

**“INFLUENCE OF MOISTURE  
REGIMES ON GROWTH, YIELD AND  
QUALITY OF CHICKPEA (*Cicer  
arietinum* L.) CULTIVARS”.**

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**B.Sc. (Ag.)**

**MASTER OF SCIENCE IN AGRICULTURE  
(AGRONOMY)**



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**“INFLUENCE OF MOISTURE REGIMES ON  
GROWTH, YIELD AND QUALITY OF  
CHICKPEA (*Cicer arietinum* L.)CULTIVARS”**

**BY**

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**B. Sc. (Ag.)**

**THESIS SUBMITTED TO THE  
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**CHAIRPERSON: Dr. S. A. HUSSAIN**



**DEPARTMENT OF AGRONOMY  
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**2014**

## **CERTIFICATE**

**Ms. D.SWETHA** has satisfactorily prosecuted the course of research and that thesis entitled **“INFLUENCE OF MOISTURE REGIMES ON GROWTH, YIELD AND QUALITY OF CHICKPEA CULTIVARS”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

**Date:**

**(Dr. S.A. HUSSAIN)**

**Place:**

**Chairman**

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## **DECLARATION**

I, **D.SWETHA**, hereby declare that the thesis entitled “**INFLUENCE OF MOISTURE REGIMES ON GROWTH, YIELD AND QUALITY OF CHICKPEA CULTIVARS**” submitted to the **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

**Place:** Hyderabad

**(D.SWETHA)**

**Date:**

**I. D. No. RAM/2012-09**

## LIST OF ABBREVIATIONS

%	:	Percent
@	:	At the rate of
°C	:	Degree centigrade
&	:	And
A.M.	:	Ante meridian
ASMD	:	Acceptable soil moisture deficit
B : C	:	Benefit cost ratio
CD	:	Critical difference
CGS	:	Critical crop growth stages
cm	:	Centimetre
CPE	:	Cumulative pan evaporation
DAS	:	Days after sowing
DMP	:	Drymatter production
dS m <sup>-1</sup>	:	Decisiemens per metre
Epan	:	Evaporation pan
<i>et al.</i>	:	And others
ET <sub>a</sub>	:	Actual evapotranspiration
ET <sub>c</sub>	:	Crop evapotranspiration
ET <sub>o</sub>	:	Reference evapotranspiration
Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram

$\text{g cm}^{-3}$	:	Gram per cubic centimetre
$\text{g plant}^{-1}$	:	Gram per plant
ha	:	Hectare
H.I.	:	Harvest index
INM	:	Integrated nutrient management
I.W.	:	Irrigation water
Kc	:	Crop coefficient
$\text{K}_2\text{O}$	:	Potassium
kg	:	Kilogram
$\text{kg ha}^{-1} \text{ cm}^{-1}$	:	Kilogram per hectare per centimetre
$\text{kg ha}^{-1}$	:	Kilogram per hectare
$\text{kg ha}^{-1} \text{ mm}^{-1}$	:	Kilogram per hectare per millimetre
$\text{km hr}^{-1}$	:	Kilometer per hour
Kpan	:	Pan coefficient
l	:	Litre
m	:	Metre
$\text{m}^2$	:	Metre square
$\text{me l}^{-1}$	:	Milliequivalent per litre
mm	:	Millimetre
$\text{mm day}^{-1}$	:	Millimetre per day
MPa	:	Mega pascal
N	:	Nitrogen
NS	:	Non significant
NWU	:	Net water use
PE	:	Pan evaporation

$P_2O_5$	:	Phosphorus
$q\ ha^{-1}$	:	Quintal per hectare
RDF	:	Recommended dose of fertilizers
$Rs\ ha^{-1}$	:	Rupees per hectare
SEm	:	Standard error mean
SMD	:	Soil moisture deficit
t	:	Tonnes
$t\ ha^{-1}$	:	Tonnes per hectare
USWB	:	United States of Weather Burea
<i>viz.</i>	:	Namely
WRc	:	Water recommendation
WUE	:	Water use efficiency
$yield\ ha^{-1}$	:	Yield per hectare
yr	:	Year

## **CERTIFICATE**

This is to certify that the thesis entitled “**INFLUENCE OF MOISTURE REGIMES ON GROWTH, YIELD AND QUALITY OF CHICKPEA CULTIVARS**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Ms. D.SWETHA** under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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## **ABSTRACT**

A field experiment entitled **“Influence of moisture regimes on growth, yield and quality of chickpea cultivars”** was conducted during *Rabi*, 2013-14 at College Farm, College of Agriculture, Rajendranagar. The soil of the experimental field was sandy loam in texture with pH of 7.8. The soil was low in available nitrogen (226 kg ha<sup>-1</sup>), available phosphorus (18.5 kg ha<sup>-1</sup>) and medium in available potassium (235 kg ha<sup>-1</sup>) contents. The experiment was laid out in a randomized block design (two factors) with one factor I: treatments of four moisture regimes *viz.*, I<sub>1</sub> (Rainfed), I<sub>2</sub> (0.3 IW:CPE), I<sub>3</sub> (0.6 IW:CPE), I<sub>4</sub> (0.9 IW:CPE) and factor II : varieties JG-11 and Annegiri and replicated thrice.

Growth parameters *viz.*, initial and final plant stand, plant height, number of branches plant<sup>-1</sup>, dry matter production and root nodules were measured/ determined at periodical intervals. Likewise yield attributes *viz.*, no. of pods plant<sup>-1</sup>, no.of seeds pod<sup>-1</sup> and 100 seed weight, seed and haulm yield, protein content were determined. NPK contents at harvest in grain is taken and expressed as NPK uptake. Also, the seasonal water use, the crop coefficient and moisture extraction pattern were also determined.

Significant effect of moisture regimes on plant height was observed at all growth stages (30, 60, 90 DAS and at harvest) where I<sub>4</sub> (0.9 IW:CPE) gave superior performance which is on par with I<sub>3</sub> (0.6 IW:CPE), number of branches plant<sup>-1</sup> and dry matter production was superior in I<sub>4</sub> (0.9 IW:CPE) which is on par with I<sub>3</sub> (0.6 IW:CPE). Each proportionate increase in moisture regimes from IW:CPE 0.3-0.9 significantly increased the plant height, number of branches plant<sup>-1</sup> and dry matter production plant<sup>-1</sup>, whereas varieties did not show significant difference in growth attributes.

Further concerning yield attributes, I<sub>4</sub> (0.9 IW:CPE) and I<sub>3</sub> (0.6 IW:CPE) registered statistically on par but superior performance in terms of no. of pods plant<sup>-1</sup> and 100 seed weight but no response on no. of seeds pod<sup>-1</sup>. The treatment I<sub>2</sub> (0.3 IW:CPE) ratio is

significantly superior to I<sub>1</sub> (Rainfed) treatment. Among varieties, JG-11 performance was better than Annegiri with respect to yield attributes.

Irrigation scheduled at 0.6 IW:CPE (I<sub>3</sub>) produced significantly higher grain and haulm yields of chickpea but it was on par with 0.9 IW:CPE (I<sub>4</sub>). The JG-11 variety has produced higher grain yield than Annegiri.

Protein content was recorded significantly superior in 0.9 IW:CPE (I<sub>4</sub>) it was on par with 0.6 IW:CPE (I<sub>3</sub>). The varieties have no influence on protein content.

N, P and K uptake was more in 0.6 IW:CPE (I<sub