diverse genotypes of chickpea and reported that pods per plant exhibited the highest amount of genetic variability, followed by seed yield per plant, 100 seed weight, seeds per pod, plant height and biological yield per plant.

Shaukat *et al.*, (2002) studied twenty elite lines of chickpea and reported that the secondary branches per plant, total weight of plant, pods per plant and seed yield per plant reflected good response to selection. Genotypic differences were

found to be significant for all quantitative characters studied.

Ali (2003) found maximum genetic coefficient of variation for secondary branches per plant, total weight of a plant, pods per plant and seed yield per plant which reflects that these traits exhibited good response to selection.

Parshuram *et al.*, (2003a) studied sixteen chickpea cultivars and observed that phenotypic coefficient of variation ranged from 4.01% for days to maturity to 58.62% for number of seeds per plant. The genotypic coefficient of variation was low for all characters except plant height and number of leaves per plant .

Yadav *et al.*, (2003) studied thirty three divergent genotypes of chickpea (*C. arietinum*) and observed maximum variability for harvest index, biological yield, grain yield per plant, and 100-seed weight.

Ajinder *et al.*, (2004) reported that 100 seed weight had comparable phenotypic and genotypic coefficients of variation under both normal and late sowing conditions.

Jahagirdar (2005) concluded that the biparental mating in F₂ of BDN-9-3xICCV-2 cross of chickpea and reported that biparental population had better mean performance than the selfed for all the characters namely plant height, primary branches per plant, secondary branches per plant, number of pods per plant, 100-seed weight and seed yield per plant.

Jeena *et al.*, (2005) studied variability using eighty genetically diverse chickpea genotypes. A high amount of genetic variability was expressed by pods per plant, 100-seed weight, biological yield per plant and seed yield per plant.

Meena *et al.*, (2006) reported that phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the characters. The phenotypic and genotypic coefficients of variation were highest for 100-seed weight followed by seed yield, while days to maturity showed the lowest PCV and GCV, respectively.

Durga *et al.*, (2007) studied genetic variability on yield and yield components of chickpea and reported that maximum genotypic coefficient of variation for branches per plant followed by pods per plant and seed yield.

Lokare *et al.*, (2007) studied sixty genotypes and showed a wide range of variation for seed yield per plant, 100- seed weight and number of pods per plant.

Vaghela *et al.*, (2008) evaluated fifty genotypes of Kabuli chickpea and estimated high genotypic coefficient of variation for seed yield and number of pods per plant.

Sreelakshmi *et al.*, (2010) found high genotypic and phenotypic coefficient of variation for seed yield and number of pods per plant.

Akhtar *et al.*, (2011) observed phenotypic coefficient of variation (PCV) for days to flowering, days to maturity, plant height and seed yield were higher than genotypic coefficient of variations (GCV).

Babbar *et al.*, (2012) evaluated forty four promising lines of chickpea under late sown condition. The maximum genotypic coefficient of variation was noticed for total number of seeds per plant and total number of pods per plant.

2.1.2 Heritability and Expected genetic Advance

Chauhan and Singh (2000) observed that the seeds per pod and secondary branches per plant showed high heritability with high genetic gain.

Jeena and Arora (2000) found that selection is likely to be effective for 100 seed weight, pods per plant, seed yield per plant, followed by harvest index, and seeds per pod.

Nimbalkar (2000) observed highest genetic advance for 100-grain weight and lowest for days to maturity. Heritability was highest for 100-grain weight and lowest for plant spread.

Arora and Jeena (2001) reported that 100 seed weight, followed by primary branches per plant and seeds per plant exhibited high genetic advance with high heritability.

Jeena and Arora (2001) observed that 100 seed weight exhibited high genetic advance with high heritability.

Kumar *et al.*, (2001) recorded that pods per plant had the highest heritability followed by primary branches per plant and number of seeds per plant.

Albinbas (2002) reported high heritability in broad sense for 100 seed weight and seed yield.

Arshad *et al.*, (2002) reported low heritability percentage coupled with low and moderate genetic advancement for primary and secondary branches, respectively.

Noor *et al.*, (2003) reported medium to high genetic advance for days to flowering, maturity, secondary branch number, and 100 seed weight. Where as for other characters, low to medium heritability was observed along with low to high genetic advance.

Parshuram *et al.*, (2003a) estimated high heritability for number branches per plant, days to 50% flowering, days to maturity and 100 seed weight. Genetic advance was high for number of pods per plant, pod weight, number of seeds, seed weight per plant and 100 seed weight.

Sable *et al.*, (2003) observed that seed yield pebiological yield per plant exhibited high estimates of heritability.

Yadav *et al.*, (2003) observed low to very high heritability coupled with low genetic advance for harvest index, biological yield, grain yield per plant, and 100-seed weight.

Ajinder *et al.* (2004) studied high heritability and average genetic advance for 100 seed weight and grain yield.

Arshad *et al.*, (2002) noted high heritability for secondary branches and biological yield coupled with high genetic advance.

Muhammad *et al.*, (2004) studied heritability and genetic advance, for yield and yield components in twenty four advance lines of chickpea and reported existence of high heritability with low genetic advance for number of days to flowering, number of days to maturity and 100-seed weight.

Pratap *et al.*, (2004) assessed thirty eight genetically diverse early maturing chickpea genotypes in four different environments, are reported that seed yield, 100-seed weight and biological yield had high genetic advance.

Jeena *et al.*, (2005) reported that pods per plant, 100-seed weight, biological yield per plant and seed yield per plant characters exhibited high genetic advance with high heritability.

Mohammad *et al.*, (2005) reported high heritability estimates for 100-seed weight, plant height, seed yield, total weight, pods per plant, seeds per pod and seeds per plant with corresponding genetic advance of 11.3, 8.05, 8.01, 4.28, 4.06, 3.71 and 0.10 respectively.

Saleem *et al.*, (2005) studied eighteen elite genotypes and observed high heritability for pods per plant, seeds per plant, 100-seed weight and total weight of plant.

Usmani *et al.*, (2005) noted high heritability and genetic advance for pod bearing length, seed yield per plant, plant height and harvest index.

Durga *et al.*, (2007) found high heritability in chickpea for days to 50% flowering and test weight.

Durga *et al.*, (2007) observed high genetic advance for days to 50% flowering; pods per plant and seed yield.

Sidramappa *et al.*, (2008) found high heritability for pods per plant, seed yield per plant, seed weight, days to 50% flowering, days to pod initiation and plant height.

Vaghela *et al.*, (2008) found that heritability was higher for all the traits except plant height in chickpea.

Vaghela *et al.*, (2008) found high genetic advance expressed as a percentage of mean for seed yield per plant and number of pods per plant.

Alwawi *et al.*, (2010) recorded high genetic advance for seeds yield per plant.

Babbar *et.al*, (2012) evaluated forty four promising lines of chickpea under late sown condition. Days to 50% flowering, days to maturity, plant height, 100 seed weight and seed yield per plant showed high heritability coupled with medium genetic advance as percentage of mean, whereas number of seeds per plant and number of pods per plant showing medium heritability and high genetic advance as percentage of mean

2.2. Character associations:

2.2.1 Correlation coefficient analysis

Arun kumar *et al.*, (2000) reported strong positive correlation for biological and grain yield per plant, harvest index and 100 seed weight both at genotypic and phenotypic levels. .

Vijaya lakshmi *et al.*, (2000) observed that seed yield was positively correlated with number of pods, seeds, primary branches and secondary branches per plant.

Mishra *et al.*, (2000) observed that number of seeds per pod was positively correlated with seed yield.

Guler *et al.*, (2001) reported significant and positive correlation of seed yield

with pods per plant, dry matter accumulation, 100 seed weight and harvest index in chickpea.

Kumar *et al.*, (2001b) observed that harvest index had the highest significant positive correlation with seed yield, followed by the number of pods per plant, biological yield and number of secondary branches per plant.

Rao (2001) assessed twenty one vascular wilt resistant chickpea genotypes and reported biological yield were positively correlated with seed yield. Biological yield and 100 seed weight had significant positive association with harvest index.

Singh *et al.*, (2001) revealed positive association of primary and secondary branches, number of pods per plant with grain yield.

Yadav *et al.*, (2001) observed the correlation between seed yield and its nine component traits. Seed yield was positively associated with number of seeds per pod and days to maturity but negatively correlated with days to 50% flowering.

Narayan and Reddy (2002) observed a significant association between seed yield and harvest index, number of pods per plant and number of secondary branches per plant both at genotypic and phenotypic levels.

Singh *et al.*, (2002) observed positive and significant association for days to initial flowering, days to 50% flowering, number of primary branches, number of pods per plant with seed yield.

Singh and Singh (2002) reported that positive and significant association of number of secondary branches, number of pods per plant, plant height, days to flowering, days to maturity and test weight per plant with seed yield.

Patel (2003) found seed yield per plant shared positive association with biological yield, pod weight per plant, number of pods per plant, pod bearing length, plant height, days to flower initiation, days to pod initiation, 50% podding, end of flowering and days to maturity.

Parshuram *et al.*, (2003b) reported that seed yield per plant was positively correlated with number of pods per plant, pod weight per plant and number of seeds per plant at the genotypic and phenotypic levels, and with plant height, number of leaves, number of branches and shelling percentage at genotypic level and it was negatively correlated with days to maturity, days to 50% flowering and 100 seed

weight at the genotypic and phenotypic levels and number of leaves at the phenotypic level.

Babbar and Patel (2005) estimated genetic correlation of twenty four genotypes which showed positive significant association of seed yield with biological yield, pod weight per plant, number of pods per plant and days to maturity.

Jeena *et al.*, (2005) recorded seed yield was significantly and positively correlated with plant height, pods per plant, 100 seed weight, biological yield per plant and harvest index.

Sidramappa *et al.*, (2008) reported that seed yield had a high positive correlation with pods per plant , plant height , number of branches , 100 seed weight , reproductive period and days to maturity.

Singh *et al.*, (2008) evaluated newly inbred lines and recorded increased seed size, early maturity and reduced plant height at the drought-prone location and early maturity at the drought-free location were of prime importance in increasing seed yield.

Yadava and Singh (2008) recorded that Dry matter accumulation, harvest index and 100-seed weight showed positive and significant association with seed yield in all the environments.

Vaghela *et al.*, (2009) reported that the magnitude of genotypic correlation coefficients was higher as compared to their corresponding phenotypic correlation coefficients for most of the characters. Seed yield per plant exhibited significant and positive correlation with biological yield, number of pods per plant, harvest index, number of seeds per pod, number of primary branches per plant and 100-seed weight at genotypic as well as phenotypic levels.

Ali *et al.*, (2010) reported pods per plant, seeds per pod and 100-seed weight were positive and significant at genotypic level but positive and highly significant at phenotypic level with biological yield per plant. Days to flowering were negative and non-significantly correlated with grain yield per plant at both genotypic and phenotypic levels.

Sreelakshmi *et al.*, (2010) exhibited significant positive correlation for days to 50% flowering, days to maturity and number of pods per plant with seed yield.

Mishra and Babbar (2011) observed that seed yield was positively and significantly correlated with pods per plant, seeds per pod, biological yield per plant, 100 seed weight and harvest index in normal and late sown.

Akhtar *et al.*, (2011) evaluated twenty advance genotypes of chickpea and observed significant and positive correlations between yield and 100-seed weight, number of pods per plant and plant height.

Babbar *et al.*, (2012) evaluated forty four promising lines of chickpea under late sown condition. Seed yield per plant showed high significant positive correlation with total number of seeds per plant, total number of pods per plant, biological yield, plant height and 100 seed weight, whereas, significant negative correlation with days to 50% flowering.

2.3.2 Path coefficient analysis

Rao and Kumar (2000) reported that number of pods per plant, 100 seed weight, plant height, days to 50 per cent flowering had high positive direct effect on seed yield.

Neter pal Singh *et al.*, (2001) reported that days to maturity and number of primary branches per plant had high indirect effect on seed yield via number of pods per plant although their direct effect was negative.

Muhammd *et al.*, (2002) carried out the path analysis in twenty genotypes and study revealed that number of pods per plant had maximum positive direct effect on seed yield. The other traits in the study also exhibited considerable indirect effect on the seed yield through number of pods per plant. It was concluded that number of pods per plant and 100- seed weight could be used as selection criteria to improve the yield.

Narayan and Reddy (2002) observed that number of pods per plant, 100 seeds weight, number of seeds per pods and harvest index had high direct effect on seed yield.

Yadav *et al.*, (2002) based on the results obtained from Path analysis suggested that biological yield, harvest index and 100 seed weight were the yield determinants.

Mardi *et al.*, (2003) found that seed and pod weight and number of seeds per plant had the greater direct effect on yield.

Patel (2003) observed biological yield, 50% podding and harvest index had high direct effect on seed yield in *desi* chickpea. Biological yield, harvest index and pod initiation showed high positive direct effect on seed yield per plant in *kabuli* chickpea, whereas 50% podding, days to flower initiation had positive direct effect on seed yield per plant in *gulabi* chickpea.

Babbar and Patel (2005) reported that biological yield per plant, 50% podding and harvest index showed maximum direct contribution on seed yield.

Lokare *et al.*, (2007) studied sixty genotypes and found that pods per plant had the highest positive direct effect on seed yield followed by 100 seed weight and seeds per pod.

Sidramappa *et al.*, (2008) observed that number of pods per plant has highest direct effect on seed yield. Further number of pods per plant, 100 seed weight, plant height and reproductive period should be taken into consideration in breeding of high yielding gram varieties.

Singh and Sandhu (2008) reported that pods per plant, harvest index, 100-seed weight, seeds per pod and biological yield showed high direct effect on grain yield.

Yadava and Singh (2008) identified the traits determining tolerance against drought and temperature in chickpea through correlation and path coefficient analyses by evaluating sixteen genotypes in six environments created by adjusting the moisture availability for three subsequent years. Path analysis showed that dry matter accumulation, harvest index and 100-seed weight were the major and stable yield factors under both moisture stress and non-stress environment

Vaghela *et al.*, (2009) reported the highest positive direct effect of biological yield per plant followed by harvest index towards seed yield. The indirect effects of most of the characters through biological yield per plant were higher and positive. The biological yields per plant and harvest index were found to be the most valuable traits for formulating selection criterion to improve seed yield in chickpea.

Shukla and Babbar (2011) studied association and path coefficient analysis of various morpho-phenological characters with yield in thirty heat tolerant lines under three environments. Very high magnitude of genotype x environment interaction were found in yield and its component characters.

2.3 Study for Drought Tolerance

Gupta *et al.*, (2000) reported that having low drought susceptibility index genotypes exhibited capacity to tolerate drought stress condition.

Mhase *et al.*, (2003) reported that maturity was hastened by 4-5 days and plant height, primary and secondary branches, leaves per plant and pods per plant were reduced due to moisture stress.

Deshmukh *et al.*, (2004) reported that the drought resistant genotype had highest drought tolerance efficiency, minimum drought susceptible index and minimum reduction in grain yield due to moisture stress. They also reported that it maintained highest harvest index and very low values of membrane injury index under stress as well as non-stress condition.

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 and stem 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.

Yadava and Singh (2007) evaluated sixteen genotypes in six environments to identify the traits determining tolerance against drought and temperature in chickpea through correlation and path coefficient analyses. Dry matter accumulation, harvest index and 100 seed weight showed positive and significant association with seed yield in all the environments. Drought tolerance index exhibited negative and significant association with seed filling period, pods per plant, and 100 seed weight. Path analysis revealed that dry matter accumulation, harvest index and 100 seed weight were the major and stable yield factors under both moisture stress and non-stress environments.

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.

Parameshwarappa and Salimath (2008) reported that the drought resistant genotype had highest drought tolerance efficiency, minimum drought susceptible

index and minimum reduction in grain yield due to moisture stress and maintained the highest harvest index (HI) under moisture stress and non-stress conditions.

Canci and Toker (2009) 377 chickpea accessions were sown two months later than normal for the Antalya region (Turkey) to increase their exposure to the drought and high-temperature conditions. Evaluations of the entire trial were made visually on a scale from '1' (free from drought/heat damage) to '9' (all plants died from drought/heat). Yield loss was observed in many of the test genotypes. The *desi* chickpea (smaller, dark seeds) were generally more drought- and heat-resistant than the *kabuli* chickpeas. Two desi chickpeas, ACC 316 and ACC 317, were selected for drought and heat resistance under field conditions. Seed weight was the trait least affected by adverse environmental conditions and having the highest heritability, and it should be used in early breeding selections.

Alwawi *et al.*, (2010) determined the desirable line for chickpea in rainfed sowing; seven local lines (K-6, G-35, D-15, F-20, B-17, H-45 and M-20) were selected from Syrian chickpea landraces. These lines were grown during two seasons 2006-07, 2007-08 at two different locations. The results showed that effect of location (L) and season (E) was highly significant ($P < 0.01$) while the interaction among Locations, Seasons and Genotypes (L x E x G) was not significant ($P > 0.05$). The environmental variance was very low for days to maturity. The results recommended to selection line M-20 that was the desirable line for seed yield per plant as compared to other lines.

Upadhyaya *et al.*, (2011) reported that global warming and extreme temperatures were predicted for future, hence identification of appropriate varieties that could adapt to such changes is imperative for sustaining crop productivity. Thirty-five early maturing chickpea (*Cicer arietinum* L.) germplasm accessions were evaluated for their tolerance to heat stress. Plant traits such as plant width, flowering duration, days to maturity, pod number, seed weight, grain yield and per-day productivity were affected under heat stress. Genotypes differed in their sensitivity to heat stress, and the yield loss among genotypes varied from 10 to 15% of potential yield for every degree increase in temperature beyond the optimum temperature range. ICC 14346 showed high tolerance to heat stress and could be used as a parent in crop improvement research. ICC 5597, ICC 5829, ICC 6121, ICC 7410, ICC 11916, ICC 13124, ICC 14284, ICC 14368, and ICC 14653 were heat stress

tolerant responsive to irrigation and nitrogen management, and consistently high yielding ($>1400 \text{ kg ha}^{-1}$) compared to control ICCV 92944 (1333 kg ha^{-1}).

CHAPTER – III

MATERIAL AND METHODS

3.1 Experimental site

The present investigation was carried out in the experimental field of AICRPDA College of Agriculture Indore (M.P.) during *Rabi* season of 2013-14.

3.2 Location and climate

Indore is situated at 22°43' North latitude and 75°66' East longitude with an altitude of 555.7 meter above the mean sea level in *Malwa* plateau of western Madhya Pradesh. This region belongs to sub-tropical semi-arid region with an average annual rainfall of 954.5 mm. Most of the rains are received through South West Monsoon during rainy season i.e., mid June to third week of September.

The mean of minimum and maximum temperature ranges between 6°-25°C and between 23-43°C, respectively. December and January being the coldest month while the temperature attains its peak towards the end of May.

The total rainfall received during the crop season 2013-14 was 50.2 mm with 7 rainy days, the maximum temperature range from 19.68°C to 34.58°C, and minimum temperature range from 8.87°C to 22.50°C and relative humidity 50.42 to 90.71%.

3.3 Experimental material

Two sets of nine chickpea genotypes were evaluated under drought stress (rain-fed) and non-stress (irrigated) conditions separately. The experiment was laid out in Randomized Block Design with three replications. The material was sown on November 14, 2013 with row to row distance of 40 cm and plant to plant 10 cm. All recommended package of practices were followed during the conduction of experiment to harness the maximum potential of the genotypes under study. Two irrigations were given at the time of branch formation and pod formation stage in second set of experiment non stress conditions.

Table 3.1 Meteorological data observed during crop growth period (November 2013 to April 2014)

SMW	Date	Temperature (°C)		RH (%)	Wind velocity (km/hr)	Rainfall (mm)	No. of rainy days
		Max.	Min.				
44	1 Nov to 3 Nov	30.2	15.3	81.6	1.1	0.0	0
45	4 Nov to 10 Nov	29.1	15.0	77.4	2.0	0.0	0
46	11 Nov to 17 Nov	27.0	12.8	77.0	2.1	0.0	0
47	18 Nov to 24 Nov	26.8	8.1	79.2	2.1	0.0	0
48	25 Nov to 1 Dec	27.9	11.0	79.8	2.5	0.0	0
49	2 Dec to 8 Dec	27.2	12.6	77.2	1.9	2.2	0
50	9 Dec to 15 Dec	25.4	8.5	80.5	1.6	0.0	0
51	16 Dec to 22 Dec	25.8	7.3	81.5	2.1	0.0	0
52	23 Dec to 29 Dec	24.1	6.5	81.5	3.2	0.0	0
53	30 Dec to 31 Dec	23.5	7.8	77.0	4.1	0.0	0
1	1 Jan to 7 Jan	24.8	7.9	78.7	3.5	0.0	0
2	8 Jan to 14 Jan	23.4	6.9	78.5	3.5	0.0	0
3	15 Jan to 21 Jan	23.1	6.8	79.1	4.4	0.0	0
4	22 Jan to 28 Jan	20.4	7.1	85.7	3.4	0.0	0
5	29 Jan to 4 Feb	25.2	6.6	78.4	2.2	0.0	0
6	5 Feb to 11 Feb	26.8	8.1	78.7	3.0	0.0	0
7	12 Feb to 18 Feb	22.4	8.0	80.5	4.0	0.6	0
8	19 Feb to 25 Feb	26.6	6.8	76.2	4.0	11.6	1
9	26 Feb to 4	27.1	8.24	79.2	4.7	30	2
10	5 March to 11	27.8	10.1	78.2	4.0	0.0	0
11	12 March to 18	32.9	12.8	77.5	3.4	0.0	0
12	19 March to 25	34.4	14.2	80.5	4.5	0.0	0
13	26 March to 1	36.4	17.3	81.5	4.3	0.0	0
14	2 April to 8 April	36.5	19.0	78.0	4.8	0.0	0
15	9 April to 15 April	37.2	18.8	76.2	4.2	0.0	0
16	16 April to 22	38.4	20.9	78.0	4.2	0.0	0
17	23 April to 29	40.1	20.7	75.0	3.5	2.4	0
18	30 April to 4 th May	41.3	21.7	77.4	5.1	0.0	0
Total						46.8	3

SOURCE: Meteorological observatory AICRPDA, College of Agriculture, Indore (M.P.)

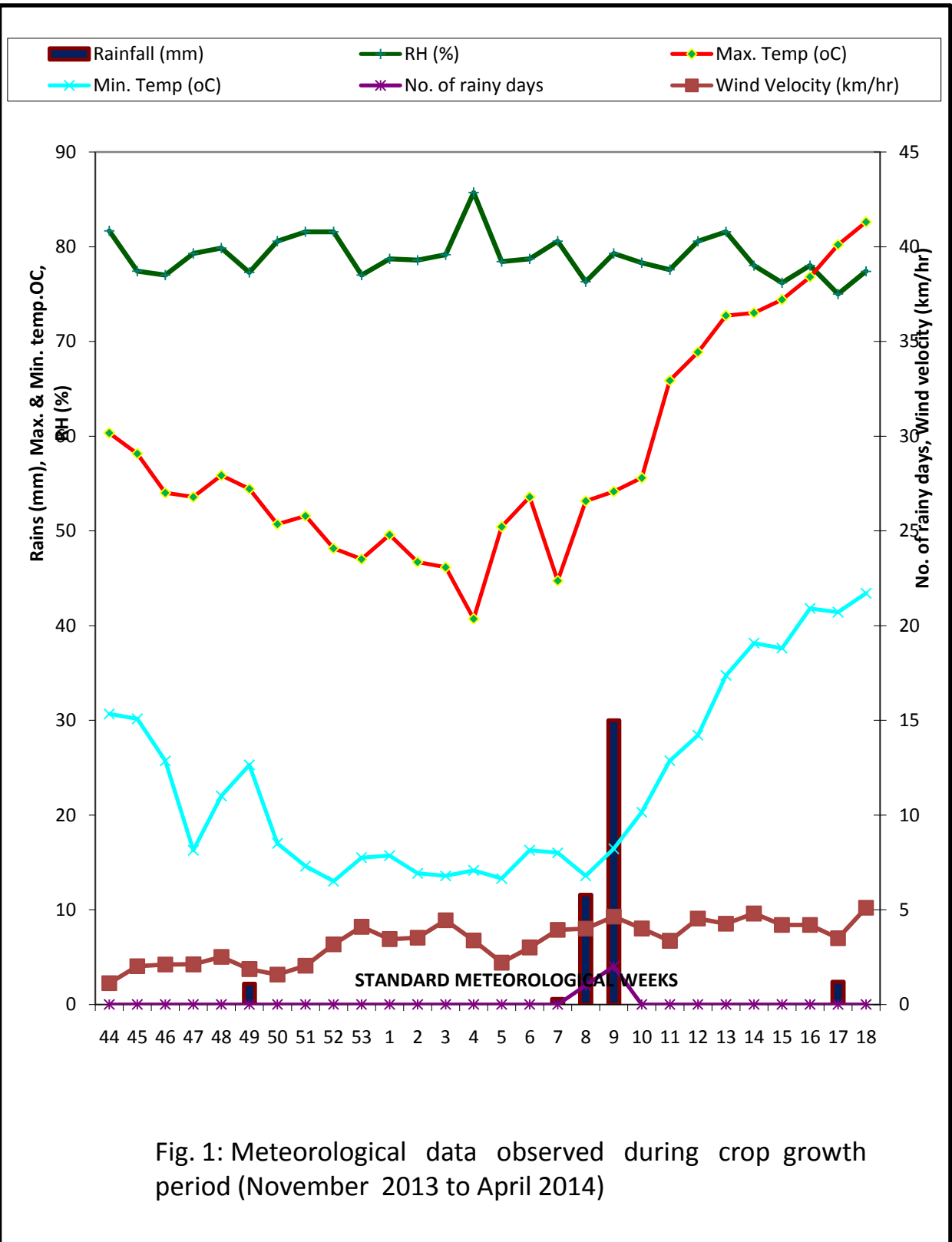


Fig. 1: Meteorological data observed during crop growth period (November 2013 to April 2014)

Table 3.2: Detail of experimental material (chickpea genotype) used for present investigation.

S. No.	Varieties	Characteristics			
		Maturity (days)	Yield (q/ha)	Distinguishing characters	Remarks
1	Ujjain 21	95-100	15-16	Early, seeds medium with rough seed coat.	Wider adaptability, suitable for rainfed condition and susceptible to Fusarium wilt.
2	JAKI - 9218	112	18-20	Semi spreading Profuse branching Light brown bold seed	Resistant to lodging shattering Rain fed / Irrigated conditions
3	IG-593	100-110	15-18	Bold seeded and spreading Profuse branching	Resistant to lodging shattering Rain fed
4	JG-6	105-108	12-15	Dark brown large seeds of angular shape and smooth surface	Resistant to fusarium wilt, moderately resistant to dry root rot
5	JG-16	110-115	18-20	Semi spreading Profuse branching	Dark foliage Light brown Medium bold Attractive seed
6	JG-130	110-115	15-16	Suitable for rainfed as well as both irrigated condition under timely sown condition	Wilt-resistant, dry root rot and pod borer-tolerance
7	JG 412	100-105	17-18 (rainfed) 20-22 (irrigated)	Brown coloured, bold seeded (26-28 g/100 seeds), fresh green pods very tasty, good perching quality of seed.	Suitable to both rainfed and irrigated conditions, tolerant to wilt.
8	JG-11	95-100	12-15	Small seeded, Semi spreading	Wilt-resistant and moderately root rot-resistant
9	KAK-2	110-115	16-20	Foliage-light green, <i>Kabuli</i> type seeds of extra bold sized.	Suitable for rainfed, irrigated & late sown conditions.

3.4 Observations recorded

a) Physiological characters

1. Relative leaf water content :

Three leaflets at top , middle and lower parts from 5 plants of each plot were taken for RLWC at flowering and pod formation stage .

The RLWC was calculated by the following formula :

$$\text{RLWC}\% = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100$$

Where ,

FW- Fresh weight (g)

TW- Turgid weight (g)

DW- Dry weight (g).

b) Yield Characters

Observations were recorded on plot as well as single plant basis .Observations on plot basis were recorded for days to flower initiation , days to 50% flowering and days to maturity . For recording single plant observations five competitive plants were randomly selected from each plot. Average of these five plants in respect of plant height , number of primary branches per plant ,number of pods per plant ,number of seeds per pod ,100 seed weight ,biological yield per plant ,harvest Index and seed yield per plant was used for statistical analysis .

The following Observations were recorded:

1. Days to flower initiation :

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

2. Days to 50% flowering:

The number of days required from sowing to 50% plants of the plot to flower (anthesis) was recorded.

3. Days to maturity:

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

4. Plant height (cm):

The height of main shoot of each selected plant was measured in cm from base of the plant to the terminal bud.

5. Number of primary branches per plant:

The number of branches emerging from the main stem was recorded.

6. Number of pods per plant:

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

7. Number of seeds per pod:

It is the ratio of number of seeds per plant and number of pods per plant.

8. Biological yield (g):

The oven dried produce of five tagged plants above the ground level from each net plot was weighed (g) before threshing were recorded .

9. Seed yield per plant (g):

The pods of selected five plants from each plot were threshed and winnowed.

The seeds obtained from each plant were weighed in grams.

10. 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.

11. 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.

3.5 Statistical analysis

3.5.1 Analysis of variance

The data on various characters were subjected to statistical analysis by using appropriate model for analysis of variance and co-variance as per Panse and Sukhatme (1954). The range and estimates of mean , phenotypic, genotypic and environmental variance and covariance, standard error, co-efficient of variation and critical difference were obtained for all the traits. The test of significance between genotypes for various characters was tested by f test. The analysis of variance for experimental design was based on the following model.

$$Y_{ij} = m + g_i + r_j + e_{ij} \quad (i, j = 1, \dots, t) \\ (K = 1, \dots, b)$$

Where,

Y_{ij} = Phenotypic observation of i^{th} genotype in j^{th} replication

M = the population mean

r_j = Effect of j^{th} replication

g_i^s = Genotypic effects which are random variable, distributed independently and normally as $N(0, \sigma^2_g)$

e_{ij}^s = Errors associated with the ij observations, distributed independently and normally $N(0, \sigma^2_g)$.

The mean values of each observation were used for analysis of data for randomized block design (RBD). The skeleton of ANOVA is given below:-

Table 3.3 Skeleton of ANOVA for Randomized Block Design (RBD)

Source of variation	Degree of freedom	MSS	'F' Calculated
Replications	(r-1)	M_r	M_r/M_e
Genotypes	(g-1)	M_g	M_g/M_e
Error	(r-1)(g-1)	M_e	

Where,

r = Number of replications

g = Number of genotypes

M_r = Mean sum of squares for replications

M_g = Mean sum of squares for genotypes

M_e = Error mean sum of squares

d.f. = degree of freedom

3.5.3 Estimation of phenotypic and genotypic coefficients of variation:

The phenotypic and genotypic coefficient of variation in percent were computed by the following formulae by Burton (1952).

$$\text{Phenotypic Coefficients of Variation (PVC)} = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Mean}} \times 100$$

$$\text{Genotypic Coefficients of Variation (GVC)} = \frac{\sqrt{\text{Genotypic variance}}}{\text{Mean}} \times 100$$

3.5.4. Estimation of heritability and genetic advance:

Heritability

Heritability in broad sense (%) was estimated as:

$$\text{Heritability in broad sense} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Genetic advance

The estimates of genetic advance from selection, $G(s)$, were obtained by formula suggested by Robinson *et al.* (1949):

$$G(s) = k \times h^2 \times \sigma_p$$

Where,

K = Selection differential in standard deviation units which is 2.06 for 5% selection intensity

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

3.5.5. Estimation of correlation coefficients:

Phenotypic and genotypic correlation coefficients between characters were computed utilizing respective components of variance and co-variance, as per the formula suggested by Miller *et al.* (1958).

$$r_{xy} = \frac{\text{Co variance } x,y}{\sqrt{(\text{Variance } x) \cdot (\text{Variance } y)}} \times 100$$

Where,

r_{xy} = correlation coefficient between character x and y

$\text{Cov } (x,y)$ = Co- variance of characters x and y

$V(x)$ = Variance of character x

$V(y)$ = Variance of character y

To test the significance of correlation coefficients, the estimated values were compared with the tabulated values at (t-2) d.f. at 0.05 and 0.01 probability level.

3.5.6. Path coefficient analysis:

The proportion of direct and indirect contributions of various characters to the total correlation coefficients was estimated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

To estimate various direct and indirect effects, the following sets of simultaneous equations were formed and solved.

$$r_{1y} = P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \dots + r_{1l} P_{ly}$$

$$r_{2y} = r_{2y} P_{1y} + P_{2y} + r_{23} P_{3y} + \dots + r_{2l} P_{ly}$$

$$r_{1y} = r_{11} P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \dots + p_{ly}$$

Where,

r_{1y} to r_{ly} = Correlation coefficient between casual factor 1 to l and dependent character y.

r_{12} to $r_{l-1,l}$ = Correlation coefficient among casual factor themselves.

P_{1y} to P_{ly} = Direct effects of characters 1 to l on character y.

Residual effect, which measures the contribution of the characters not considered in the casual scheme, was obtained as:

$$\text{Residual effect } (P_{RY}) = \sqrt{1 - R^2}$$

Where,

$$R^2 = \sum P_i^2 Y + 2 \sum_{\substack{i, j \\ i > j}} P_{iy} P_{jy} R_{ij}$$

3.6. Study for drought tolerance:

(1) Relative performance of genotypes under drought stress and non-stress conditions for all the traits under study.

(2) Seed yield (kg/ha) and drought tolerance related characters influenced by different genotypes:

(i) Percent reduction due to drought stress:

This was estimated by the following formula:-

$$\text{Percent reduction due to drought stress} = \frac{Y_{i0} - Y_{i1}}{Y_{i1}} \times 100$$

Where,

Y_{i0} -yield under drought stress condition
 Y_{i1} -yield under non-stress condition

(ii) Drought Index (DI):

This was estimated by the following formula:-

$$DI = \frac{\text{Yield under drought stress condition}}{\text{Yield under non-stress condition}}$$

(iii) Drought tolerance efficiency (DTE):

This was estimated as per the procedure outlined by Fisher and Maure (1978).

$$DTE (\%) = \frac{\text{Yield under drought stress condition}}{\text{Yield under non-stress condition}} \times 100$$

(iv) Drought susceptibility index (DSI):

Drought susceptibility index (DSI) was calculated by the formula given by Fischer and Maurer (1978).

$$DSI = (1 - Y_{I0}/Y_{I1}) / D$$

Where,

Y_{I0} = Grain yield of the genotype under drought stress condition

Y_{I1} = Grain yield of the genotypes under non-stress condition

$$D = \frac{\text{Mean yield of all strains under moisture drought stress condition}}{\text{Mean yield of all strains under non-stress condition}}$$

(3) Amount and rate of dry matter accumulation in plant at 15 days intervals under drought stress and non-stress conditions:

Three plants are selected from each plot randomly and their fresh weights were taken with the help of electrical balance and then their dry weight are taken.

Amount of Dry matter accumulation (g/plant) was calculated by the following formula :-

$$\text{Amount of dry matter accumulation (g/plant)} = \text{Fresh weight} - \text{Dry weight}$$

Rate of dry matter accumulation (g/plant) was calculated by the following formula:

$$\text{Rate of dry matter accumulation (g/plant)} = \frac{\text{Amount of dry matter accumulation}}{\text{Age of plant (Day)}}$$

(4) Study the depletion of soil moisture in soil profile during the crop season under drought stress and non-stress conditions. :-

Soil samples are taken with the help of gravimetric method at 15 cm, 30 cm and 45 cm depth at every 15 days of interval. Fresh weight and dry weight of soil samples are taken with the help of electrical balance. Soil moisture Content (%) by weight was calculated by the following formula:-

$$\text{Soil moisture content (\%)} = \frac{\text{Wt. of moist soil (g)} - \text{Wt. of oven dry soil (g)}}{\text{Wt. of oven dry soil (g)}} \times 100$$

CHAPTER – IV

RESULTS

The results obtained from the present investigation “Relative performance of chickpea genotypes under drought stress and non-stress situations” are presented under the following.

4.1 Analysis of variance

4.2 Genetic Variability

4.2.1 Mean performance of the genotypes.

4.2.2 Coefficient of variation

4.2.3 Heritability

4.2.4 Genetic advance

4.3 Correlation Coefficient analysis

4.4 Path coefficient analysis

4.5 Study on drought tolerance

4.1 Analysis of variance

The analysis of variances for all the characters studied in drought stress and non-stress situations and has been presented in Table 4.1a and b. The mean differences due to genotypes were highly significant for all the characters except number of seeds pod⁻¹ under stress condition (Table 4.1a) where as highly significant difference among genotypes under non-stress condition (Table 4.1b).

Table 4.1a: Analysis of variance for various physiological and yield contributing traits of chickpea under drought stress condition (mean square)

Characters d.f.	Source of variation		
	Replications 2	Genotypes 8	Error 16
Physiological traits			
R.W.C at flowering stage	1.765	50.048**	3.505
R.W.C at pod formation stage	4.875	109.527**	5.082
W.S.D at flowering stage	1.773	50.048**	3.503
W.S.D at pod formation stage	4.878	109.527**	5.083
Days to flower initiation	2.480	56.259**	1.523
Days to 50% flowering	13.812	67.342**	3.731
Days to maturity	6.703	49.092**	4.578
Vegetative phase (days)	17.371	47.120**	10.661
Reproductive phase (days)	11.257	140.398**	1.634
Days to pod initiation	9.593	47.925**	4.425
Yield contributing traits			
Plant height at maturity (cm)	28.321	55.620**	1.024
Number of branches plant ⁻¹	0.259	11.731**	2.884
Number of pods plant ⁻¹	10.111	201.666**	45.152
Number of seeds pod ⁻¹	0.037	0.0648	0.0787
Biological yield plant ⁻¹ (g)	19.878	228.525**	0.432
Test weight (g)	4.703	137.717**	5.234
Harvest index (%)	119.946	84.495**	13.555
Seed yield plant ⁻¹ (g)	32.383	78.603**	1.521

Table 4.1b: Analysis of variance for various physiological and yield contributing traits of chickpea under non-stress condition (mean square)

Characters d.f.	Source of variation		
	Replications 2	Genotypes 8	Error 16
Physiological traits			
R.W.C at flowering stage	1.162	10.139*	2.770
R.W.C at pod formation stage	15.251	69.190**	2.221
W.S.D at flowering stage	1.240	10.160*	2.769
W.S.D at pod formation stage	23.574	65.862**	3.715
Days to flower initiation	8.444	179.750**	8.986
Days to 50% flowering	26.925	155.092**	10.092
Days to maturity	3.370	23.314**	4.162
Vegetative phase (days)	10.333	151.416**	10.375
Reproductive phase (days)	3.814	134.564**	8.648
Days to pod initiation	41.592	220.759**	23.384
Yield contributing traits			
Plant height at maturity (cm)	19.507	31.180**	0.432
Number of branches plant ⁻¹	12.259	14.481**	0.217
Number of pods plant ⁻¹	21.925	154.898**	0.300
Number of seeds pod ⁻¹	0.066	0.166**	0.310
Biological yield plant ⁻¹ (g)	27.011	176.948**	1.499
Test weight (g)	19.564	200.918**	0.460
Harvest index (%)	36.384	131.588**	0.865
Seed yield plant ⁻¹ (g)	30.522	65.643**	0.996

4.2 Genetic variability

4.2.1 Mean performance of genotypes

Under drought stress and non-stress situations mean and range maximum and minimum of all the nine genotypes for all the eighteen characters are depicted in Table 4.2 and 4.3

4.2.1.1 Physiological traits

4.2.1.1.1 R.W.C at flowering stage (%)

Relative water content at flowering stage ranged from 74.19 %(JAKI-9218) to 85.43%(JG-130) and 85.80%(JAKI-9218) to 91.33%(JG-130) in stress and non-stress situations, respectively. The overall mean performance of 81.60% and 88.83% were recorded under stress and non-stress situations, respectively. The maximum relative water content per cent 85.43% and 91.33% were observed in genotypes JG-130 at stress and non-stress situations, respectively. While, it's were recorded minimum 74.19% and 85.80% in JAKI-9218 at both situations respectively.

4.2.1.1.2 R.W.C at pod formation stage(%)

Relative water content per cent at pod formation stage varied from 65.07%(Ujjain-21) to 83.76%(IG-593) and 72.63%(Ujjain-21) to 86.50%(IG-593) and overall mean performance of 76.06% and 80.29% were recorded at stress and non-stress situations, respectively. The genotype viz., IG-593 exhibited the maximum 83.76% and 86.50% relative water content per cent at pod formation stage under stress and non-stress situations, while genotype Ujjain-21 showed minimum mean 65.07% and 72.63% under stress and non-stress situations, respectively for the same.

4.2.1.1.3 W.S.D at flowering stage

W.S.D at flowering stage varied from 14.57%(JG-130) to 25.81%(JAKI-9218) and 8.67%(JG-130) to 14.20%(JAKI-9218) with an overall mean performance of 18.39% and 11.16% under stress and non-stress situations, respectively. The significantly maximum 25.81% and 14.20% W.S.D at flowering stage was observed in genotype JAKI-9218, while, the minimum (14.57 and 8.67%) W.S.D was recorded in JG-130 under stress and non-stress situations, respectively.

4.2.1.1.4 W.S.D at pod formation stage

W.S.D at pod formation stage varied from 16.24 % (IG-593) to 34.93%(Ujjain-21) and 13.50%(IG-593) to 27.37%(Ujjain-21) with an overall mean performance of 23.93% and 19.48% under stress and non-stress situations, respectively. The maximum W.S.D at pod formation stage was observed in Ujjain-21(34.93% and 27.37%) while, it was observed minimum in IG-593(16.24% and 13.50%) under stress and non-stress situations, respectively.

4.2.1.1.5 Days to flower initiation

The mean for days to flower initiation was 45.14 days and it ranged from 40.0 to 50.67 days. Maximum days to flower initiation were noted in JG-6(50.67 days) and it revealed earliest days to flower initiation in genotype JG-412(40.0 days) under stress situations. It was ranged from 39.33 (KAK-2) to 66.0 days (IG-593) and over all mean performance of 58.44 days was observed at non-stress situations.

4.2.1.1.6 Days to 50% flowering

The mean for days to 50% flowering was 56.81 days and it ranged from 49.67 to 61.33 days. Maximum days to 50% flowering were noted in JG-6 (61.33 days) and it revealed earliest days to 50% flowering in genotype JG-412 (49.67 days) under stress situations. It was ranged from 56.00 (KAK-2) to 82.0 days (IG-593) and over all mean performance of 70.81 days was observed at non-stress situations.

4.2.1.1.7 Days to maturity

Days to maturity ranged between 104.0 to 116.0 days and the mean for all genotype was 111.85 days. Genotype KAK-2 recorded considerably maximum (116.0) days, while genotype JG-16 expressed minimum (104.0) days under stress situations. At non-stress situations, it was ranged from 118.33 to 127.0 days with an overall mean of 121.92 days. Genotype KAK-2 recorded considerably maximum (127.0) days, while genotype JG-16 expressed minimum (118.33) days

Table 4.2: Mean performance of physiological contributing traits of chickpea under drought stress and non-stress condition

Genotypes		R.W.C at flowering stage	R.W.C at pod formatio n stage	W.S.D at flowerin g stage	W.S.D at pod formation stage	Days to flower initiatio n	Days to 50% flowerin g	Days to maturity	Vegetative phase (days)	Reproducti ve phase (days)	Days to pod initiation
JG-130	S	85.43	73.90	14.57	26.10	48.33	60.33	107.67	48.33	59.33	60.67
	NS	91.33	84.33	8.67	15.67	57.33	69.33	119.67	57.33	62.33	83.00
IG-593	S	85.25	83.76	14.75	16.24	45.00	59.67	114.67	45.00	69.67	59.33
	NS	87.60	86.50	12.40	13.50	66.00	82.00	122.00	66.00	56.00	87.00
JG-6	S	84.37	81.50	15.63	18.50	50.67	61.33	109.00	50.67	58.33	61.00
	NS	89.13	82.43	10.87	15.57	61.00	74.00	121.00	61.00	60.00	83.33
JAKI-9218	S	74.19	75.80	25.81	24.20	42.00	55.67	113.00	42.00	71.00	54.67
	NS	85.80	78.70	14.20	21.30	64.33	76.33	125.67	54.67	71.00	77.33
KAK-2	S	81.97	82.77	18.03	17.23	40.33	50.33	116.00	40.33	75.67	51.67
	NS	90.27	86.03	9.73	13.97	39.33	56.00	127.00	61.67	65.33	58.00
JG-16	S	83.60	74.44	16.40	25.56	49.00	60.67	104.00	49.00	55.00	59.33
	NS	90.10	78.67	9.90	21.33	60.67	71.00	118.33	60.67	57.67	78.33
Ujjain-21	S	78.46	65.07	21.54	34.93	49.67	60.67	113.00	49.67	63.33	61.00
	NS	87.40	72.63	12.60	27.37	61.33	73.33	120.33	40.67	79.67	80.00
JG-11	S	76.94	70.63	23.06	29.37	41.33	53.00	114.67	50.33	64.33	55.67
	NS	87.47	77.67	12.53	20.53	57.33	67.67	121.00	57.33	63.67	85.67
JG-412	S	84.27	76.73	15.73	23.27	40.00	49.67	114.67	57.00	57.67	51.00
	NS	90.40	75.67	9.60	24.10	58.67	67.67	122.33	56.67	65.67	79.67
SEm±	S	1.08	1.30	1.08	1.30	0.71	1.11	1.23	1.88	0.73	1.21
	NS	0.96	0.86	0.96	1.11	1.73	1.83	1.17	1.85	1.69	2.79
C.D. at 5% level	S	3.23	3.90	3.23	3.90	2.13	3.34	3.70	5.65	2.21	3.64
	NS	2.88	2.58	2.88	3.33	5.18	5.49	3.53	5.57	5.09	8.37

S- DROUGHT STRESS CONDITION

NS-NON-STRESS CONDITION

4.2.1.1.8 Vegetative phase (days)

Vegetative phase varied from 40.33 to 57.0 days with average of 47.37 days. The genotype JG-412 recorded maximum vegetative phase, while, genotype KAK-2 exhibited 40.33 days was least under stress situations. At non-stress situations, it was ranged from 40.67 to 66.0 days with an overall mean of 57.33 days. Genotype IG-593 recorded considerably maximum (66.0) days, while genotype Ujjain-21 expressed minimum (40.67) days.

4.2.1.1.9 Reproductive phase (days)

Reproductive phase (days) varied from 55.0 to 75.67 days with average of 63.92 days. The genotype KAK-2 recorded long reproductive phase (75.67 days), while, genotype JG-16 exhibited short reproductive phase (55.0 days) under stress situations. Similarly genotype Ujjain-21 recorded long reproductive phase (79.67 days), while, genotype IG-593 exhibited short reproductive phase (56.0 days) under non stress situations.

4.2.1.1.10 Days to pod initiation

Days to pod initiation ranged between 51.0 to 61.0 and average was calculated to be 57.14. The maximum (61.0) days to pod initiation was noted in JG-6 and Ujjain-21, while, it was observed minimum (51.0) in the genotypes JG-412 under stress situations. Similarly genotype IG-593 was recorded maximum (87.0) days to pod initiation, while, genotype KAK-2 exhibited minimum (58.0) days under non-stress situations.

4.2.1.2 Yield contributing traits

4.2.1.2.1 Plant height at maturity (cm)

Plant height ranged from 40.67 to 55.60 cm and 55.0 to 65.87 cm and overall mean performance in 46.36 and 60.13 cm were recorded under stress and non-stress situations, respectively. The maximum plant height 55.60 cm and 65.87 cm were observed in genotypes IG-593 under stress and non-stress situations, respectively. While, it's were recorded minimum 40.67 cm and 55.0 cm in JG-11 under stress and non-stress situations, respectively.

4.2.1.2.2 Number of branches plant⁻¹

Number of branches plant⁻¹ ranged between 5.33 to 10.0 and 6.0 to 11.67 and average was calculated to be 7.40 and 8.07 cm at stress and non-stress situations, respectively. The maximum branches plant⁻¹ was noted in KAK-2 (10.0 and 11.67) while, it was observed minimum (5.33 and 6.0) in the genotype JG-130 at stress and non-stress situations, respectively.

4.2.1.2.3 Number of pods plant⁻¹

Number of pods plant⁻¹ ranged between 41.33 to 63.0 and 43.67 to 63.67 pods with an overall mean performance of 50.33 and 54.07 pods at stress and non-stress situations, respectively. The maximum 63.0 and 63.67 pods plant⁻¹ were recorded in genotype KAK-2, while, it was recorded least in genotype Ujjain-21 (41.33 and 43.67) at stress and non- stress situations, respectively.

4.2.1.2.4 Number of seeds pod⁻¹

Number of seeds pod⁻¹ ranged between 1.0 to 1.33 and 1.0 to 1.67 seeds pod⁻¹, while, the average, was 1.07 and 1.11 seeds pod⁻¹ at stress and non-stress situations, respectively. The maximum 1.33 seeds pod⁻¹ was observed in genotypes IG-593 and JG-11 and it was found in least 1.00 in remaining genotypes under stress situations. Similarly under non stress situations, the maximum 1.67 and 1.33 seeds pod⁻¹ was observed in genotypes KAK-2 and JG-16 and remaining genotypes exhibited 1.0 seeds pod⁻¹.

4.2.1.2.5 Biological yield plant⁻¹ (g)

This trait ranged between 23.13 to 50.93 g and 29.67 to 55.67 g with an overall mean of 32.16 g and 45.29 g at stress and non-stress situations, respectively. Genotypes KAK-2 was recorded maximum 50.93 and 55.67 g biological yield but it was minimum in genotype Ujjain-21(23.13 and 29.67 g) at stress and non-stress situations, respectively.

Table 4.3: Mean performance of yield contributing traits of chickpea under drought stress and non-stress condition									
Genotypes		Plant height	Number of	Number of	Number of	Biological	Test	Harvest	Seed yield
		at maturity	branches	pods plant ⁻¹	seeds pod ⁻¹	yield plant ⁻¹	weight	index (%)	plant ⁻¹ (g)
		(cm)	plant ⁻¹			(g)	(g)		
JG-130	S	44.47	5.33	54.67	1.00	33.70	24.67	49.16	16.55
	NS	62.33	6.00	56.33	1.00	50.60	25.17	53.97	26.87
IG-593	S	55.60	8.33	45.67	1.33	31.93	35.33	47.50	15.21
	NS	65.87	7.00	48.00	1.00	46.20	37.00	50.10	21.67
JG-6	S	42.67	5.67	57.00	1.00	34.33	32.50	41.38	14.28
	NS	59.33	7.00	61.00	1.00	49.13	34.67	39.20	19.97
JAKI-9218	S	47.20	6.00	42.33	1.00	37.99	26.83	41.02	15.60
	NS	60.33	11.00	48.33	1.00	41.70	26.33	49.10	24.47
KAK-2	S	47.00	10.00	63.00	1.00	50.93	38.17	52.70	26.72
	NS	61.00	11.67	63.67	1.67	55.67	44.33	54.33	29.23
JG-16	S	44.67	9.67	58.67	1.00	28.80	19.83	52.35	15.20
	NS	56.00	7.33	59.33	1.33	41.67	21.50	51.87	20.33
Ujjain-21	S	45.67	6.33	41.33	1.00	23.13	18.00	37.44	11.05
	NS	60.67	6.00	43.67	1.00	29.67	18.67	39.10	19.50
JG-11	S	40.67	9.67	48.67	1.33	23.63	24.67	43.56	10.30
	NS	55.00	10.00	58.67	1.00	41.58	24.67	42.93	16.20
JG-412	S	49.33	5.67	41.67	1.00	25.07	28.83	47.67	9.41
	NS	60.67	6.67	47.67	1.00	51.33	28.00	38.47	15.03
SEm±	S	0.58	0.98	3.87	0.16	0.37	1.32	2.12	0.71
	NS	0.37	0.26	0.31	0.10	0.70	0.39	0.53	0.57
C.D. at 5% level	S	1.75	2.93	11.63	N.S.	1.13	3.96	6.37	2.13
	NS	1.13	0.80	0.94	0.30	2.11	1.17	1.61	1.72
S- DROUGHT STRESS CONDITION					NS-NON-STRESS CONDITION				

4.2.1.2.6 Test weight (g)

Test weight varied from 18.0 to 38.17 g and 18.67 to 44.33 g with an overall average weight of 27.64 and 28.92 g at stress and non- stress situations, respectively. The genotype KAK-2 exhibited maximum 38.17 and 44.33 g test weight, while genotype Ujjain-21 recorded minimum 18.0 and 18.67 g test weight.

4.2.1.2.7 Harvest index (%)

Harvest index varied from 37.44% to 52.70% and 39.10% to 54.33% with an overall mean performance of 45.86% and 46.56% at stress and non-stress situations, respectively. Genotype KAK-2 was recorded maximum (52.70% and 54.33%) harvest index, while, it was recorded lowest in genotypes Ujjain-21 (37.44% and 39.10%) at stress and non-stress situations, respectively.

4.2.1.2.8 Seed yield plant⁻¹ (g)

Maximum seed yield plant⁻¹ was recorded in KAK-2 (26.72 and 29.23 g) and minimum in Ujjain-21 (9.41 and 15.03 g) at stress and non- stress situations, respectively. It was varied from 9.41 to 26.72 g and 15.03 to 29.23 g and overall mean performance of 14.92 g and 21.47g at stress and non stress situations, respectively.

4.2.2 Coefficient of variation

Estimation of components of genetic parameters of variation for physiological, yield and its contributing characters exhibited a wide range of variation for the characters studied. Result indicated that the values of phenotypic coefficient of variation were of higher magnitude than that of genotypic coefficient of variation for all the characters.

4.2.2.1 Drought Stress situations:

The highest phenotypic coefficient of variation was observed for seed yield plant⁻¹(34.95), followed by number of branches plant⁻¹ (32.61), biological yield plant⁻¹(27.18), W.S.D at pod formation stage (26.39), test weight (25.42), number of seeds pod⁻¹ (25.34) and W.S.D at flowering stage (23.71). Days to maturity (3.94), R.W.C at flowering stage (5.34), days to pod initiation (7.61), R.W.C at pod formation stage (8.30), days to 50 per cent flowering (8.76) plant height at maturity (9.46), days to

flower initiation (9.85), vegetative phase (10.08) and reproductive phase (10.83) showed the low estimate of PCV under stress condition.

Moderate phenotypic coefficient of variation was recorded for harvest index (13.30) and number of pods plant⁻¹(19.60).

The highest genotypic coefficient of variation was observed for seed yield plant⁻¹ (33.96), followed by biological yield plant⁻¹ (27.10), W.S.D at pod formation stage (24.65), test weight (24.04) number of branches plant⁻¹ (23.18) and W.S.D at flowering stage (21.42) whereas days to maturity (3.44), R.W.C at flowering stage (4.83), number of seeds pod⁻¹ (6.33), days to pod initiation (6.66), vegetative phase (7.36), R.W.C at pod formation stage (7.76), days to 50 per cent flowering (8.10), plant height at maturity (9.20) and days to flower initiation (9.46) showed the low estimate of GCV under stress condition.

Moderate genotypic coefficient of variation was recorded for harvest index (10.60), reproductive phase (10.64) and number of pods plant⁻¹ (14.35) in (Table 4.4)

4.2.2.2 Non- stress situations:

The phenotypic coefficient of variation was highest for test weight (28.36) followed by number of branches plant⁻¹ (27.62), W.S.D at pod formation stage (25.37), number of seeds pod⁻¹ (24.90), seed yield plant⁻¹ (22.11) and W.S.D at flowering stage (20.49). However R.W.C at flowering stage (2.57), days to maturity (2.66), plant height at maturity (5.44), and R.W.C at pod formation stage (6.17) showed the low estimate of PCV under non-stress condition.

Moderate phenotypic coefficient of variation was recorded for reproductive phase (10.68), days to 50 per cent flowering (10.79), days to pod initiation (11.93), vegetative phase (13.21), number of pods plant⁻¹ (13.31), days to flower initiation (13.89), harvest index (14.32) and biological yield plant⁻¹ (17.10).

The genotypic coefficient of variation was highest for test weight (28.26), followed by number of branches plant⁻¹ (27.01), W.S.D at pod formation stage (23.36) and seed yield plant⁻¹ (21.62).while, R.W.C at flowering stage (1.76), days to maturity (2.07), plant height at maturity (5.32), R.W.C at pod formation stage (5.88), reproductive phase (9.73) and days to 50 per cent flowering (9.82) showed the low estimate of GCV under non-stress condition.

Moderate genotypic coefficient of variation was recorded for, days to pod initiation (10.25), vegetative phase (11.96), days to flower initiation (12.91), number of pods plant⁻¹ (13.28), W.S.D at flowering stage (14.06), harvest index (14.18), biological yield plant⁻¹ (16.89) and number of seeds pod⁻¹ (19.10).

The difference between PCV and GCV was less for days to flower initiation, days to 50% flowering, days to maturity, reproductive phase, plant height at maturity and biological yield plant⁻¹ under stress condition, however the difference between PCV and GCV was less for number of branches plant⁻¹, number of pods plant⁻¹, test weight and harvest index under non-stress condition.

4.2.3 Heritability

Heritability (broad sense) was computed for each trait under study in drought stress and non-stress conditions and is presented in Table (4.4)

4.2.3.1 Stress situations:

Heritability was recorded from 6.25 % for number of seeds pod⁻¹ to 99.43 % for biological yield plant⁻¹ (Table 4.4). The values of heritability were found high for characters viz, biological yield plant⁻¹ (99.43%), followed by reproductive phase (96.60%), plant height at maturity (94.67%), seed yield plant⁻¹ (94.41%) and days to flower initiation (92.30%), test weight (89.40%), R.W.C at pod formation stage (87.30%), W.S.D at pod formation stage (87.30%), days to 50 per cent flowering (85.0%), R.W.C at flowering stage (81.60%), W.S.D at flowering stage (81.60%), days to pod initiation (76.60%) and days to maturity (76.40%) however it was recorded to be medium for number of branches plant⁻¹ (50.56%), vegetative phase (53.30%), number of pods plant⁻¹ (53.61%), and harvest index (63.56%). Low estimate of heritability was recorded for number of seeds pod⁻¹ (6.25%), However it was recorded to be medium for number of branches plant⁻¹ (50.56%), vegetative phase (53.30%), number of pods plant⁻¹ (53.61%) and harvest index (63.56%).

Table 4.4: Genetic parameters in different characters of chickpea under drought stress and non- stress condition

Characters		Grand Mean	Range		Coefficient of variations		Heritability % (BS)	Genetic Advance	GA as % of mean
			Min.	Max.	Phe.	Gen.			
R.W.C at flowering stage	S	81.60	74.19	85.43	05.34	04.83	81.60	07.33	08.98
	NS	88.83	85.80	91.33	02.57	01.76	47.00	02.21	02.49
R.W.C at pod formation stage	S	76.06	65.07	83.76	08.30	07.76	87.30	11.35	14.92
	NS	80.29	72.63	86.50	06.17	05.88	90.95	09.28	11.56
W.S.D at flowering stage	S	18.39	14.57	25.81	23.71	21.42	81.60	07.33	39.86
	NS	11.16	08.67	14.20	20.49	14.06	47.07	02.22	19.88
W.S.D at pod formation stage	S	23.93	16.24	34.93	26.39	24.65	87.30	11.35	47.43
	NS	19.48	13.50	27.37	25.37	23.36	84.79	08.63	44.32
Days to flower initiation	S	45.14	40.00	50.67	09.85	09.46	92.30	08.45	18.72
	NS	58.44	39.33	66.00	13.89	12.91	86.37	14.44	24.72
Days to 50% flowering	S	56.81	49.67	61.33	08.76	08.10	85.00	08.75	15.40
	NS	70.81	56.00	82.00	10.79	09.82	82.73	13.03	18.40
Days to maturity	S	111.85	104.00	116.0	03.94	03.44	76.40	06.94	06.20
	NS	121.92	118.33	127.00	02.66	02.07	60.54	04.05	03.32
Vegetative phase (days)	S	47.37	40.33	57.00	10.08	07.36	53.30	05.24	11.06
	NS	57.33	40.67	66.00	13.21	11.96	81.92	12.78	22.30
Reproductive phase (days)	S	63.92	55.00	75.67	10.83	10.64	96.60	13.77	21.54

	NS	66.59	56.00	79.67	10.68	09.73	82.92	12.15	18.25
Days to pod initiation	S	57.14	51.00	61.00	07.61	06.66	76.60	06.87	12.02
	NS	79.14	58.00	87.00	11.93	10.25	73.78	14.35	18.14
Plant height at maturity (cm)	S	46.36	40.67	55.60	09.46	09.20	94.67	08.55	18.44
	NS	60.13	55.00	65.87	05.44	05.32	95.95	06.46	10.74
Number of branches plant ⁻¹	S	07.40	05.33	10.00	32.61	23.18	50.56	02.52	33.99
	NS	08.07	06.00	11.67	27.62	27.01	95.62	04.39	54.43
Number of pods plant ⁻¹	S	50.33	41.33	63.00	19.60	14.35	53.61	10.89	21.65
	NS	54.07	43.67	63.67	13.31	13.28	99.42	14.75	27.27
Number of seeds pod ⁻¹	S	01.07	01.00	01.33	25.34	06.33	06.25	00.04	03.28
	NS	01.11	01.00	01.67	24.90	19.10	58.83	00.34	30.22
Biological yield plant ⁻¹ (g)	S	32.16	23.13	50.93	27.18	27.10	99.43	17.91	55.69
	NS	45.29	29.67	55.67	17.10	16.89	97.50	15.56	34.35
Test weight (g)	S	27.64	18.00	38.17	25.42	24.04	89.40	12.94	46.83
	NS	28.92	18.67	44.33	28.36	28.26	99.32	16.78	58.03
Harvest index (%)	S	45.86	37.44	52.70	13.30	10.60	63.56	07.99	17.41
	NS	46.56	39.10	54.33	14.32	14.18	98.05	13.46	28.92
Seed yield plant ⁻¹ (g)	S	14.92	09.41	26.72	34.95	33.96	94.41	10.15	68.00
	NS	21.47	15.03	29.23	22.11	21.62	95.58	09.35	43.54

S- DROUGHT STRESS CONDITION

NS- NON STRESS CONDITION

4.2.3.2 Non stress situations:

The heritability (broad sense) was varied from 47.00 % for R.W.C at flowering stage to 99.42 % for number of pods plant⁻¹(Table 4.4). High heritability was observed for traits like number of pods plant⁻¹ (99.42%), followed by test weight (99.32%), harvest index (98.05%), biological yield plant⁻¹ (97.50%), plant height at maturity (95.95%), number of branches plant⁻¹ (95.62%), seed yield plant⁻¹ (95.58%) and R.W.C at pod formation stage (90.95%), flower initiation (86.37%), W.S.D at pod formation stage (84.79%), reproductive phase (82.92%), days to 50 per cent flowering (82.73%), vegetative phase (81.92%) and days to pod initiation (73.78%).however it was recorded to be medium for number of seeds pod⁻¹ (58.83%) and days to maturity (60.54%).

Low estimate of heritability was recorded for R.W.C at flowering stage (47.0%), W.S.D at flowering stage (47.07%).

4.2.4 Genetic advance

Based on the estimate of heritability (broad sense) expected genetic advance was computed on the hypothetical selection at 5 % best individual ($K = 2.06$). Due to masking influence of environment upon characters concerned high fluctuations. Therefore to attain relative comparison of the characters in relation to environment, genetic advance as percentage of mean was calculated to predict Table 4.4 under drought stress and non-stress condition.

4.2.4.1 Drought Stress situations:

The highest estimate of genetic advance as percentage of mean (Table 4.4) was recorded for seed yield plant⁻¹ (68.00%), followed by biological yield plant⁻¹ (55.69%), W.S.D at pod formation stage (47.43%), test weight (46.83%), W.S.D at flowering stage (39.86%) and number of branches plant⁻¹ (33.99%). While its low value was observed for days to maturity (6.20%), R.W.C at flowering stage (8.98%), vegetative phase (11.06%), days to pod initiation (12.02%) and R.W.C at pod formation stage (14.92%).

Number of pods plant⁻¹ (21.65%), reproductive phase (21.54%), days to flower initiation (18.72%), plant height at maturity (18.44%), harvest index (17.41%) and

days to 50 per cent flowering (15.40%) were found to have moderate genetic advance as percentage of mean.

4.2.4.2 Non- stress situations:

The characters test weight (58.03%), number of branches plant⁻¹ (54.43%), W.S.D at pod formation stage (44.32%), seed yield plant⁻¹ (43.54%), biological yield plant⁻¹ (34.35%) and number of seeds pod⁻¹ (30.22%) exhibited high genetic advance as percentage of mean (Table 4.4). While, its low value was observed for R.W.C at flowering stage (2.49%), days to maturity (3.32%), plant height at maturity (10.74%), and R.W.C at pod formation stage (11.56%).

Moderate genetic advance as percentage of mean was recorded for harvest index (28.92%), number of pods plant⁻¹ (27.27%), days to flower initiation (24.72%), vegetative phase (22.30%), W.S.D at flowering stage (19.88%), days to 50 per cent flowering (18.40%), reproductive phase (18.25%) and days to pod initiation (18.14%).

4.3 Correlation coefficient analysis

Correlation coefficient was worked out at phenotypic, genotypic and environmental levels for all possible combinations of physiological traits and yield attributing characters with seed yield plant⁻¹ (Table 4.5, 4.6, 4.7 & 4.8). Results indicated that genotypic correlation coefficient in general, was of higher in magnitude than the corresponding phenotypic ones and similarly phenotypic correlation were higher as compared to environmental correlations.

4.3.1 Drought Stress situations:

4.3.1.1 Correlation coefficients for various physiological characters with seed yield plant⁻¹ themselves-

Negative and highly significant correlation with vegetative phase (-0.528) whereas it was positive and significant with R.W.C at pod formation stage (0.427), reproductive phase (0.472) and negative with W.S.D at pod formation stage (-0.427)

4.3.1.2 Correlation coefficients among different physiological traits-

R.W.C at flowering stage

Highly significant and positive association of R.W.C at flowering stage was recorded with R.W.C at pod formation stage (0.576), while it was significant but negative with W.S.D at flowering stage (-0.699) and W.S.D at pod formation stage (-0.576).

R.W.C at pod formation stage

Correlation coefficient of R.W.C at pod formation stage was positive and significant with reproductive phase (0.478) and seed yield plant⁻¹ (0.427), while it was significant but negative with W.S.D at flowering stage (-0.576), W.S.D at pod formation stage (-0.499) and vegetative phase (-0.405).

W.S.D at flowering stage

W.S.D at flowering stage exhibited significance and positive association with W.S.D at pod formation stage (0.576).

W.S.D at pod formation stage

W.S.D at pod formation stage showed positive and significant association with vegetative phase (0.405), while it was significant but negatively associated with reproductive phase (-0.478) and seed yield plant⁻¹ (-0.427).

Days to flower initiation

The correlation of days to flower initiation was significant and positive with days to 50 per cent flowering (0.913), days to pod initiation (0.894) and vegetative phase (0.427). While it was significant but negatively associated with days to maturity (-0.598) and reproductive phase (-0.582).

Table 4.5: Estimates of genotypic and phenotypic correlation coefficients among yield and its contributing traits in chickpea under drought stress condition

Characters		R.W.C at pod formation stage	W.S.D at flowering stage	W.S.D at pod formation stage	Days to flower initiation	Days to 50% flowering	Days to maturity	Vegetative phase (days)	Repro - ductive phase (days)	Days to pod initiation	Seed yield plant ⁻¹ (g)
R.W.C at flowering stage	G	0.754	-0.741	-0.754	0.349	0.286	-0.432	0.068	-0.108	0.234	0.250
	P	0.576**	-0.699**	-0.576**	0.321	0.242	-0.296	0.097	-0.099	0.224	0.214
R.W.C at pod formation stage	G		-0.754	-0.521	-0.022	-0.050	0.127	-0.555	0.527	-0.192	0.689
	P		-0.576**	-0.499**	-0.019	-0.031	0.065	-0.405*	0.478*	-0.153	0.427*
W.S.D at flowering stage	G			0.754	-0.349	-0.286	0.432	-0.168	0.108	0.234	-0.250
	P			0.576**	-0.321	-0.242	0.296	-0.097	0.099	-0.224	-0.214
W.S.D at pod formation stage	G				0.022	0.050	-0.126	0.555	-0.527	0.192	-0.689
	P				0.019	0.031	-0.065	0.405*	-0.478*	0.153	-0.427*
Days to flower initiation	G					0.946	-0.822	0.439	-0.617	0.958	-0.217
	P					0.913**	-0.598**	0.427*	-0.582**	0.894**	-0.076
Days to 50% flowering	G						-0.761	0.363	-0.522	0.997	-0.325
	P						-0.523**	0.260	-0.479*	0.932**	-0.101
Days to maturity	G							-0.516	0.759	-0.749	0.129
	P							-0.181	0.711**	-0.424*	0.107
Vegetative phase (days)	G								-0.998	0.484	-0.559
	P								-0.696**	0.385*	-0.528**
Reproductive phase (days)	G									-0.624	0.673
	P									-0.526**	0.472*
Days to pod initiation	G										-0.395
	P										-0.161

*Significant at 5% level = (0.381)

** Significant at 1% level = (0.487)

Days to 50% flowering

The correlation of days to 50 per cent flowering was significant and positive with days to pod initiation (0.932). While it was significant but negatively associated with days to maturity (-0.523) and reproductive phase (-0.479).

Days to maturity

Days to maturity had positive and significant association with reproductive phase (0.711), While it was significant but negatively associated with days to pod initiation (-0.424).

Vegetative phase (days)

Correlation coefficient of vegetative phase was positive and significant with days to pod initiation (0.385), while it was significant but negative with reproductive phase (-0.696) and seed yield plant⁻¹ (-0.528).

Reproductive phase (days)

Correlation coefficient of reproductive phase was positive and significant with seed yield plant⁻¹ (0.472) and it was significant but negative with days to pod initiation (-0.526).

4.3.1.3 Correlation coefficients for various yield contributing characters and seed yield plant⁻¹ themselves-

Positive and highly significant correlation with biological yield(0.926),harvest index (0.612),test weight(0.559) and number of pods plant⁻¹ (0.515).

4.3.1.4 Correlation coefficients among different yield contributing traits-

Plant height at maturity

Plant height at maturity expressed positive and significant association with test weight (0.447), while it was significant but negative with number of pods plant⁻¹ (-0.414).

Number of branches plant⁻¹

Number of branches plant⁻¹ expressed a highly significant and positive correlation with harvest index (0.426) and number of pods plant⁻¹ (0.415).

Table 4.6: Estimates of genotypic and phenotypic correlation coefficients among yield and its contributing traits in chickpea under drought stress condition

Characters		Plant height at maturity	Number of branches plant ⁻¹	Number of pods plant ⁻¹	Biological yield plant ⁻¹ (g)	Test weight (g)	Harvest index (%)	Seed yield plant ⁻¹ (g)
Plant height at maturity	G	1.000	-0.012	-0.572	0.144	0.453	0.015	0.131
	P	1.000	-0.044	-0.414*	0.144	0.447*	-0.014	0.117
Number of branches plant ⁻¹	G		1.000	0.362	0.237	0.199	0.726	0.452
	P		1.000	0.415*	0.170	0.112	0.426*	0.316
Number of pods plant ⁻¹	G			1.000	0.602	0.195	0.791	0.765
	P			1.000	0.443*	0.079	0.423*	0.515**
Biological yield plant ⁻¹ (g)	G				1.000	0.705	0.389	0.960
	P				1.000	0.667**	0.286	0.926**
Test weight (g)	G					1.000	-0.091	0.588
	P					1.000	-0.044	0.559**
Harvest index (%)	G						1.000	0.624
	P						1.000	0.612**

*Significant at 5% level = (0.381)

** Significant at 1% level = (0.487)

Number of pods plant⁻¹

Number of pods plant⁻¹ expressed a highly significant and positive correlation with , biological yield plant⁻¹(0.443) and harvest index (0.423).

Biological yield plant⁻¹ (g)

The correlation of biological yield plant⁻¹ was significant and positive with test weight (0.667).

4.3.2 Non- stress situations:

4.3.2.1 Correlation coefficients of various physiological characters with seed yield plant⁻¹ themselves-

Positive and highly significant correlation with R.W.C at pod formation stage (0.815),negative and highly significant correlation with W.S.D at pod formation stage(-0.774),days to pod initiation (-0.578),days to flower initiation(-0.520),however negative and significant correlation with days to maturity(-0.446)and vegetative phase(-0.441),and positive and significant with reproductive phase (0.491).

4.3.1.2 Correlation coefficients among various physiological traits-

R.W.C at flowering stage

Highly significant and negative association of R.W.C at flowering stage was recorded with W.S.D at flowering stage (-0.991) and days to 50 per cent flowering (-0.471).

R.W.C at pod formation stage

Correlation coefficient of R.W.C at pod formation stage was positive and significant with reproductive phase (0.404), while it was significant but negative with W.S.D at pod formation stage (-0.978), days to maturity (-0.426) and days to pod initiation (-0.432).

W.S.D at flowering stage

W.S.D at flowering stage exhibited significance and positive association with days to 50 per cent flowering (0.471).

W.S.D at pod formation stage

W.S.D at pod formation stage showed positive and significant association with days to maturity (0.442) and days to pod initiation (0.413), while it was significant but negatively associated with reproductive phase (-0.384).

Days to flower initiation

The correlation of days to flower initiation was significant and positive with vegetative phase (0.903), days to 50 per cent flowering (0.869) and days to pod initiation (0.720). While it was significant but negatively associated with reproductive phase (-0.538).

Table 4.7: Estimates of genotypic and phenotypic correlation coefficients among yield and its contributing traits in chickpea under non -stress condition

Characters		R.W.C at pod formation stage	W.S.D at flowering stage	W.S.D at pod formation stage	Days to flower initiation	Days to 50% flowering	Days to maturity	Vegetative phase (days)	Reproductive phase (days)	Days to pod initiation	Seed yield plant ⁻¹ (g)
R.W.C at flowering stage	G	0.214	-0.999	-0.233	-0.618	-0.653	-0.938	-0.385	-0.155	-0.568	0.624
	P	0.204	-0.901**	-0.127	-0.316	-0.471*	-0.367	-0.145	-0.143	-0.276	0.380
R.W.C at pod formation stage	G		-0.213	-0.991	-0.385	-0.124	-0.642	-0.306	0.489	-0.494	0.891
	P		-0.204	-0.978**	-0.325	-0.110	-0.426*	-0.245	0.404*	-0.432*	0.815**
W.S.D at flowering stage	G			0.232	0.618	0.653	0.936	0.387	0.155	0.565	-0.623
	P			0.127	0.315	0.471*	0.366	0.145	0.145	0.276	-0.379
W.S.D at pod formation stage	G				0.403	0.154	0.680	0.316	-0.485	0.463	-0.861
	P				0.335	0.130	0.442*	0.248	-0.384*	0.413*	-0.774**
Days to flower initiation	G					0.989	0.367	0.904	-0.518	0.887	-0.569
	P					0.869**	0.336	0.903**	-0.538**	0.720**	-0.520**
Days to 50% flowering	G						0.393	0.904	-0.322	0.740	-0.404
	P						0.339	0.807**	-0.288	0.526**	-0.327
Days to maturity	G							0.128	0.325	0.296	-0.654
	P							0.179	0.253	0.277	-0.446*
Vegetative phase (days)	G								-0.680	0.742	-0.517
	P								-0.642**	0.585**	-0.441*
Reproductive phase (days)	G									-0.740	0.532
	P									-0.525**	0.491*
Days to pod initiation	G										-0.707
	P										-0.578**

*Significant at 5% level = (0.381)

** Significant at 1% level = (0.487)

Days to 50% flowering

The correlation of days to 50 per cent flowering was significant and positive with vegetative phase (0.807) and days to pod initiation (0.526).

Vegetative phase (days)

Correlation coefficient of vegetative phase was positive and significant with days to pod initiation (0.585), while it was significant but negative with reproductive phase (-0.642).

4.3.2.3 Correlation coefficients of various yield contributing characters with seed yield plant⁻¹ themselves-

Positive and highly significant correlation with biological yield plant⁻¹ (0.763), harvest index (0.749), test weight (0.667), plant height at maturity (0.528) however positive and significant correlation with number of seeds per pod⁻¹ (0.491)

4.3.1.4 Correlation coefficients among various yield contributing traits-

Plant height at maturity

Plant height at maturity expressed positive and significant association with biological yield plant⁻¹ (0.593), and test weight (0.591).

Number of branches plant⁻¹

Number of branches plant⁻¹ expressed a highly significant and negative correlation with number of pods plant⁻¹ (-0.447).

Table 4.8: Estimates of genotypic and phenotypic correlation coefficients among yield and its contributing traits in chickpea under non -stress condition

Characters		Plant height at maturity	Number of branches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Biological yield plant ⁻¹ (g)	Test weight (g)	Harvest index (%)	Seed yield plant ⁻¹ (g)
Plant height at maturity	G	1.000	0.167	-0.069	-0.148	0.601	0.606	0.226	0.549
	P	1.000	0.152	-0.067	-0.139	0.593**	0.591**	0.225	0.528**
Number of branches plant ⁻¹	G		1.000	-0.465	-0.305	0.075	-0.214	-0.347	-0.289
	P		1.000	-0.447*	-0.263	0.071	-0.210	-0.331	-0.285
Number of pods plant ⁻¹	G			1.000	0.281	0.336	0.048	0.156	0.310
	P			1.000	0.184	0.331	0.048	0.150	0.298
Number of seeds pod ⁻¹	G				1.000	0.438	0.557	0.593	0.670
	P				1.000	0.338	0.437*	0.461*	0.491*
Biological yield plant ⁻¹ (g)	G					1.000	0.751	0.245	0.797
	P					1.000	0.742**	0.247	0.763**
Test weight (g)	G						1.000	0.233	0.686
	P						1.000	0.237	0.667**
Harvest index (%)	G							1.000	0.770
	P							1.000	0.749**

*Significant at 5% level = (0.381)

** Significant at 1% level = (0.487)

Number of seeds pod⁻¹

Number of seeds pod⁻¹ expressed a highly significant and positive correlation with , harvest index (0.461) and test weight (0.437).

Biological yield plant⁻¹ (g)

The correlation of biological yield plant⁻¹ was highly significant and positive with test weight (0.742).

4.4 Path coefficient analysis

The estimation of path coefficient is furnished in the Table 4.9, 4.10, 4.11& 4.12. In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects since the value of genotypic path are more reliable in predicting the correct idea about the direct and indirect effects of the component traits hence, only this has been described as below.

4.4.1 Drought Stress situations

4.4.1.1 Physiological characters

The results of path coefficients analysis of physiological characters showing direct and indirect effects on seed yield plant⁻¹ as dependable variable have been give as below (Table 4.9).

Direct effects

Path coefficient analysis of different physiological characters contributing towards seed yield plant⁻¹(Table 4.9) showed that W.S.D at flowering stage (9.516) had highest positive direct effect followed by R.W.C at flowering stage (5.134),R.W.C at pod formation stage (3.808) and days to pod initiation (0.385).Whereas,days to maturity(-3.335) exhibited the highest negative direct effect on seed yield plant⁻¹ followed by days to flower initiation (-1.486), reproductive phase(-1.464),W.S.D at pod formation stage(-1.249) and days to 50 per cent flowering (-1.158).

Indirect effect

R.W.C at flowering stage imported highest positive indirect effect on seed yield plant⁻¹ via R.W.C at pod formation stage (2.870), followed by days to maturity (1.441), W.S.D at pod formation stage (0.941) and reproductive phase

(0.159).Whereas, negative indirect effect was visible to be highest via W.S.D at flowering stage (-9.517),days to flower initiation (-0.519) and days to 50 per cent flowering (-0.332).

R.W.C at pod formation stage exhibited highest positive indirect effect via R.W.C at flowering stage (3.868),W.S.D at pod formation stage (1.248) and vegetative phase (0.138).Indirect effect through W.S.D at flowering stage (-7.171),reproductive phase (-0.772) and days to maturity (-0.422) found to be negative.

W.S.D at flowering stage manifested highest positive indirect effect through days to flower initiation (0.519) and days to 50 per cent flowering (0.332). It exhibited negative indirect effect via R.W.C at flowering stage (-5.134), R.W.C at pod formation stage (-2.870),days to maturity (-1.441),W.S.D at pod formation stage (-0.941) and reproductive phase (-0.159).

W.S.D at pod formation stage was reported to have highest positive indirect effects on seed yield plant⁻¹ through, W.S.D at flowering stage (7.171),reproductive phase (0.772) and days to maturity (0.422).Whereas, it expressed high negative indirect effect via R.W.C at flowering stage (-3.868), R.W.C at pod formation stage (-3.808) and vegetative phase (-0.138).

Days to flower initiation revealed high positive indirect effect on seed yield per plant through days to maturity (2.742),R.W.C at flowering stage (1.791),reproductive phase (0.903) and days to pod initiation (0.368).While the remaining characters showed negative indirect effect namely, W.S.D at flowering stage (-3.321),days to 50 per cent flowering (-1.095) and vegetative phase (-0.109).

Days to 50 per cent flowering was reported to have highest positive indirect effects on seed yield plant⁻¹ through days to maturity (2.538), R.W.C at flowering stage (1.471), reproductive phase (0.764) and days to pod initiation (0.384).It exhibited negative indirect effect via W.S.D at flowering stage (-2.726),days to flower initiation (-1.405),vegetative phase (-0.090) and R.W.C at pod formation stage (-0.076).

Days to maturity imported highest positive indirect effect on seed yield plant⁻¹ via W.S.D at flowering stage (4.112), days to flower initiation (1.222), days to 50 per cent flowering (0.881) and R.W.C at pod formation stage (0.482).Whereas, negative

indirect effect was visible to be highest via R.W.C at flowering stage (-2.219) and reproductive phase (-1.112).

Vegetative phase manifested highest positive indirect effect through days to maturity (1.720), reproductive phase (1.461) and R.W.C at flowering stage (0.351). It exhibited negative indirect effect via R.W.C at pod formation stage (-2.113), W.S.D at pod formation stage (-0.693), days to flower initiation (-0.653), W.S.D at flowering stage (-0.651) and days to 50 per cent flowering (-0.420).

Table 4.9: Path coefficients showing direct and indirect effects of different characters on seed yield plant⁻¹ (g) under drought stress condition at genotypic level.

Characters		R.W.C at flowering stage	R.W.C at pod formation stage	W.S.D at flowering stage	W.S.D at pod formation stage	Days to flower initiation	Days to 50% flowering	Days to maturity	Vegetative phase (days)	Reproductive phase (days)	Days to pod initiation	Seed yield plant ⁻¹ (g)
R.W.C at flowering stage	G	5.134	2.870	-9.517	0.941	-0.519	-0.332	1.441	-0.017	0.159	0.090	0.250
	P	0.154	-0.111	0.123	0.025	0.326	-0.131	-0.037	-0.059	-0.027	-0.049	0.214
R.W.C at pod formation stage	G	3.868	3.808	-7.171	1.248	0.003	0.023	-0.422	0.138	-0.772	-0.035	0.689
	P	0.088	-0.192	0.071	0.043	-0.020	0.017	0.008	0.247	0.133	0.034	0.427*
W.S.D at flowering stage	G	-5.134	-2.870	9.516	-0.941	0.519	0.332	-1.441	0.017	-0.159	-0.090	-0.250
	P	-0.154	0.111	-0.123	-0.025	-0.326	0.131	0.037	0.059	0.027	0.049	-0.214
W.S.D at pod formation stage	G	-3.868	-3.808	7.171	-1.249	-0.003	-0.023	0.422	-0.138	0.772	0.035	-0.689
	P	-0.088	0.192	-0.071	-0.043	0.020	-0.017	-0.008	-0.247	-0.133	-0.034	-0.427*
Days to flower initiation	G	1.791	-0.008	-3.321	-0.003	-1.486	-1.095	2.742	-0.109	0.903	0.368	-0.217
	P	0.049	0.004	0.039	-0.001	1.017	-0.493	-0.074	-0.260	-0.161	-0.197	-0.076
Days to 50% flowering	G	1.471	-0.076	-2.726	-0.025	-1.405	-1.158	2.538	-0.090	0.764	0.384	-0.325
	P	0.037	0.006	0.030	-0.001	0.929	-0.540	-0.065	-0.158	-0.133	-0.205	-0.101
Days to maturity	G	-2.219	0.482	4.112	0.158	1.222	0.881	-3.335	0.128	-1.112	-0.288	0.129
	P	-0.046	-0.012	-0.036	0.003	-0.608	0.283	0.124	0.110	0.197	0.093	0.107
Vegetative phase (days)	G	0.351	-2.113	-0.651	-0.693	-0.653	-0.420	1.720	-0.248	1.461	0.186	-0.559
	P	0.015	0.078	0.012	-0.017	0.434	-0.141	-0.022	-0.608	-0.193	-0.085	-0.528**
Reproductive phase (days)	G	-0.556	2.008	1.032	0.658	0.917	0.604	-2.532	0.248	-1.464	-0.240	0.673
	P	-0.015	-0.092	-0.012	0.021	-0.593	0.259	0.088	0.423	0.277	0.116	0.472*
Days to pod initiation	G	1.204	-0.350	-2.231	-0.115	-1.424	-1.155	2.498	-0.120	0.914	0.385	-0.395
	P	0.034	0.029	0.027	-0.007	0.910	-0.503	-0.052	-0.234	-0.146	-0.220	-0.161

P = Phenotypic path

G= Genotypic path

Bold figures denote direct effects

Residual effects: Phenotypic = 0.0527 and Genotypic = 0.1162

Reproductive phase revealed high positive indirect effect on seed yield per plant through R.W.C at pod formation stage (2.008), W.S.D at flowering stage (1.032), days to flower initiation (0.917), W.S.D at pod formation stage (0.658) and days to 50 per cent flowering (0.604). While the remaining characters showed negative indirect effect namely, days to maturity (-2.532), R.W.C at flowering stage (-0.556) and days to pod initiation (-0.240).

Days to pod initiation showed highest positive indirect effect on seed yield plant⁻¹ through, days to maturity (2.498), R.W.C at flowering stage (1.204) and reproductive phase (0.914). It exhibited negative indirect effect via W.S.D at flowering stage (-2.231), days to flower initiation (-1.424), days to 50 per cent flowering (-1.155) and R.W.C at pod formation stage (-0.350).

Residual effect: It was 0.1162.

4.4.1.2 Yield contributing characters

The results of path coefficients analysis of yield contributing characters showing direct and indirect effects on seed yield plant⁻¹ at genotypic level have been give as below (Table 4.10).

Direct effects

Path coefficient analysis of different seed yield contributing characters towards seed yield plant⁻¹ (Table 4.10) showed that biological yield plant⁻¹ (0.7755), had highest positive direct effect followed by harvest index (0.3533), test weight (0.0997) and number of branches plant⁻¹ (0.0014). Whereas, plant height at maturity (-0.0473) exhibited the highest negative direct effect on seed yield plant⁻¹ followed by number of pods plant⁻¹ (-0.0280).

Indirect effect

Plant height at maturity imported highest positive indirect effect on seed yield plant⁻¹ via number of pods plant⁻¹ (0.0271) whereas, negative indirect effect was high via test weight (-0.0214) and biological yield plant⁻¹ (-0.0068).

Number of branches plant⁻¹ revealed high value of positive indirect effect on seed yield per plant through harvest index (0.0011). While the remaining characters showed very less value of positive or negative indirect effects.

Table 4.10: Path coefficients showing direct and indirect effects of different characters on seed yield plant⁻¹ (g) of chickpea under drought stress condition

Characters		Plant height at maturity	Number of branches plant ⁻¹	Number of pods plant ⁻¹	Biological yield plant ⁻¹ (g)	Test weight (g)	Harvest index (%)	Seed yield plant ⁻¹ (g)
Plant height at maturity	G	-0.0473	0.0006	0.0271	-0.0068	-0.0214	-0.0007	0.131
	P	-0.0290	0.0013	0.0121	-0.0042	-0.0131	0.0004	0.117
Number of branches plant ⁻¹	G	-0.00002	0.0014	0.0005	0.0003	0.0003	0.0011	0.452
	P	-0.0006	0.0150	0.0063	0.0026	0.0017	0.0064	0.316
Number of pods plant ⁻¹	G	0.0161	-0.0102	-0.0280	-0.0169	-0.0055	-0.0222	0.765
	P	0.0085	-0.0085	-0.0210	-0.0091	-0.0016	-0.0087	0.515**
Biological yield plant ⁻¹ (g)	G	0.1117	0.1834	0.4667	0.7755	0.5471	0.3018	0.960
	P	0.1119	0.1320	0.3445	0.7770	0.5179	0.2223	0.926**
Test weight (g)	G	0.0452	0.0199	0.0195	0.0704	0.0997	-0.0091	0.588
	P	0.0319	0.0080	0.0057	0.0475	0.0710	-0.0031	0.559**
Harvest index (%)	G	0.0054	0.2566	0.2795	0.1375	-0.0323	0.3533	0.624
	P	-0.0054	0.1680	0.1668	0.1129	-0.0172	0.3950	0.612**

P = Phenotypic path G= Genotypic path Bold figures denote direct effects
Residual effects: Phenotypic = 0.0081 and Genotypic = 0.0033

Number of pods plant⁻¹ manifested highest positive indirect effect through plant height at maturity (0.0161). It exhibited negative indirect effect via harvest index (-0.0222), biological yield plant⁻¹ (-0.0169) and number of branches plant⁻¹ (-0.0102).

Biological yield plant⁻¹ revealed high value of positive indirect effect on seed yield per plant through test weight (0.5471), number of pods plant⁻¹ (0.4667), harvest index (0.3018), number of branches plant⁻¹ (0.1834) and plant height at maturity (0.1117).

Test weight was reported to have highest positive indirect effects on seed yield plant⁻¹ through, biological yield plant⁻¹ (0.0704), plant height at maturity (0.0452), number of branches plant⁻¹ (0.0199) and number of pods plant⁻¹ (0.0195). It exhibited negative indirect effect via harvest index (-0.0091).

Harvest index manifested highest positive indirect effect through number of pods plant⁻¹ (0.2795), number of branches plant⁻¹ (0.2566), biological yield plant⁻¹ (0.1375) and plant height at maturity (0.0054). It exhibited negative indirect effect via test weight (-0.0172).

Residual effect: It was very low 0.0033

4.4.2 Non- stress situations

4.4.2.1 Physiological characters

The results of path coefficients analysis of physiological characters showing direct and indirect effects on seed yield plant⁻¹ under non-stress situation have been give as below (Table 4.11).

Direct effect

The highest positive direct effect (Table 4.11) was recorded for R.W.C at flowering stage (12.9677) on seed yield plant⁻¹ followed by W.S.D at flowering stage (12.8185), days to flower initiation (1.5054), R.W.C at pod formation stage (1.0493), W.S.D at pod formation stage (0.6632) and days to 50 per cent flowering (0.2872), while vegetative phase (-1.3790) exhibited highest negative direct effect on seed yield plant⁻¹ followed by days to pod initiation (-0.9359), days to maturity (-0.4548) and reproductive phase (-0.2171).

Table 4.11: Path coefficients showing direct and indirect effects of different characters on seed yield plant⁻¹ (g) of chickpea under non - stress condition

Characters		R.W.C at flowering stage	R.W.C at pod formation stage	W.S.D at flowering stage	W.S.D at pod formation stage	Days to flower initiation	Days to 50% flowering	Days to maturit y	Vegetativ e phase (days)	Reprodu- ctive phase (days)	Days to pod initiation	Seed yield plant ⁻¹ (g)
R.W.C at flowering stage	G	12.9677	0.2244	-12.8184	-	-0.9301	-	0.4266	0.5310	0.0337	0.5316	0.624
	P	3.6829	0.1155	-3.4089	-	-0.0061	-	0.0809	0.0219	-0.0427	0.0221	0.380
R.W.C at pod formation stage	G	2.7730	1.0493	-2.7241	-	-0.5789	-	0.2920	0.4221	-0.1062	0.4624	0.891
	P	0.7526	0.5650	-0.6954	-	-0.0062	-	0.0941	0.0369	0.1201	0.0346	0.815**
W.S.D at flowering stage	G	-	-	12.8185	-	0.9302	-	-0.4256	-0.5339	-0.0336	-0.5288	-0.623
	P	-3.6827	-	3.4091	-	0.0060	-	-0.0807	-0.0218	0.0433	-0.0220	-0.379
W.S.D at pod formation stage	G	-3.0223	-	2.9689	0.6632	0.6063	-	-0.3094	-0.4354	0.1053	-0.4338	-0.861
	P	-0.4693	-	0.4324	0.0706	0.0064	-	-0.0976	-0.0373	-0.1144	-0.0330	-
Days to flower initiation	G	-8.0122	-	7.9209	0.2671	1.5054	-	-0.1670	-1.2462	0.1124	-0.8298	-0.569
	P	-1.1647	-	1.0723	0.0236	0.0192	-	-0.0742	-0.1359	-0.1601	-0.0576	-
Days to 50% flowering	G	-8.4726	-	8.3699	0.1021	1.4881	0.2872	-0.1786	-1.2470	0.0700	-0.6924	-0.404
	P	-1.7345	-	1.6057	0.0092	0.0167	0.1626	-0.0747	-0.1213	-0.0858	-0.0421	-0.327
Days to maturity	G	-	-	11.9954	0.4512	0.5528	0.1128	-0.4548	-0.1760	-0.0489	-0.2494	-0.654

		12.1639	0.6736									
	P	-1.3499	-	1.2469	0.0312	0.0064	0.0551	-0.2207	-0.0270	0.0754	-0.0221	-0.446*
Vegetative phase (days)	G	-4.9933	-	4.9625	0.2094	1.3604	0.2597	-0.0580	-1.3790	0.1367	-0.6947	-0.517
	P	-0.5348	-	0.4940	0.0175	0.0173	0.1311	-0.0396	-0.1504	-0.1911	-0.0468	-0.441*
Reproductive phase (days)	G	-2.0155	-	1.9863	0.3218	-0.7792	0.0926	-0.1025	0.8687	-0.2171	0.6923	0.532
	P	-0.5283	-	0.4957	0.0271	-0.0103	0.0469	-0.0559	0.0966	0.2976	0.0420	0.491*
Days to pod initiation	G	-7.3658	-	7.2426	0.3074	1.3346	0.2125	-0.1212	-1.0235	0.1606	-0.9359	-0.707
	P	-1.0174	-	0.9402	0.0292	0.0138	0.0856	-0.0611	-0.0880	-0.1562	-0.0799	-

P = Phenotypic path

G= Genotypic path

Bold figures denote direct effects

Residual effects: Phenotypic = 0.1917 and Genotypic = 0.0631

Indirect effect

R.W.C at flowering stage revealed the positive indirect effects through days to pod initiation (0.5316), vegetative phase (0.5310), days to maturity (0.4266), R.W.C at pod formation stage (0.2244) and reproductive phase (0.0337). while it was expressed in negative for W.S.D at flowering stage (-12.8184), days to flower initiation (-0.9301), days to 50 per cent flowering (-0.1876).

The positive indirect effect was observed for R.W.C at pod formation stage via., R.W.C at flowering stage (2.7730), days to pod initiation (0.4624), vegetative phase (0.4221) and days to maturity (0.2920), while it was negative through W.S.D at flowering stage (-2.7241), W.S.D at pod formation stage (-0.6626), days to flower initiation (-0.5789), reproductive phase (-0.1062) and days to 50 per cent flowering (-0.0357).

Indirect effect of W.S.D at flowering stage via days to flower initiation (0.9302), days to 50 per cent flowering (0.1875) and W.S.D at pod formation stage (0.1536) were found to be positive whereas, it was exhibited negative indirect effect via R.W.C at flowering stage (-12.9676), vegetative phase (-0.5339), days to pod initiation (-0.5288), days to maturity (-0.4256) and R.W.C at pod formation stage (-0.2230).

W.S.D at pod formation stage had positive indirect effect on seed yield plant⁻¹ via W.S.D at flowering stage (2.9689), days to flower initiation (0.6063), reproductive phase (0.1053) and days to 50 per cent flowering (0.0442). However, negative indirect effects was recorded via R.W.C at flowering stage (-3.0223), followed by R.W.C at pod formation stage (-1.0483), vegetative phase (-0.4354), days to pod initiation (-0.4338) and days to maturity (-0.3094).

High positive indirect effect of days to flower initiation on seed yield plant⁻¹ was revealed through W.S.D at flowering stage (7.9209), days to 50 per cent flowering (0.2839), W.S.D at pod formation stage (0.2671) and reproductive phase (0.1124), while it was expressed negative for R.W.C at flowering stage (-8.0122), vegetative phase (-1.2462), days to pod initiation (-0.8298), R.W.C at pod formation stage (-0.4035) and days to maturity (-0.1670).

Days to 50 per cent flowering imported highest positive indirect effect on seed yield plant⁻¹ via W.S.D at flowering stage (8.3699) followed by days to flower initiation (1.4881), W.S.D at pod formation stage (0.1021) and reproductive phase (0.0700),

whereas negative indirect effect was visible via R.W.C at flowering stage (-8.4726), vegetative phase (-1.2470), days to pod initiation (-0.6924), days to maturity (-0.1786) and R.W.C at pod formation stage (-0.1306).

Days to maturity exhibited highest positive indirect effect via W.S.D at flowering stage (11.9954), days to flower initiation (0.5528), W.S.D at pod formation stage (0.4512) and days to 50 per cent flowering (0.1128). Indirect effect through R.W.C at flowering stage (-12.1639), R.W.C at pod formation stage (-0.6736), days to pod initiation (-0.2494), vegetative phase (-0.1760) and reproductive phase (-0.0489) found to be negative.

Vegetative phase manifested highest positive indirect effect on seed yield plant⁻¹ through W.S.D at flowering stage (4.9625), days to flower initiation (1.3604), days to 50 per cent flowering (0.2597), W.S.D at pod formation stage (0.2094) and reproductive phase (0.1367). It exhibited negative indirect effect via R.W.C at flowering stage (-4.9933), days to pod initiation (-0.6947), R.W.C at pod formation stage (-0.3212) and days to maturity (-0.0580).

Reproductive phase was reported to have highest positive indirect effect on seed yield plant⁻¹ through, W.S.D at flowering stage (1.9863), vegetative phase (0.8687), days to pod initiation (0.6923) and R.W.C at pod formation stage (0.5132). Whereas, it expressed negative indirect effect via R.W.C at flowering stage (-2.0155), days to flower initiation (-0.7792), W.S.D at pod formation stage (-0.3218), days to maturity (-0.1025) and days to 50 per cent flowering (-0.0926).

Days to pod initiation revealed high value of positive indirect effect on seed yield plant⁻¹ through W.S.D at flowering stage (7.2426), days to flower initiation (1.3346), W.S.D at pod formation stage (0.3074), days to 50 per cent flowering (0.2125) and reproductive phase (0.1606), while the remaining characters showed negative indirect effect namely, R.W.C at flowering stage (-7.3658), vegetative phase (-1.0235), R.W.C at pod formation stage (-0.5184), and days to maturity (-0.1212).

4.4.2.2 Yield contributing characters

The results of path coefficients analysis of yield contributing characters showing direct and indirect effects on seed yield plant⁻¹ at genotypic level have been given in Table (4.12).

Direct effects

Path coefficient analysis of different yield contributing characters towards seed yield plant^{-1} (Table 4.12) showed that harvest index (0.8882), had highest positive direct effect followed by test weight (0.5865), biological yield plant^{-1} (0.5716), number of pods plant^{-1} (0.0895) and number of branches plant^{-1} (0.0628). Whereas, number of seeds pod^{-1} (-0.4939) exhibited highest negative direct effect on seed yield plant^{-1} followed by plant (-0.4185).

Indirect effect

Plant height at maturity imported highest positive indirect effect on seed yield plant^{-1} via test weight (0.3554), biological yield plant^{-1} (0.3436), harvest index (0.2011), number of seeds pod^{-1} (0.0634) and number of branches plant^{-1} (0.0105). Whereas, negative indirect effect was observed via number of pods plant^{-1} (0.0062).

Number of branches plant^{-1} revealed high value of positive indirect effect on seed yield plant^{-1} through number of seeds pod^{-1} (0.1504) and biological yield plant^{-1} (0.0427). While, negative indirect effect was observed via harvest index (-0.3081), test weight (-0.1252), plant height at maturity (-0.0697) and number of pods plant^{-1} (-0.0416).

Number of pods plant^{-1} manifested highest positive indirect effect through biological yield plant^{-1} (0.1923), harvest index (0.1388), plant height at maturity (0.0289) and test weight (0.0283). It exhibited negative indirect effect via number of seeds pod^{-1} (-0.1386) and number of branches plant^{-1} (-0.0292).

Table 4.12: Path coefficients showing direct and indirect effects of different characters on seed yield plant⁻¹ (g) of chickpea under non - stress condition

Characters		Plant height at maturity	Number of branches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Biological yield plant ⁻¹ (g)	Test weight (g)	Harvest index (%)	Seed yield plant ⁻¹ (g)
Plant height at maturity	G	-0.4185	0.0105	-0.0062	0.0634	0.3436	0.3554	0.2011	0.549
	P	0.0685	-0.0321	0.0057	-0.0019	0.3867	-0.0146	0.1160	0.528**
Number of branches plant ⁻¹	G	-0.0697	0.0628	-0.0416	0.1504	0.0427	-0.1252	-0.3081	-0.289
	P	0.0104	-0.2111	0.0386	-0.0035	0.0461	0.0052	-0.1702	-0.285
Number of pods plant ⁻¹	G	0.0289	-0.0292	0.0895	-0.1386	0.1923	0.0283	0.1388	0.310
	P	-0.0046	0.0944	-0.0863	0.0025	0.2158	-0.0012	0.0773	0.298
Number of seeds pod ⁻¹	G	0.0538	-0.0191	0.0251	-0.4939	0.2501	0.3266	0.5270	0.670
	P	-0.0095	0.0556	-0.0159	0.0134	0.2202	-0.0108	0.2376	0.491*
Biological yield plant ⁻¹ (g)	G	-0.2516	0.0047	0.0301	-0.2161	0.5716	0.4405	0.2180	0.797
	P	0.0406	-0.0149	-0.0286	0.0045	0.6520	-0.0182	0.1274	0.763**
Test weight (g)	G	-0.2536	-0.0134	0.0043	-0.2750	0.4293	0.5865	0.2074	0.686
	P	0.0405	0.0444	-0.0041	0.0059	0.4835	-0.0246	0.1219	0.667**
Harvest index (%)	G	-0.0947	-0.0218	0.0140	-0.2931	0.1403	0.1370	0.8882	0.770
	P	0.0154	0.0698	-0.0130	0.0062	0.1613	-0.0058	0.5148	0.749**

P = Phenotypic path G= Genotypic path Bold figures denote direct effects
Residual effects: Phenotypic = 0.0564 and Genotypic = 0.0092

Number of seeds pod⁻¹ revealed high positive indirect effect on seed yield plant⁻¹ through harvest index (0.5270), test weight (0.3266), biological yield plant⁻¹ (0.2501), plant height at maturity (0.0538) and number of pods plant⁻¹ (0.0251). The remaining characters showed very less value of negative indirect effect.

Biological yield plant⁻¹ was reported highest positive indirect effects on seed yield plant⁻¹ through, test weight (0.4405), harvest index (0.2180), number of pods plant⁻¹ (0.0301) and number of branches plant⁻¹ (0.0047). It exhibited negative indirect effect via plant height at maturity (-0.2516) and number of seeds pod⁻¹ (-0.2161).

Test weight was reported highest positive indirect effect on seed yield plant⁻¹ through, biological yield plant⁻¹ (0.4293), harvest index (0.2074) and number of pods plant⁻¹ (0.0043). It exhibited negative indirect effect via number of seeds pod⁻¹ (-0.2750), plant height at maturity (-0.2536) and number of branches plant⁻¹ (-0.0134).

Harvest index manifested highest positive indirect effect through biological yield plant⁻¹ (0.1403), test weight (0.1370) and number of pods plant⁻¹ (0.0140). It exhibited negative indirect effect via number of seeds pod⁻¹ (-0.2931), plant height at maturity (-0.0947) and number of branches plant⁻¹ (-0.0218).

4.5 Study on drought tolerance

4.5.1 Seed yield (g) drought stress condition

Significantly maximum seed yield plant⁻¹ 26.72 g was recorded by genotype KAK – 2 under stress condition, followed by JG – 130 (16.55 g), JAKI – 9218 (15.60 g), IG – 593 (15.21 g) and JG – 16 (15.20 g) as compared to other genotypes (Table 4.13 and Fig 2). While, the minimum yield of 9.41 g was recorded by JG – 412.

4.5.2 Seed yield (g) non-stress condition

Genotype KAK –2 was superior and recorded significantly maximum seed yield plant⁻¹ 29.23 g under non - stress condition, followed by JG – 130 (26.87 g), JAKI – 9218 (24.47 g), IG – 593 (21.67 g) and JG – 16 (20.33 g) as compared to other genotypes (Table 4.13 and Fig 2). However, the minimum seed yield of 15.038 g was exhibited by JG – 412.

Table 4.13: Seed yield and parameters of drought tolerance of different genotypes of chickpea

Genotypes	Seed yield plant⁻¹ (g) stress condition	Seed yield plant⁻¹ (g) non-stress condition	Reduction of yield due to stress (%)	Drought index	Drought tolerance efficiency (%)	Drought susceptibility index
JG-130	16.55	26.87	38.25	0.62	61.75	0.62
IG-593	15.21	21.67	29.82	0.62	62.15	0.56
JG-6	14.28	19.97	29.19	0.71	70.81	0.46
JAKI-9218	15.60	24.47	36.27	0.81	80.66	0.31
KAK-2	26.72	29.23	13.78	0.92	91.94	0.11
JG-16	15.20	20.33	24.60	0.70	70.14	0.41
Ujjain-21	11.05	19.50	42.90	0.74	73.99	0.48
JG-11	10.30	16.20	36.50	0.64	63.50	0.58
JG-412	9.41	15.03	36.91	0.47	46.73	0.88
S E (m) ±	0.71	0.57	3.04	0.03	3.23	0.07
C.D. at 5% level	2.13	1.72	9.13	0.09	9.69	0.23

4.5.3 Reduction of yield due to drought stress (%)

Minimum reduction in seed yield plant⁻¹ due to stress was observed in genotype KAK– 2 of 13.78% (Table 4.13 and Fig 3), followed by JG – 16 (24.60%), JG – 6 (29.19%) and IG 593 (29.82%). The maximum reduction in seed yield due to drought stress was observed in genotype Ujjain-21 (42.90%).

4.5.4 Drought index

Genotype KAK – 2 exhibited maximum drought index 0.92, followed by JAKI-9218 (0.807),Ujjain-21 (0.740), JG – 6 (0.708) and JG – 16 (0.701), and it was noted minimum in genotype JG-412 (0.467) (Table 4.13 and Fig 4).

4.5.5 Drought tolerance efficiency

Genotype KAK – 2 exhibited maximum drought tolerance efficiency 91.94%, followed by JAKI-9218 (80.66%), Ujjain-21 (73.99%) and JG – 6 (70.81%) as compared to other genotypes (Table 4.13 and Fig 5), while it was observed minimum in genotype JG-412 (46.73%).

4.5.6 Drought susceptibility index

Genotype KAK – 2 and JAKI-9218 were recorded least drought susceptibility index 0.11 and 0.31, respectively and which were at par with each other. While it was observed maximum in genotype JG-412 (0.88)(Table 4.13 and Fig 6).

Fig 2: Seed yield of different genotypes of chickpea under drought stress and non- stress condition

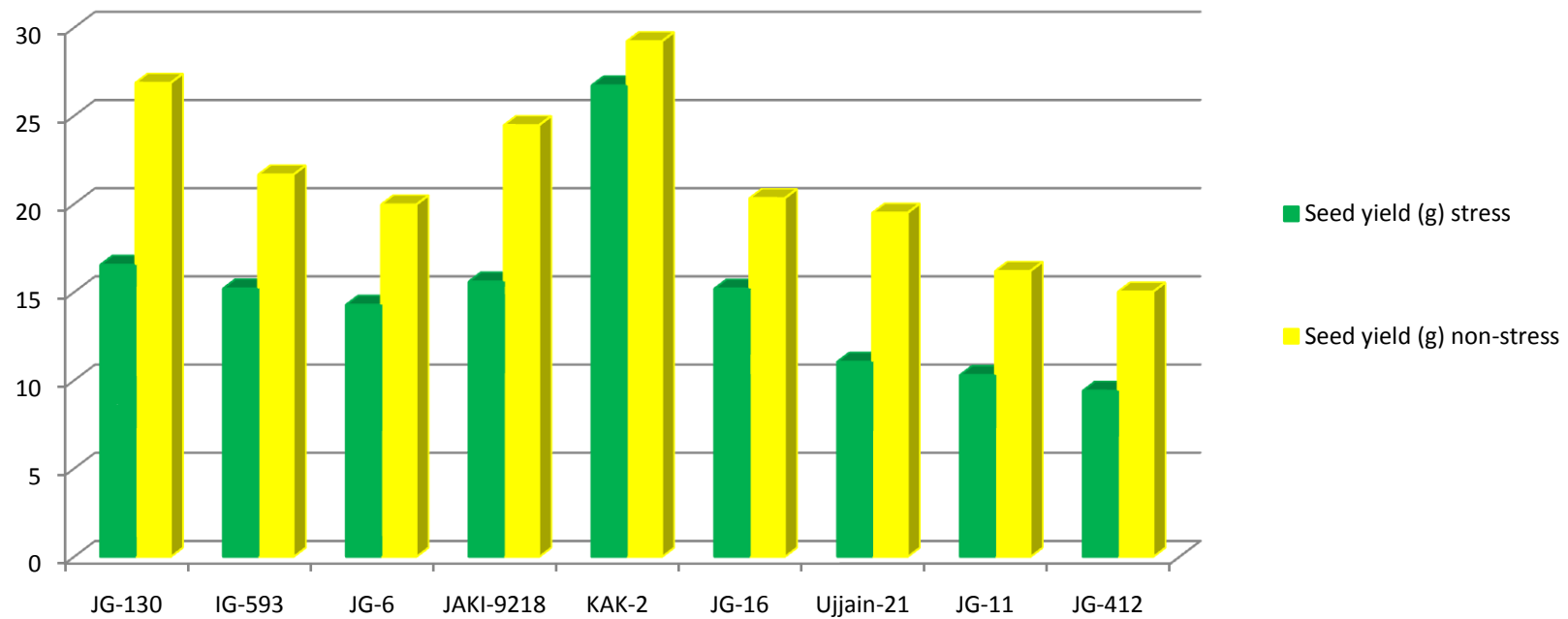


Fig 3: Reduction of yield due to stress (%) of different genotypes of chickpea under drought stress and non - stress condition

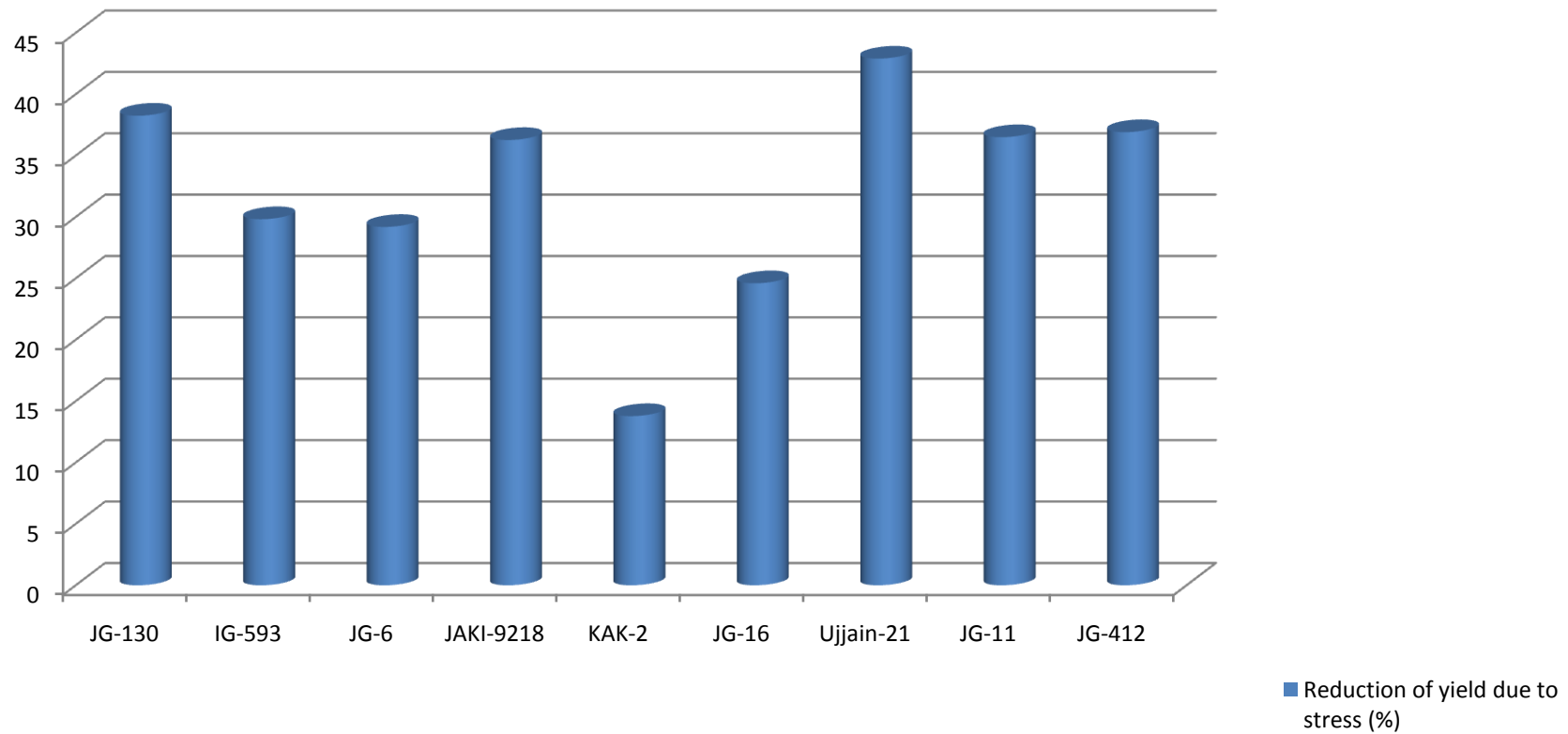


Fig 4: Drought index of different genotypes of chickpea

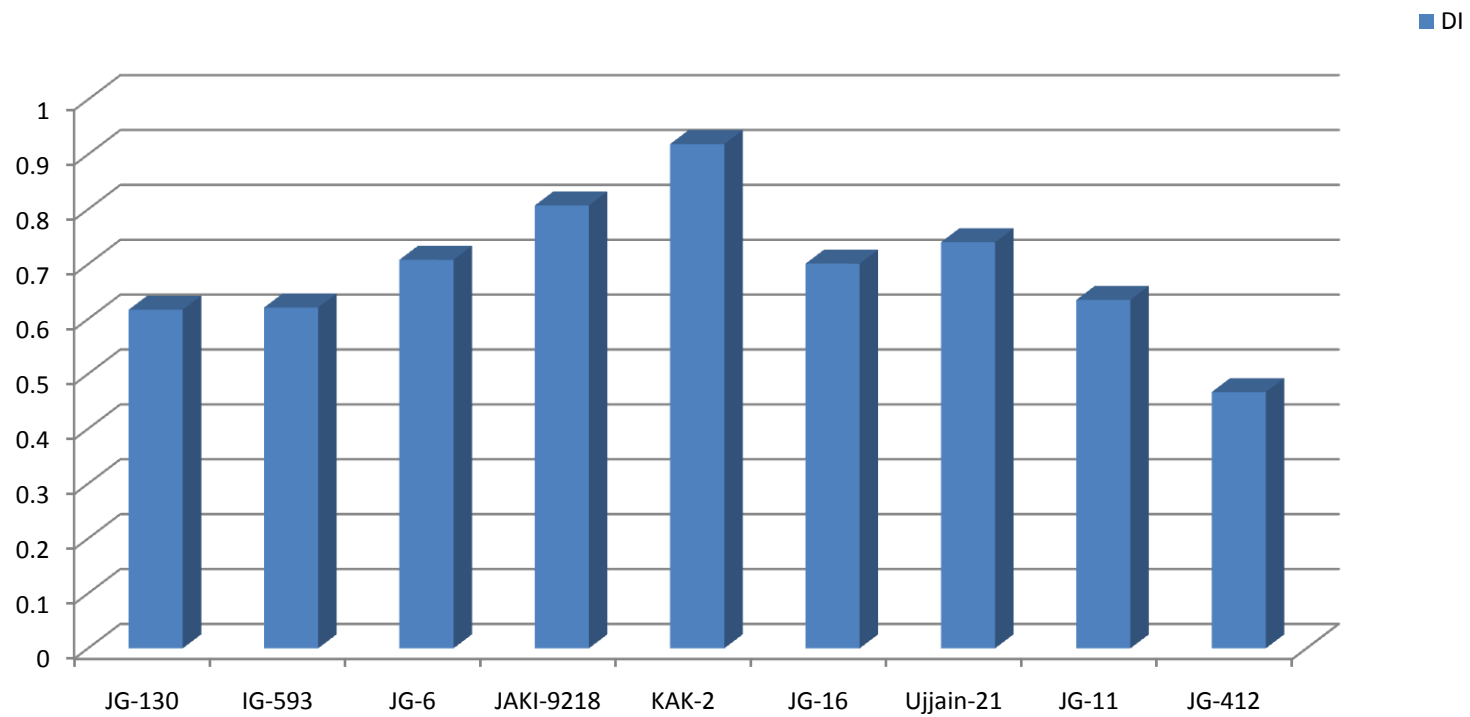


Fig 5: Drought tolerance efficiency (%) of different genotypes of chickpea

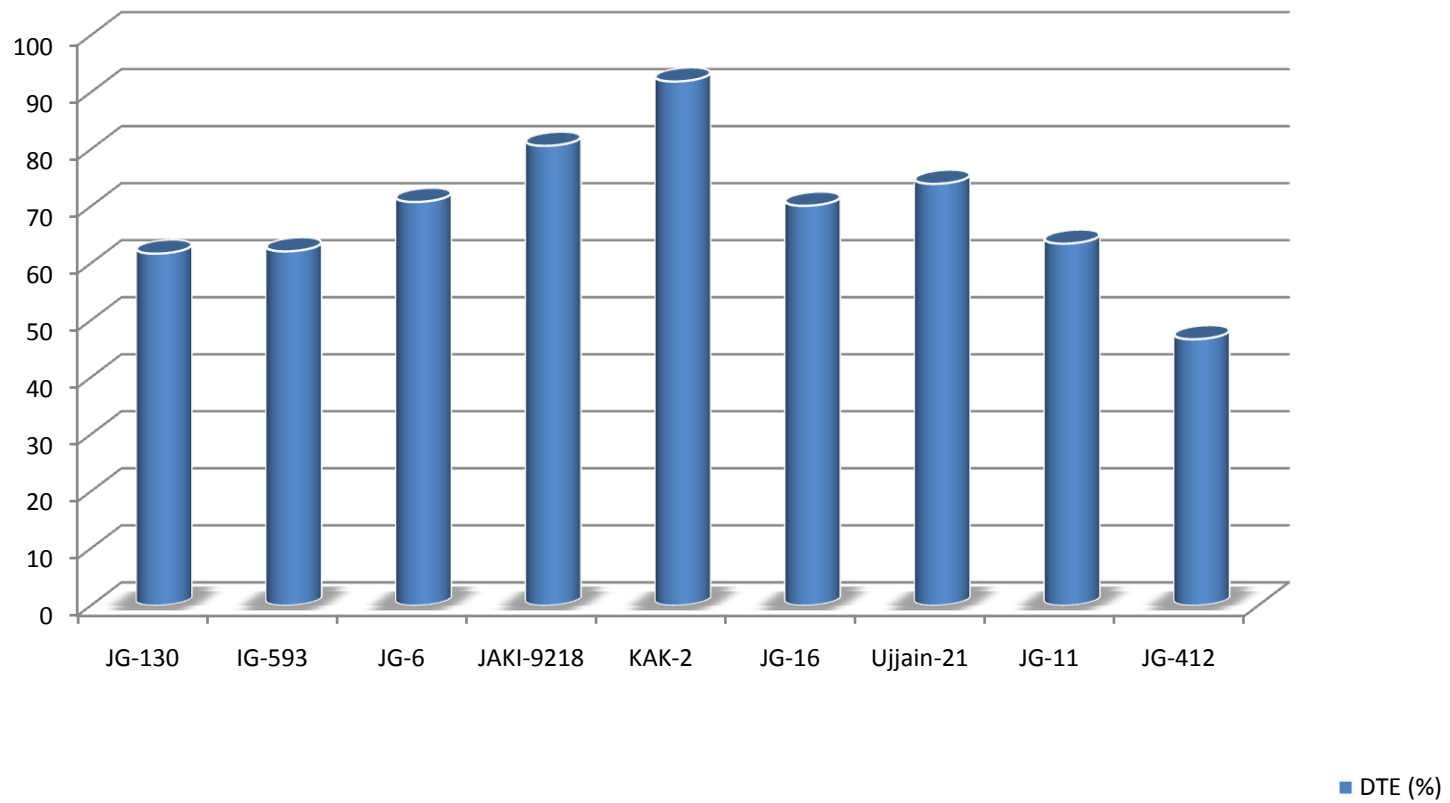
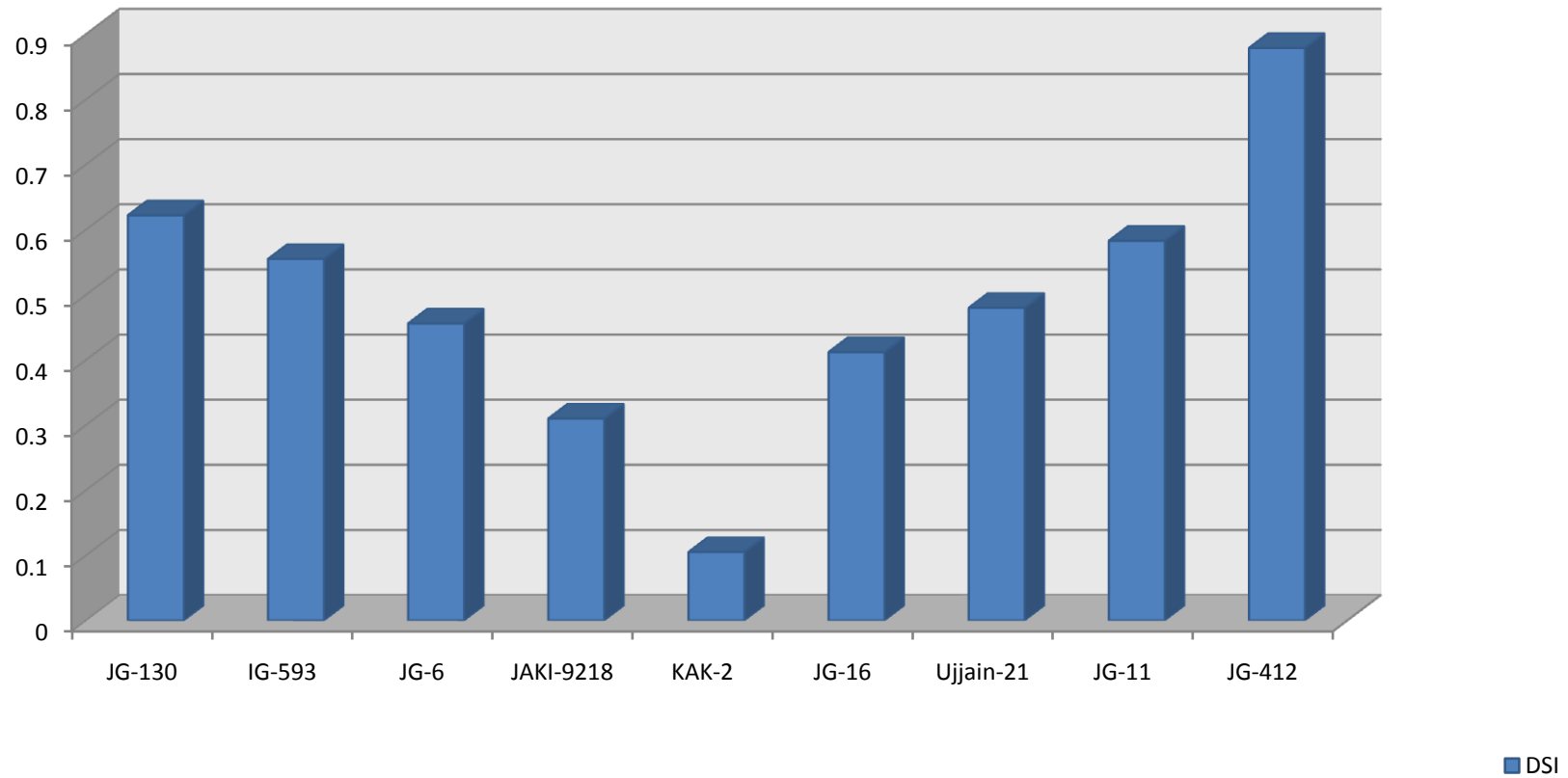


Fig 6: Drought susceptibility index of different genotypes of chickpea



4.5.7 Dry matter accumulation (DMA)

4.5.7.1 Amount of dry matter accumulation in plant under stress condition

Amount of dry matter accumulation in plant under stress condition was recorded at 30, 45 and 60 DAS and has been presented in Table 4.14 and Fig. 7. The analysis of variance is given in Appendix –I.

At 30, 45 and 60 DAS, genotype JAKI-9218 was recorded significantly maximum amount of dry matter accumulation , 9.40, 23.39 and 56.71 g plant⁻¹, followed by KAK-2 (6.47, 22.68 and 45.81g plant⁻¹) and IG-593 (5.79, 18.30 and 35.75g plant⁻¹), respectively and genotypes JAKI-9218 and KAK-2 were at par at 45 DAS. However, it was noted lowest amount of dry matter accumulation 2.54, 7.94 and 17.84g plant⁻¹ in genotype Ujjain-21 at 30, 45 and 60 DAS respectively.

Table 4.14: Mean performance of amount and rate of dry matter accumulation under drought stress condition of chickpea

Treat. symb.	Genotypes	Amount of dry matter accumulation (g plant ⁻¹) at			Rate of dry matter accumulation (g day ⁻¹) at		
		30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T ₁	JG-130	2.98	13.32	23.73	0.10	0.30	0.44
T ₂	IG-593	5.79	18.30	35.75	0.19	0.41	0.66
T ₃	JG-6	4.71	18.17	30.70	0.16	0.40	0.51
T ₄	JAKI-9218	9.40	23.39	56.71	0.31	0.52	0.94
T ₅	KAK-2	6.47	22.68	45.81	0.22	0.50	0.76
T ₆	JG-16	2.83	13.93	23.37	0.09	0.31	0.39
T ₇	Ujjain-21	2.54	7.94	17.84	0.08	0.18	0.29
T ₈	JG-11	4.00	8.72	30.90	0.13	0.19	0.51
T ₉	JG-412	2.91	10.07	29.69	0.10	0.22	0.49
SEm±		0.88	0.75	1.05	0.029	0.016	0.031
C.D. at 5% level		2.65	2.24	3.15	0.088	0.050	0.093

4.5.7.2 Rate of dry matter accumulation in plant under drought stress condition

The rate of dry matter accumulation in plant of different genotypes is given in Table 4.14 and Fig.8 under stress condition at 30, 45 and 60 DAS. The ANOVA is given in Appendix – I.

At 30, 45 and 60 DAS, significantly maximum rate of dry matter accumulation of 0.31, 0.52 and 0.94 g day⁻¹ was recorded in genotype JAKI-9218, followed by KAK-2 (0.22, 0.50 and 0.76g day⁻¹) and IG-593 (0.19, 0.41 and 0.66g day⁻¹), respectively and genotypes JAKI-9218 and KAK-2 were at par at 45 DAS. However, it was lowest in genotype Ujjain-21, of 0.08, 0.18 and 0.29g day⁻¹ at 30, 45 and 60 DAS respectively.

4.5.7.3 Amount of dry matter accumulation in plant under non- stress condition

Amount of dry matter accumulation in plant under non- stress condition was recorded at 30, 45 and 60 DAS and has been presented in Table 4.15 and Fig. 9. The analysis of variance is given in Appendix –I.

At 30, 45 and 60 DAS, genotype KAK-2 was recorded significantly maximum amount of dry matter accumulation of 7.62, 22.53 and 43.07 g plant⁻¹, followed by JG-16 (5.45, 22.23 and 43.00g plant⁻¹) and JG-6 (5.15, 20.77 and 42.90g plant⁻¹), respectively and which were at par at 45 DAS. However, it was noted lowest of 2.45, 6.46 and 33.92g plant⁻¹ in genotype Ujjain-21 at 30, 45 and 60 DAS respectively.

4.5.7.4 Rate of dry matter accumulation in plant under non- stress condition

The rate of dry matter accumulation in plant of different genotypes is given in Table 4.15 and Fig. 10 under non -stress condition at 30, 45 and 60 DAS. The ANOVA is given in Appendix – I.

At 30, 45 and 60 DAS, significantly maximum rate of dry matter accumulation of 0.18, 0.50 and 0.72 g day⁻¹ was recorded in genotype, KAK-2 followed by JG-16 (0.17, 0.49 and 0.72g day⁻¹) and JG-6 (0.17, 0.46 and 0.71g day⁻¹), respectively and which were at par at all the stages. However, it was noted lowest of 0.08, 0.14 and 0.57g day⁻¹ in genotype Ujjain-21 at 30, 45 and 60 DAS respectively.

Table 4.15: Mean performance of amount and rate of dry matter accumulation under non- stress condition of chickpea

Treat. symp.	Genotypes	Amount of dry matter accumulation (g plant ⁻¹) at			Rate of dry matter accumulation (g day ⁻¹) at		
		30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T ₁	JG-130	3.89	17.29	38.76	0.13	0.38	0.64
T ₂	IG-593	4.07	18.49	40.27	0.14	0.41	0.67
T ₃	JG-6	5.15	20.77	42.90	0.17	0.46	0.71
T ₄	JAKI-9218	4.25	8.52	41.04	0.14	0.19	0.68
T ₅	KAK-2	7.62	22.53	43.07	0.18	0.50	0.72
T ₆	JG-16	5.45	22.23	43.00	0.17	0.49	0.72
T ₇	Ujjain-21	2.45	6.46	33.92	0.08	0.14	0.57
T ₈	JG-11	3.43	16.00	40.47	0.11	0.36	0.67

T ₉	JG-412	3.36	13.22	39.61	0.11	0.29	0.66
SEm±		0.68	0.76	0.32	0.007	0.017	0.011
C.D. at 5% level		2.06	2.29	0.98	0.023	0.050	0.034

4.5.8 Studies on soil moisture in soil profile

4.5.8.1 Studies on depletion of soil moisture in different genotypes in 0-15, 15-30 and 30-45 cm soil profile under drought stress condition

Mean soil moisture content at weight basis in different genotypes in 0-15, 15-30 and 30-45 cm soil profile at sowing, 20, 40, 60, 80 DAS and at harvest was recorded and has been given in the Table 4.16a and 4.16b under drought stress condition. Its graphical presentation has been shown in Fig. 11 to 16. The ANOVA is given in Appendix – II.

At the time of sowing, 20 DAS, 40 DAS, 60 DAS, 80 DAS and at harvest the significantly maximum soil moisture was recorded in JAKI-9218 at 0-15, 15-30 and 30-45 cm depth of soil profile, followed by KAK-2, IG-593 and JG-16 respectively. While, it was observed minimum in Ujjain-21 at 0-15, 15-30 and 30-45 cm depth of soil profile respectively.

4.5.8.2 Studies on depletion of soil moisture in different genotypes in 0-15, 15-30 and 30-45 cm soil profile under non- stress condition

Soil moisture in 0-15, 15-30 and 30-45 cm soil profile at sowing, 20, 40, 60, 80 DAS and at harvest was recorded and has been given in the Table 4.17a and 4.17b under non- stress condition. Its graphical presentation has been shown in Fig. 17 to 22. The ANOVA is given in Appendix – III.

At the time of sowing, 20 DAS, 40 DAS, 60 DAS, 80 DAS and at harvest the significantly maximum soil moisture was recorded in KAK-2 at 0-15, 15-30 and 30-45 cm depth of soil profile, followed by JG-16, and JG-6 respectively. While, it was observed minimum in Ujjain-21 at 0-15, 15-30 and 30-45 cm depth of soil profile respectively.

Table 4.16a: Mean performance of soil moisture percentage under drought stress condition of chickpea

Treat. symb.	Genotypes	Soil moisture percentage in depth cm								
		At sowing			20 DAS			40 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T ₁	JG-130	26.91	23.36	23.72	19.26	20.78	21.85	15.77	15.97	15.74
T ₂	IG-593	27.09	25.21	25.16	22.26	22.12	24.11	16.54	16.09	16.44
T ₃	JG-6	26.93	25.11	24.44	20.68	20.77	22.10	15.05	15.86	15.73
T ₄	JAKI-9218	27.98	26.82	26.12	28.45	28.34	29.81	19.01	17.58	19.78
T ₅	KAK-2	27.86	25.99	25.70	24.53	25.04	24.96	17.73	17.11	16.53
T ₆	JG-16	27.09	25.09	24.98	22.26	21.82	24.11	15.92	16.04	16.09
T ₇	Ujjain-21	26.19	23.34	23.70	17.75	20.46	21.21	14.91	15.11	15.58
T ₈	JG-11	26.85	23.69	24.50	19.92	21.82	21.75	14.93	15.95	15.73
T ₉	JG-412	26.91	23.81	24.52	22.55	20.16	22.26	15.72	15.95	15.93
SEm±		0.26	0.26	0.19	0.17	0.25	0.63	0.50	0.19	0.67
C.D. at 5% level		0.80	0.78	0.57	0.51	0.76	1.91	1.50	0.56	2.03

Table 4.16b: Mean performance of soil moisture percentage under drought stress condition of chickpea

Treat. symp.	Genotypes	Soil moisture percentage in depth cm								
		60 DAS			80 DAS			At harvest		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T ₁	JG-130	14.90	14.67	15.15	12.82	12.71	13.27	11.65	11.57	10.89
T ₂	IG-593	15.61	14.80	15.63	13.70	13.71	14.23	11.66	11.86	12.06
T ₃	JG-6	14.88	14.67	14.59	13.12	12.94	13.18	11.33	11.57	11.22
T ₄	JAKI-9218	16.70	15.45	15.76	13.85	13.84	14.46	12.40	12.30	12.30
T ₅	KAK-2	16.03	15.02	15.76	13.70	13.84	14.46	11.92	11.89	12.30
T ₆	JG-16	14.90	14.79	15.55	13.64	13.33	13.68	11.63	11.83	12.05
T ₇	Ujjain-21	14.38	14.40	14.46	12.50	12.68	12.68	11.08	10.74	10.85
T ₈	JG-11	14.68	14.54	14.49	12.57	12.97	13.11	11.58	11.57	11.43
T ₉	JG-412	14.73	14.46	15.26	12.82	12.97	13.33	11.44	11.73	11.76
SEm±		0.25	0.20	0.20	0.18	0.28	0.17	0.18	0.15	0.24
C.D. at 5% level		0.77	N.S.	0.61	0.55	0.85	0.52	0.56	0.47	0.73

Table 4.17a: Mean performance of soil moisture percentage under non- stress condition of chickpea

Treat. Genotypes symb.		soil moisture percentage in depth cm								
		At sowing			20 DAS			40 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T ₁	JG-130	26.91	25.09	25.93	22.26	21.82	21.75	21.81	20.11	19.64
T ₂	IG-593	26.49	25.21	25.44	20.92	21.67	21.21	21.89	21.09	19.58
T ₃	JG-6	27.65	26.39	26.12	22.45	22.12	23.11	22.39	21.41	20.79
T ₄	JAKI-9218	26.58	24.69	25.82	20.93	20.77	22.43	21.23	20.49	20.33
T ₅	KAK-2	27.93	27.11	26.98	23.57	23.82	23.29	24.53	22.90	21.76
T ₆	JG-16	27.85	26.66	26.52	23.20	22.88	23.14	23.57	22.42	21.14
T ₇	Ujjain-21	26.18	24.03	23.70	19.42	20.46	20.80	20.38	19.89	18.34
T ₈	JG-11	27.37	25.65	25.36	21.59	20.78	21.52	21.86	21.33	20.30
T ₉	JG-412	26.43	25.81	24.80	21.35	21.16	22.15	22.17	20.37	19.09
SEm±		0.25	0.18	0.13	0.19	0.24	0.18	0.13	0.30	0.26
C.D. at 5% level		0.77	0.56	0.41	0.58	0.72	0.54	0.41	0.91	0.78

Table 4.17b: Mean performance of soil moisture percentage under non- stress condition of chickpea

Treat. symb	Genotypes	Soil moisture percentage in depth cm								
		60 DAS			80 DAS			At harvest		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
T ₁	JG-130	16.54	16.69	16.65	17.16	17.10	15.99	14.00	14.31	14.94
T ₂	IG-593	15.75	16.85	16.42	18.46	15.87	16.26	13.91	15.09	14.41
T ₃	JG-6	16.70	17.82	17.25	18.49	17.24	17.01	14.88	15.77	15.23
T ₄	JAKI-9218	16.48	17.22	16.09	18.33	17.04	15.86	14.70	15.59	15.17
T ₅	KAK-2	17.39	18.26	17.75	18.53	17.63	17.53	15.96	15.83	16.14
T ₆	JG-16	17.35	17.99	17.33	18.53	17.44	17.21	15.09	15.80	15.77
T ₇	Ujjain-21	15.55	15.67	15.74	15.31	15.12	14.98	13.73	14.30	14.37
T ₈	JG-11	16.16	17.36	17.02	16.07	15.55	15.37	14.77	15.03	14.67
T ₉	JG-412	16.42	16.59	17.00	17.91	16.89	16.66	14.50	14.90	15.10
SEm±		0.26	0.31	0.38	0.69	0.49	0.45	0.50	0.24	0.29
C.D. at 5% level		0.80	0.94	N.S.	N.S.	1.48	N.S.	N.S.	0.73	0.88

Fig 7: Mean performance of amount of dry matter accumulation under drought stress condition of chickpea

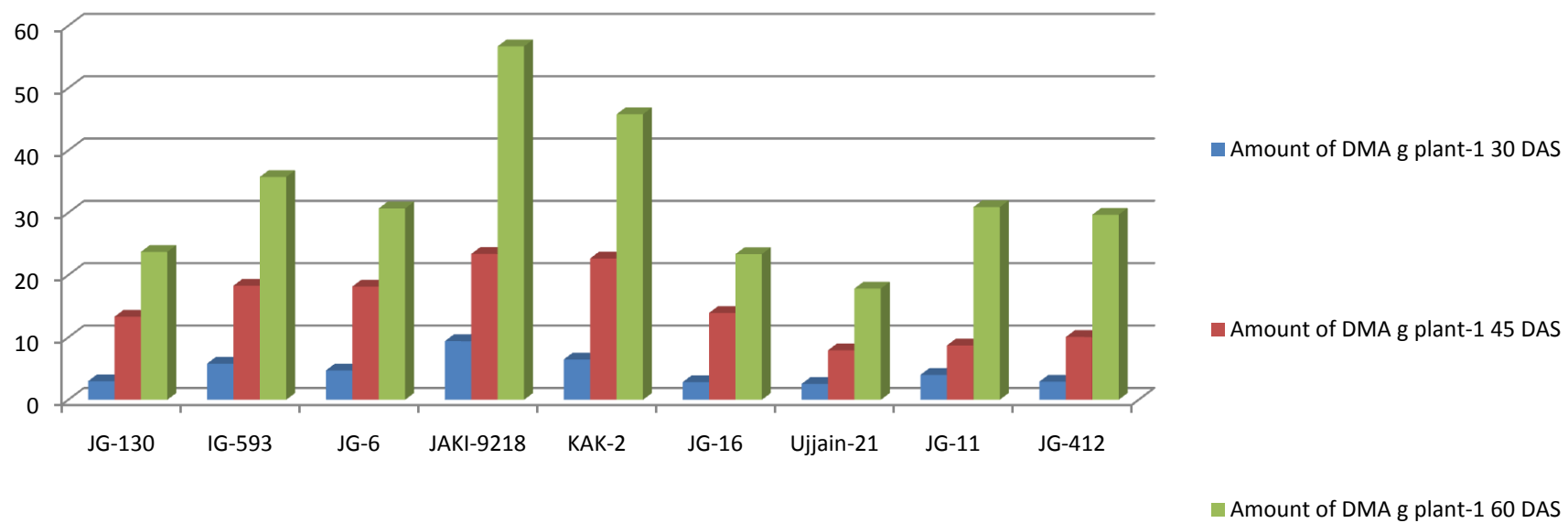


Fig 8: Mean performance of rate of dry matter accumulation underdrought stress condition of chickpea

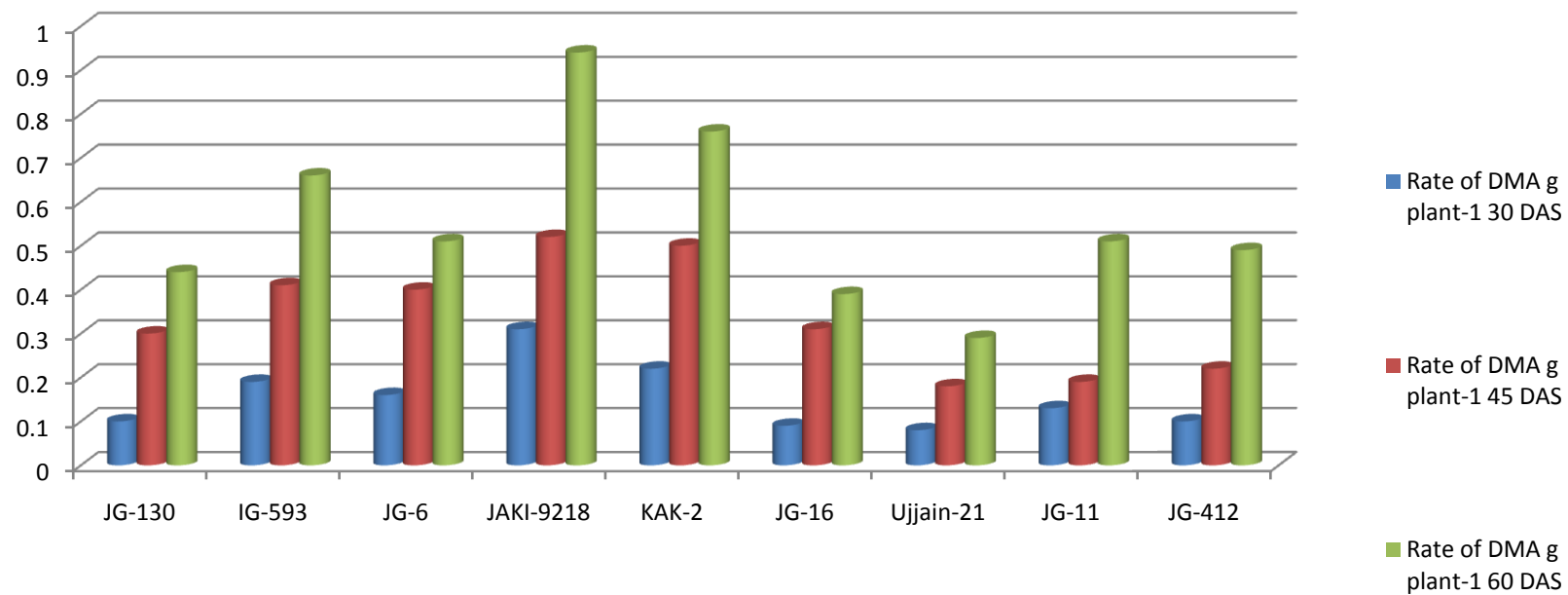


Fig 9: Mean performance of amount of dry matter accumulation under non-stress condition of chickpea

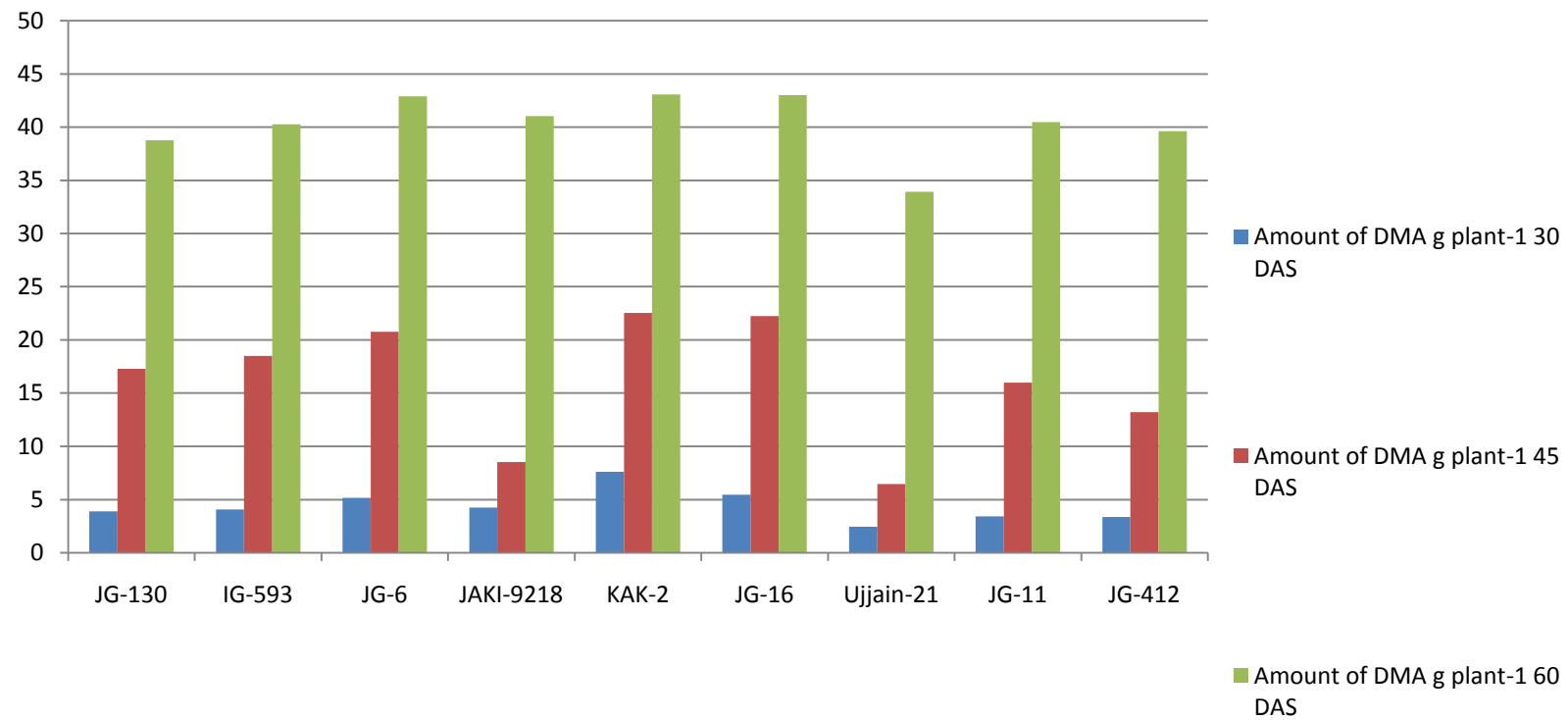


Fig 10: Mean performance of rate of dry matter accumulation under non stress condition of chickpea

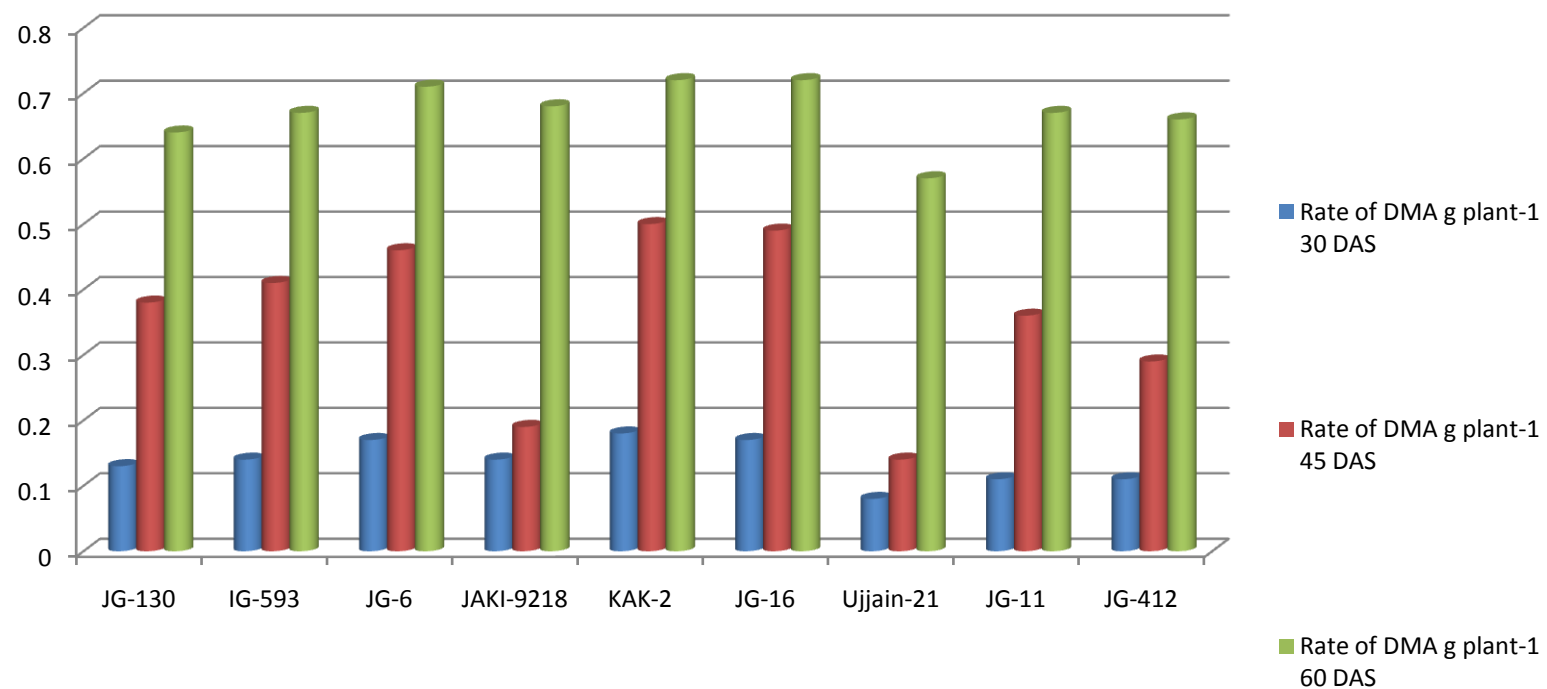


Fig 11: Mean performance of soil moisture percentage under stress condition of chickpea at sowing

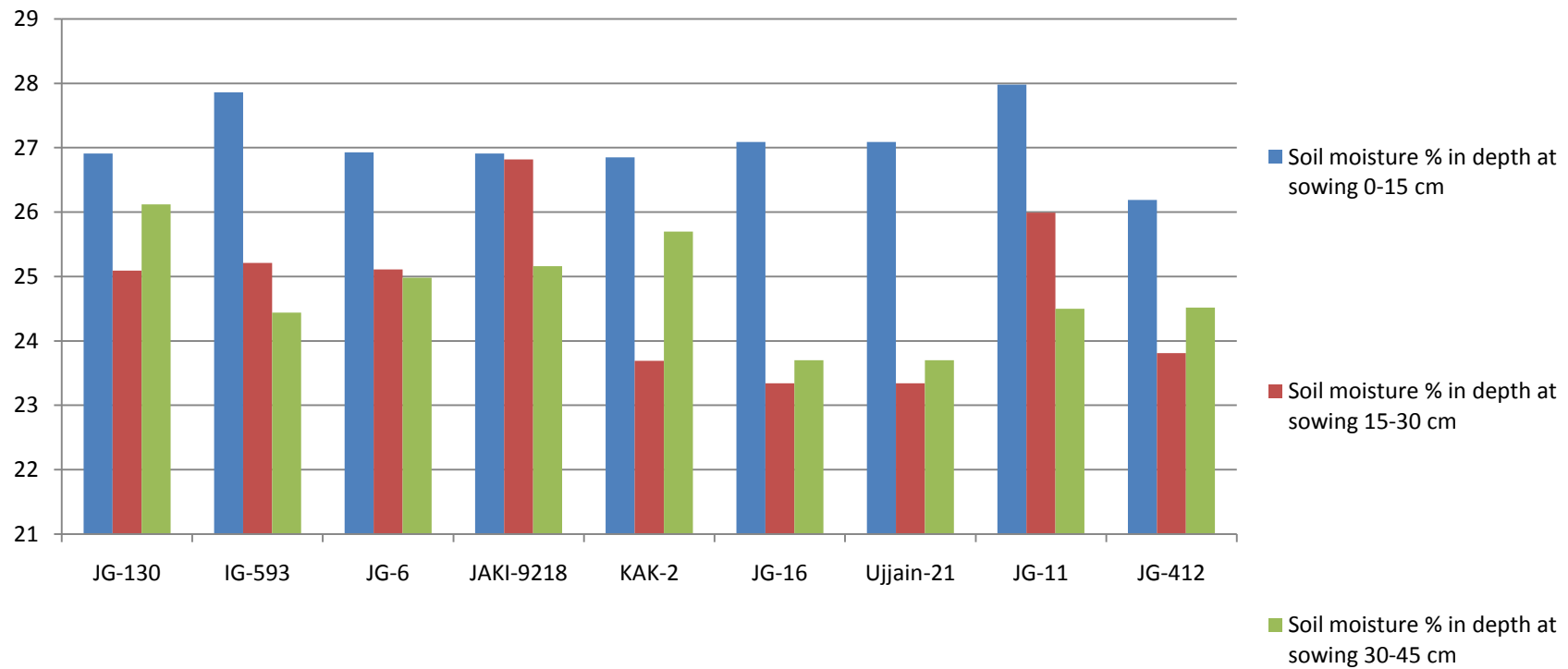


Fig 12: Mean performance of soil moisture percentage under stress condition of chickpea at 20 DAS

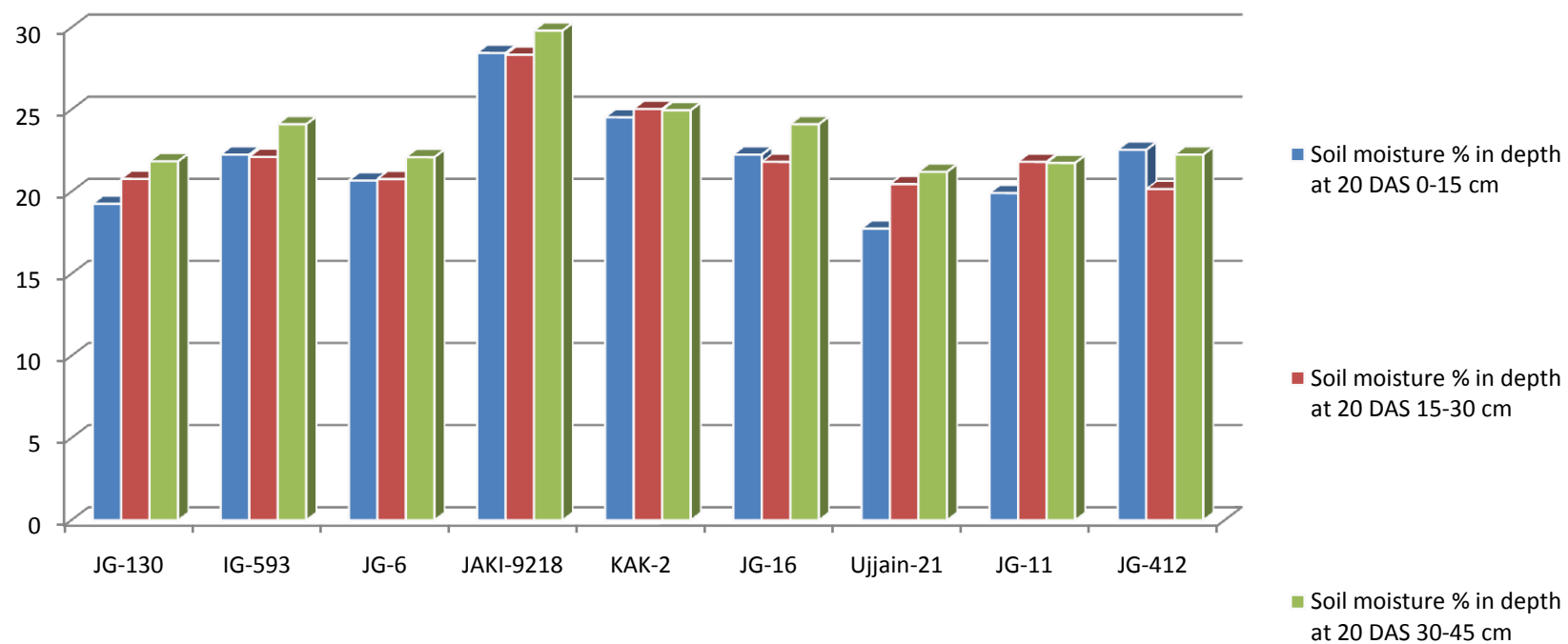


Fig 13: Mean performance of soil moisture percentage under drought stress condition of chickpea at 40 DAS

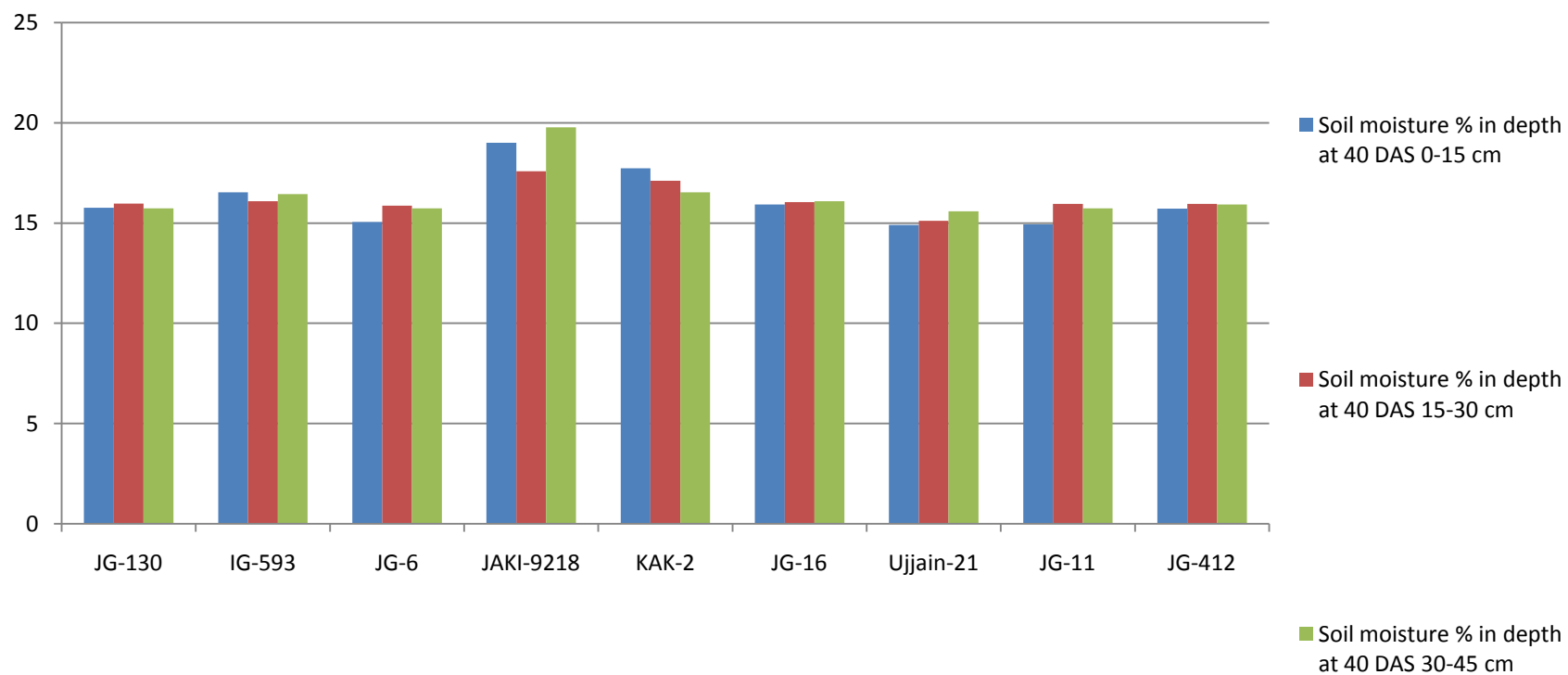


Fig 14: Mean performance of soil moisture percentage under drought stress condition of chickpea at 60 DAS

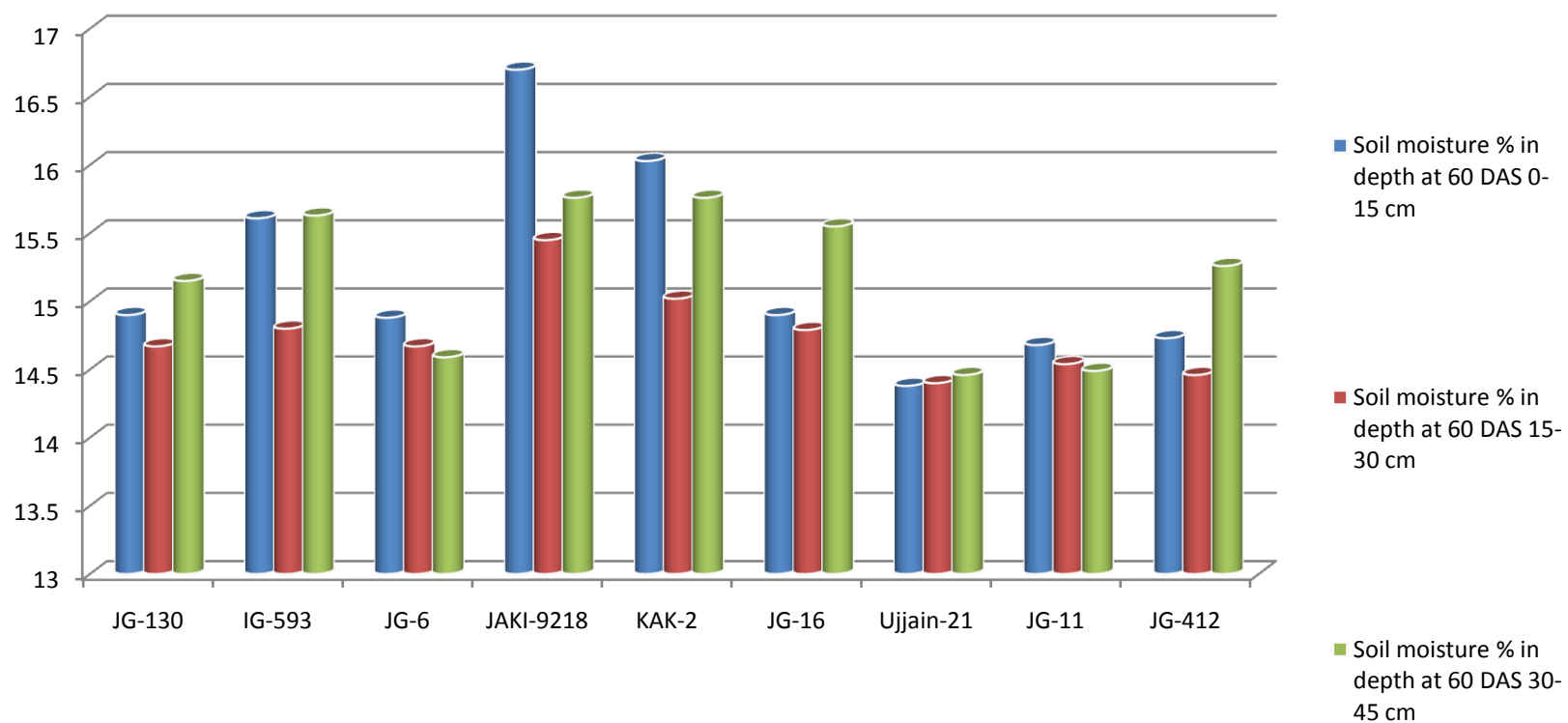


Fig 15: Mean performance of soil moisture percentage under drought stress condition of chickpea at 80 DAS

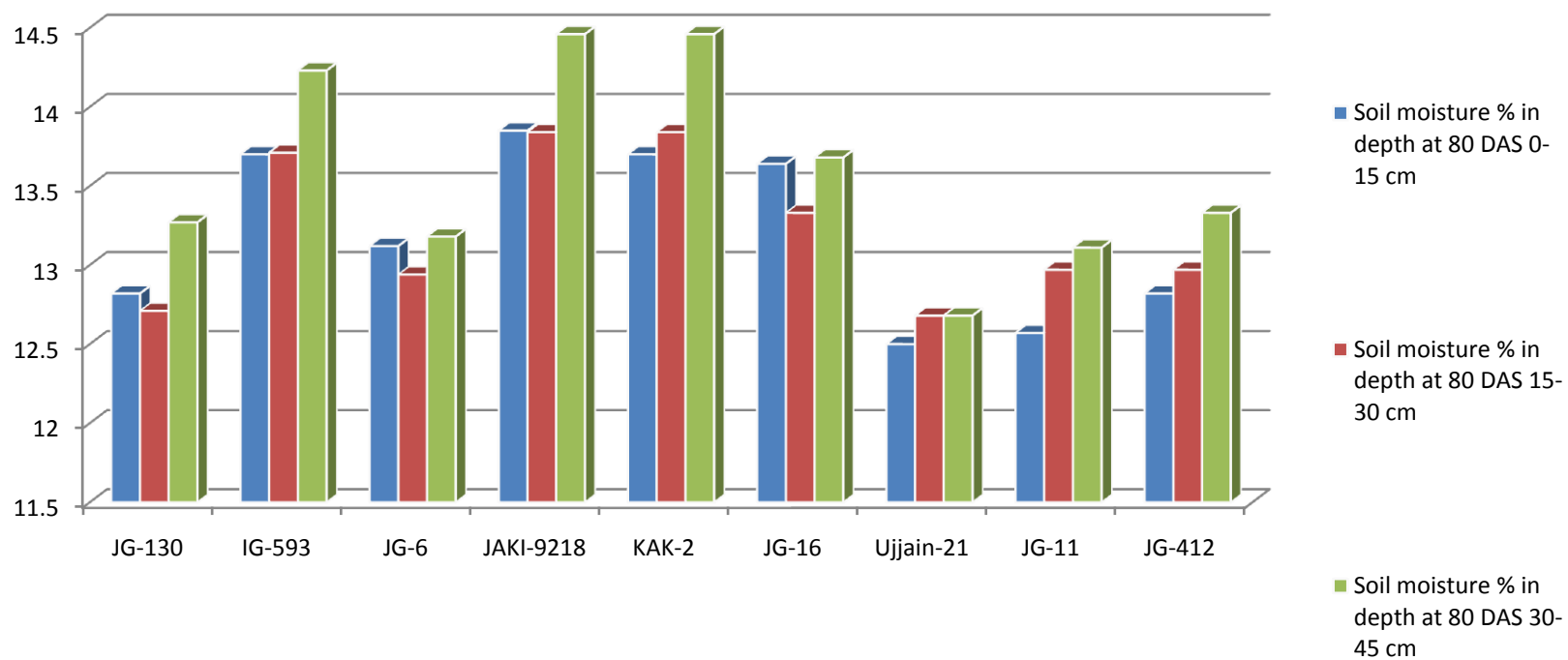


Fig 16: Mean performance of soil moisture percentage under drought stress condition of chickpea at harvest

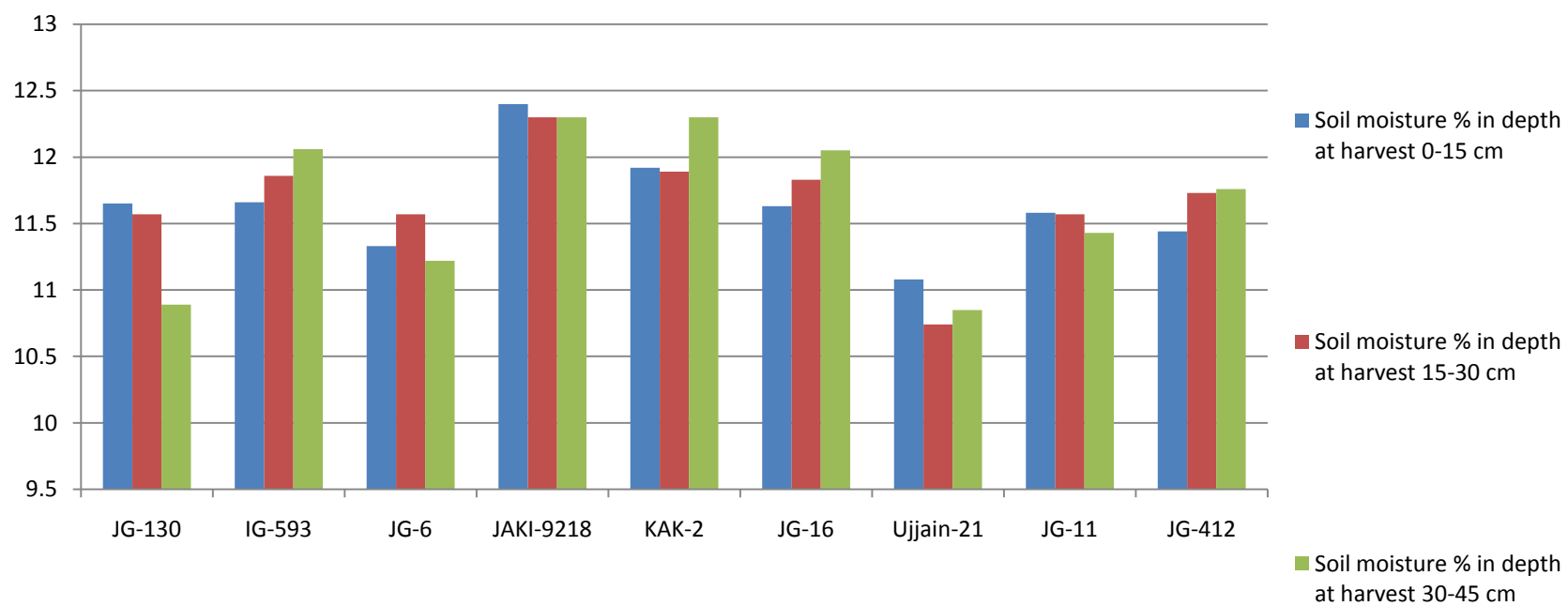


Fig 17: Mean performance of soil moisture percentage under non stress condition of chickpea at sowing

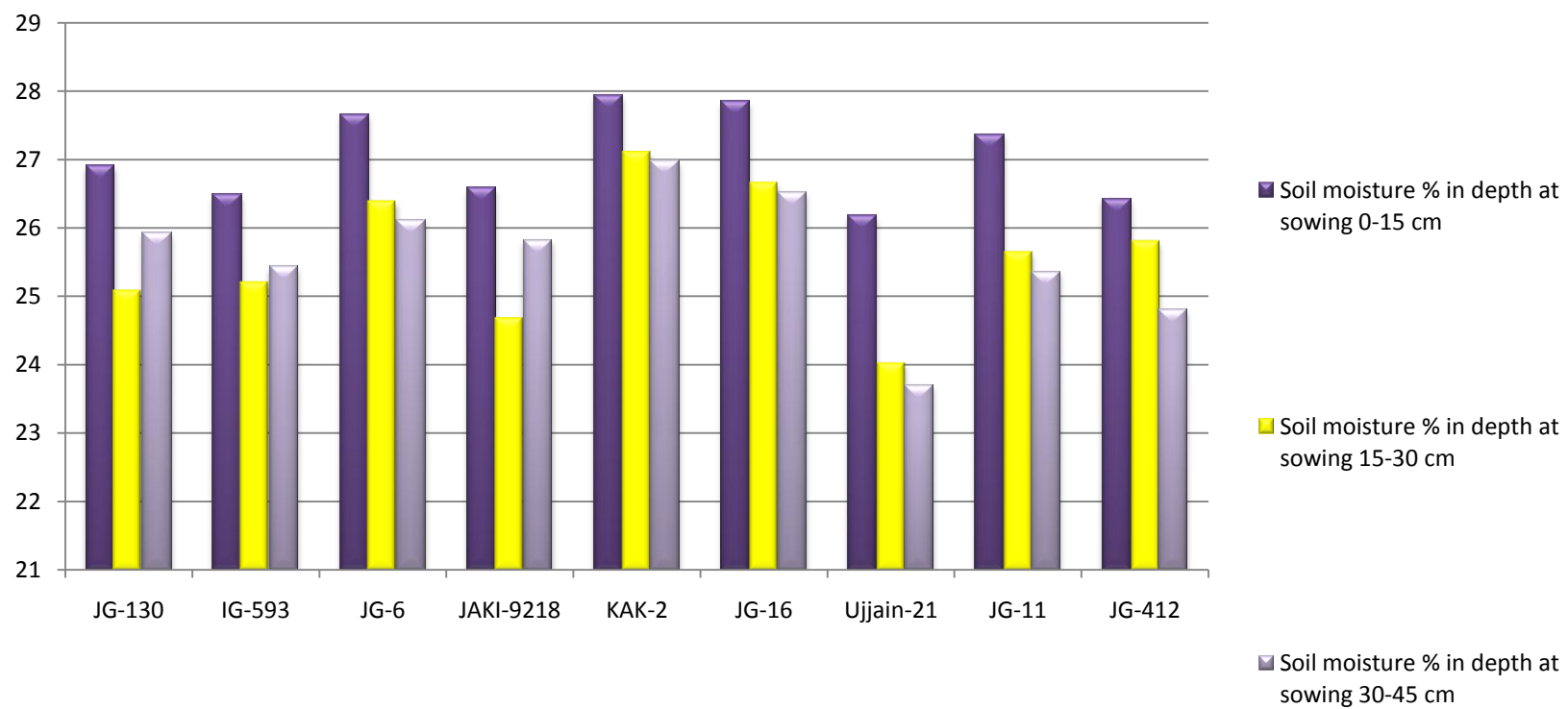


Fig 18: Mean performance of soil moisture percentage under non stress condition of chickpea at 20 DAS

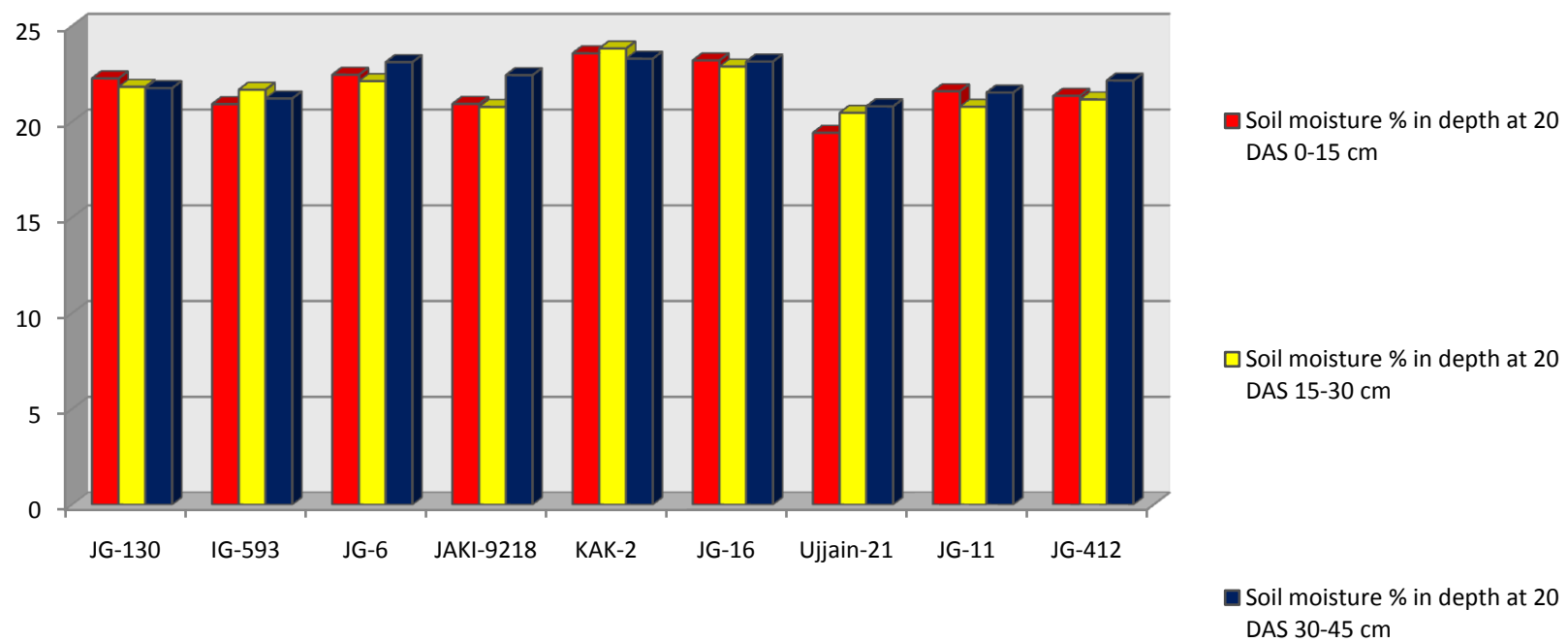


Fig 19: Mean performance of soil moisture percentage under non stress condition of chickpea at 40 DAS

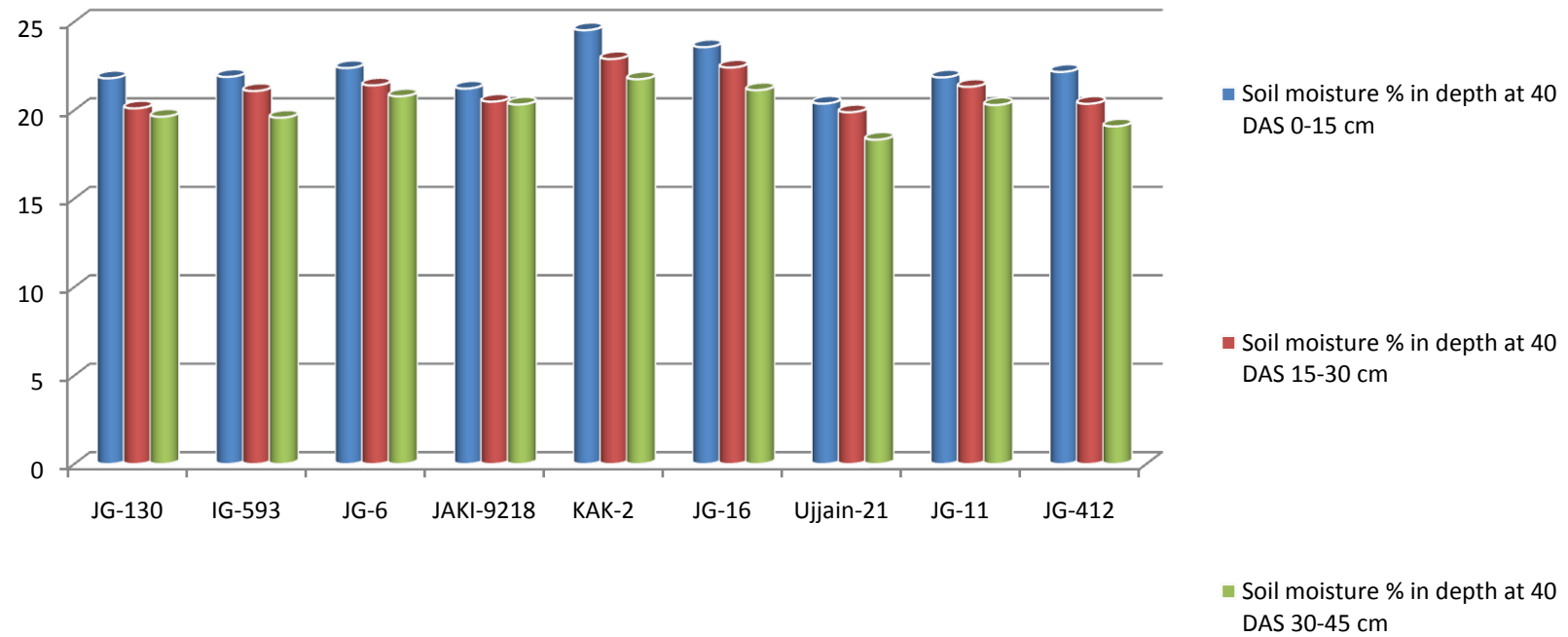


Fig 20: Mean performance of soil moisture percentage under non stress condition of chickpea at 60 DAS

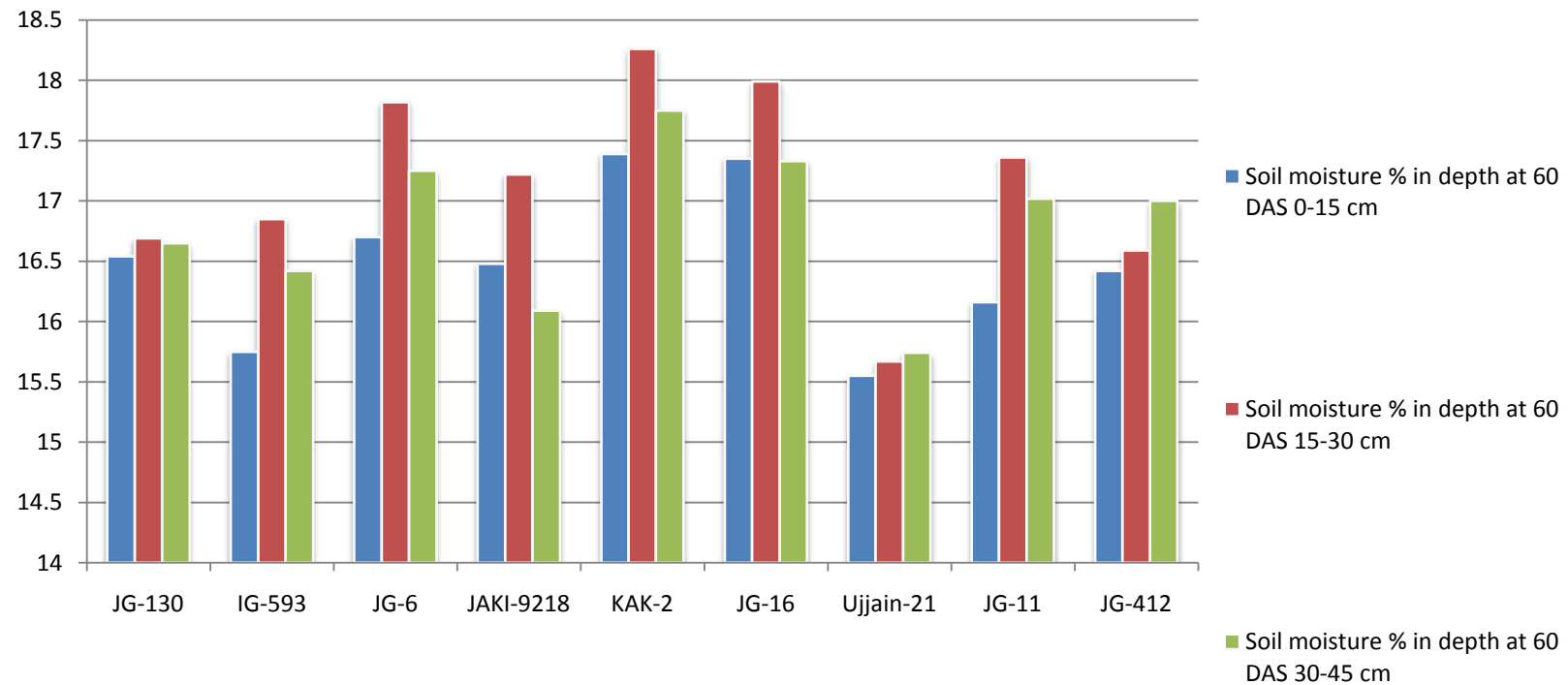


Fig 21: Mean performance of soil moisture percentage under non stress condition of chickpea at 80 DAS

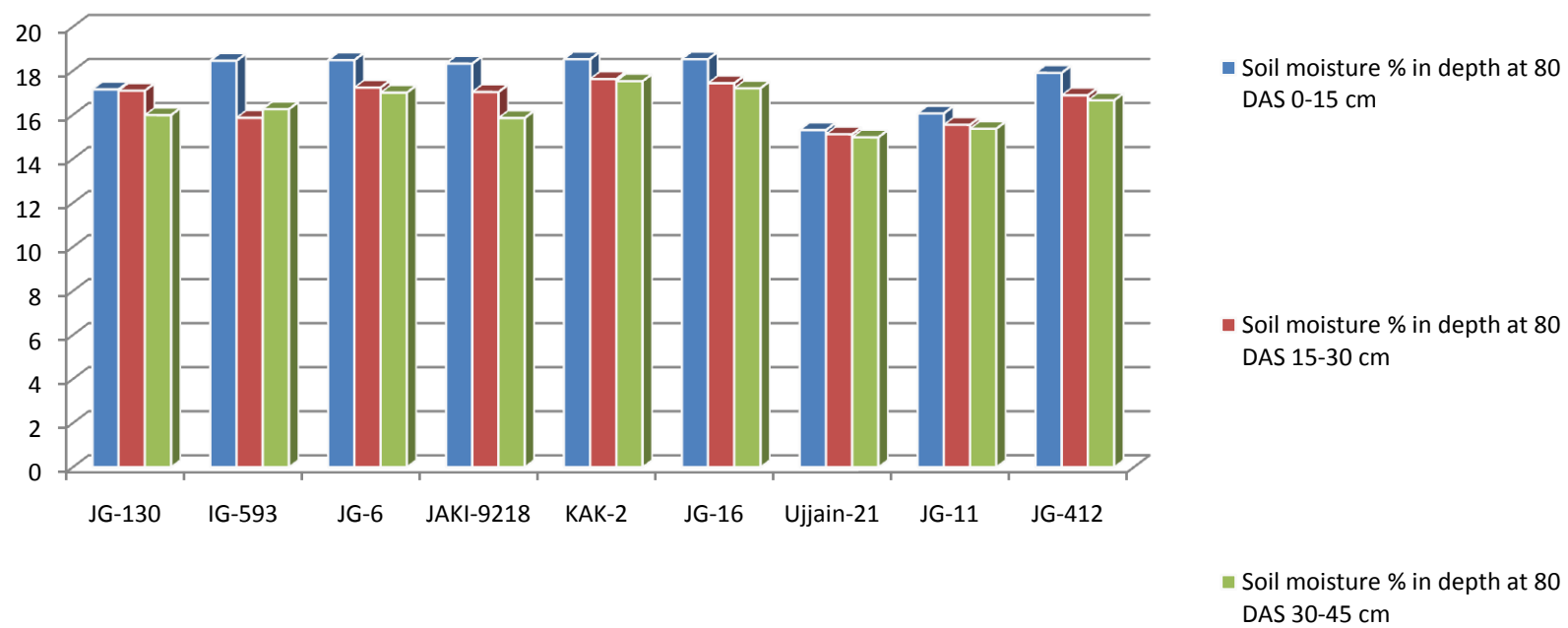
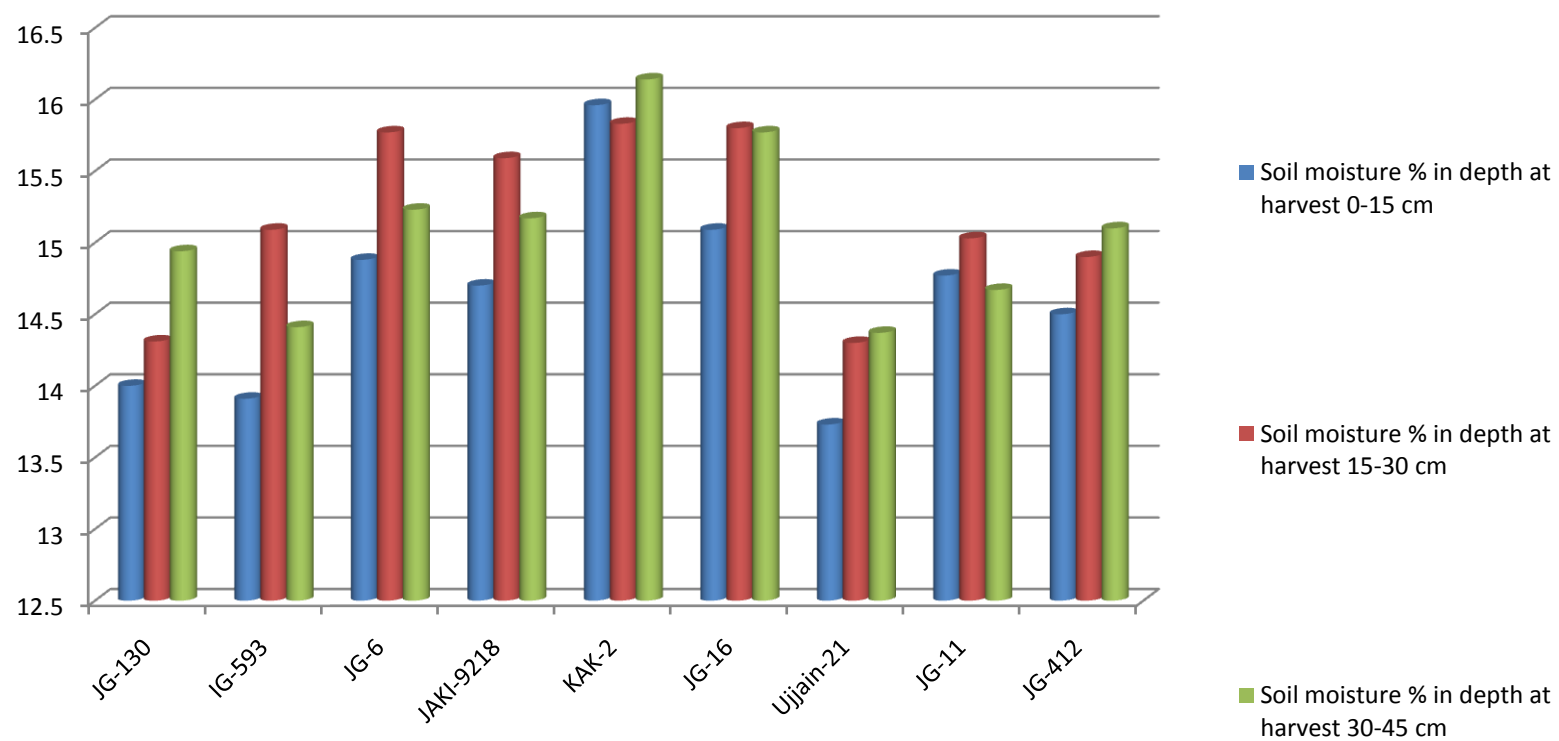


Fig 22: Mean performance of soil moisture percentage under non stress condition of chickpea at harvest



CHAPTER-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

6.1 Summary

The present investigation entitled “Relative performance of chickpea genotypes under drought stress and non-stress situations” was carried out during the year 2013-2014 at the Research Farm, All India Co-ordinated Research Project for Dryland Agriculture, Indore, (M.P.). The experimental material for the present investigation was comprised of nine genotypes of chickpea which were evaluated under drought stress and non-stress situations. These genotypes were sown in Randomized Complete Block Design with three replications, to observed physiological and yield contributing traits. Observations were recorded on the basis of five random competitive plants selected from each genotype separately for physiological and yield contributing traits were evaluated as per standard procedure. On the basis of results, the present investigation is summarized as follows:

The mean sum of square due to genotypes was highly significant for all the characters except number of seeds pod⁻¹ under drought stress situations indicating the presence of substantial genetic variability in the existing material.

The mean performance of the genotypes under drought stress condition revealed a wide range of variability for all the traits. The variation was highest for biological yield plant⁻¹, followed by number of pods plant⁻¹, reproductive phase, test weight, R.W.C at pod formation, W.S.D at pod formation, seed yield plant⁻¹, vegetative phase and harvest index (%). Under non-stress condition, the variation was highest for days to pod initiation, followed by days to flower initiation, days to 50% flowering, biological yield plant⁻¹, test weight, vegetative phase, reproductive phase and number of pods plant⁻¹.

The present study revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits under both situations which might be due to interaction of the genotypes with the environment to some degree or other explaining

environmental factors influencing the expression of these characters. High phenotypic and genotypic coefficient of variation was observed for seed yield plant⁻¹, followed by number of branches plant⁻¹, biological yield plant⁻¹, W.S.D at pod formation stage, test weight, number of seeds pod⁻¹ and W.S.D at flowering stage under both the condition. The high values of GCV suggested greater genetic variability among the genotypes and responsiveness of the attributes for making further improvement by selection.

The values of heritability was found high for characters viz, biological yield plant⁻¹ followed by reproductive phase, plant height at maturity, seed yield plant⁻¹ and days to flower initiation, test weight, R.W.C at pod formation stage, W.S.D at pod formation stage, days to 50 per cent flowering, R.W.C at flowering stage, W.S.D at flowering stage, days to pod initiation and days to maturity under drought stress condition. But heritability was observed high under non-stress condition for traits like number of pods plant⁻¹, followed by test weight, harvest index, biological yield plant⁻¹, plant height at maturity, number of branches plant⁻¹, seed yield plant⁻¹ and R.W.C at pod formation stage, flower initiation, W.S.D at pod formation stage, reproductive phase, days to 50 per cent flowering, vegetative phase and days to pod initiation. This indicates these characters were least influenced by environmental modification. It reflected that the phenotypes were the true representative of their genotypes and selection based on phenotypic performance would be reliable.

High heritability coupled with high genetic advance as percentage of mean were observed seed yield plant⁻¹ and biological yield plant⁻¹ under both the conditions. However, traits like test weight and number of branches plant⁻¹ exhibited high heritability and high genetic advance as percentage of mean at non stress condition. This suggests that the preponderance of additive genes in inheritance of these traits. It also indicates higher response for selection for high yield and associated characters due to predominance of additive gene actions.

The magnitude of genotypic correlation was higher than the phenotypic correlation for all the traits indicating inherent association between various characters.

Highly significant and positive association of seed yield plant⁻¹ was recorded with R.W.C at pod formation stage and reproductive phase under both the condition. While it was significant but negatively associated with W.S.D at pod formation stage and vegetative phase at both condition and days to flower initiation and days to maturity (at non-stress condition). The highest positive and significant correlation coefficient of seed yield plant⁻¹ was noted with R.W.C at pod formation stage and reproductive phase indicating that these characters were the primary yield determinant in chickpea.

The correlation of seed yield plant⁻¹ was highly significant and positive with number of pods plant⁻¹, biological yield plant⁻¹, test weight and harvest index under drought stress condition. But seed yield plant⁻¹ with plant height at maturity, number of seeds pod⁻¹, biological yield plant⁻¹, test weight and harvest index under non-stress condition, indicating that these characters were the primary yield determinant in chickpea.

Path coefficient analysis of different physiological characters contributing towards seed yield plant⁻¹ showed that W.S.D at flowering stage had highest positive direct effect followed by R.W.C at flowering stage, R.W.C at pod formation stage and days to pod initiation. Whereas, days to maturity exhibited the highest negative direct effect on seed yield plant⁻¹ followed by days to flower initiation, reproductive phase, W.S.D at pod formation stage and days to 50 per cent flowering under drought stress condition.

The highest positive direct effect was recorded for R.W.C at flowering stage on seed yield plant⁻¹ followed by W.S.D at flowering stage, days to flower initiation, R.W.C at pod formation stage, W.S.D at pod formation stage and days to 50 per cent flowering. Vegetative phase exhibited highest negative direct effect on seed yield plant⁻¹ followed by days to pod initiation, days to maturity and reproductive phase under non-stress condition.

Path coefficient analysis of different yield contributing characters contributes towards seed yield plant⁻¹ showed that biological yield plant⁻¹, had highest positive direct effect followed by harvest index, test weight and number of branches plant⁻¹. Whereas, plant height at maturity exhibited the highest negative direct effect on seed

yield plant⁻¹ followed by number of pods plant⁻¹ under drought stress as well as non-stress condition.

Significantly maximum seed yield plant⁻¹ was recorded in genotype KAK – 2 under drought stress condition, followed by JG – 130, JAKI – 9218, IG – 593 and JG – 16 as compared to other genotypes. While, it was observed minimum in genotypes JG – 412 in both condition.

Out of nine genotypes, genotypes KAK – 2, JG – 16, JG – 6 and IG 593 exhibited minimum reduction in seed yield due to moisture stress condition. Further it also maintained highest seed yield along with minimum drought index, high drought tolerance efficiency and least drought susceptibility index. Therefore, it is revealed that these genotypes will be suitable for enhancing seed yield under drought stress condition.

In the present studies genotypes JAKI-9218, KAK-2 and IG-593 were found to be promising for dry matter production under drought stress condition. Genotypes KAK-2, JG-16 and JG-6 were found to be suitable for dry matter production under non stress condition. Therefore, it is concluded that genotype KAK-2 was most promising for dry matter production under both drought stress as well as non- stress condition.

Results revealed that genotypes JAKI-9218 followed by KAK-2, IG-593 and JG-16 were recorded maximum soil moisture percentage in all the depth of soil profile and stages of crop growth under drought stress condition. In the non-stress condition genotypes KAK-2, JG-16 and JG-6 were observed maximum soil moisture percentage in all the depth of soil profile and stages of crop growth. Therefore, it is concluded that genotype KAK-2 and JG-16 was most promising for soil moisture percentage under both drought stress as well as non- stress condition.

6.2 Conclusion

Out of nine genotypes, KAK – 2, JG – 16, JG – 6 and IG 593 exhibited minimum reduction in seed yield due to drought stress condition. Further it also maintained highest seed yield along with maximum drought index, high drought tolerance efficiency and least drought susceptibility index. Thus, it reveals that these genotypes will be suitable for enhancing crop productivity under drought stress condition.

High heritability coupled with high genetic advance as percentage of mean for traits like seed yield plant⁻¹ and biological yield plant⁻¹ under both the condition. However, traits like test weight and number of branches plant⁻¹ exhibited high heritability and high genetic advance as percentage of mean under non- stress condition.

Path coefficient analysis of different physiological characters contributing towards seed yield plant⁻¹ showed that W.S.D at flowering stage had highest positive direct effect followed by R.W.C at flowering stage, R.W.C at pod formation stage and days to pod initiation. Whereas, days to maturity exhibited the highest negative direct effect on seed yield plant⁻¹ followed by days to flower initiation, reproductive phase, W.S.D at pod formation stage and days to 50 per cent flowering had correlation coefficient values at par with their direct effect on seed yield plant⁻¹. This indicates true relationships with seed yield plant⁻¹ and direct selection for these traits would result in higher breeding efficiency for improving yield under drought stress condition.

Correlation coefficient and path coefficient analysis of different yield contributing characters contributes towards seed yield plant⁻¹ showed that biological yield plant⁻¹, had highest positive direct effect followed by harvest index, test weight and number of branches plant⁻¹. Whereas, plant height at maturity exhibited the highest negative direct effect on seed yield plant⁻¹ followed by number of pods plant⁻¹ under drought stress as well as non-stress condition. This indicates true relationships with seed yield plant⁻¹ and direct selection for these traits would result in higher breeding efficiency for improving yield under both condition.

6.3 Suggestions for further work

1. The genetic variability present in the experimental material should be further exploited for yield improvement.
2. Identifying the drought tolerance genotypes of chickpea for cultivation in rainfed / dryland areas.

Appendix – I

Analysis of variance for dry matter accumulation in plants under drought stress and non stress condition of chickpea (mean square)

Source of variation	d.f.	Amount of dry matter accumulation under drought stress condition at		
		30 DAS	45 DAS	60 DAS
Replications	2	2.671	2.582	5.363
Varieties	8	15.439**	100.372**	435.852**
Error	16	2.344	1.688	3.316

Source of variation	d.f.	Rate of dry matter accumulation under drought stress condition at		
		30 DAS	45 DAS	60 DAS
Replications	2	0.0030	0.0012	0.0040
Varieties	8	0.0172**	0.0495**	0.1199**
Error	16	0.0025	0.0008	0.0029

Source of variation	d.f.	Amount of dry matter accumulation under non stress condition at		
		30 DAS	45 DAS	60 DAS
Replications	2	5.130	1.630	19.431
Varieties	8	6.844**	99.950**	24.662**
Error	16	1.416	1.754	0.321

Source of variation	d.f.	Rate of dry matter accumulation under non stress condition at		
		30 DAS	45 DAS	60 DAS
Replications	2	0.0070	0.0008	0.0109
Varieties	8	0.0032**	0.0493**	0.0068**
Error	16	0.0001	0.0008	0.0003

Appendix – II

Analysis of variance for soil moisture percentage in 0-15, 15-30, and 30-45 cm depth under stress condition of chickpea (mean square)

Source of variation	d.f.	Soil moisture percentage in depth cm					
		At sowing			20 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	3.087	3.053	3.683	3.485	4.460	1.996
Varieties	8	0.878**	4.595**	2.019**	30.002**	21.399**	21.425**
Error	16	0.214	0.204	0.109	0.089	0.193	1.224

Source of variation	d.f.	Soil moisture percentage in depth cm					
		40 DAS			60 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	1.727	5.335	1.267	8.520	6.757	6.256
Varieties	8	5.807**	1.592**	5.166*	1.704**	0.313	0.883**
Error	16	0.752	0.108	1.384	0.201	0.130	0.125

Source of variation	d.f.	Soil moisture percentage in depth cm					
		80 DAS			At harvest		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	6.411	3.554	2.537	7.348	4.632	5.925
Varieties	8	0.856**	0.675*	1.238**	0.412**	0.523**	0.990**
Error	16	0.101	0.242	0.090	0.104	0.075	0.179

Appendix – III

Analysis of variance for soil moisture percentage in 0-15, 15-30, and 30-45 cm depth under non stress condition of chickpea (mean square)

Source of variation	d.f.	Soil moisture percentage in depth cm					
		At sowing			20 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	5.963	3.904	4.770	3.036	4.779	3.985
Varieties	8	1.337**	2.921**	2.810**	4.933**	3.611**	2.462**
Error	16	0.199	0.106	0.057	0.115	0.174	0.100

Source of	d.f.	Soil moisture percentage in depth cm					
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variation		40 DAS			60 DAS		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	4.333	4.476	6.117	0.619	1.177	1.984
Varieties	8	4.466	3.180**	3.381**	2.123**	2.157**	1.028
Error	16	0.056	0.277	0.204	0.218	0.300	0.438

Source of variation	d.f.	Soil moisture percentage in depth cm					
		80 DAS			At harvest		
		0-15	15-30	30-45	0-15	15-30	30-45
Replications	2	3.921	0.996	2.916	0.673	1.025	0.618
Varieties	8	2.812	2.177*	1.361	1.560	1.746**	1.695**
Error	16	1.455	0.738	0.627	0.750	0.181	0.262

VITA

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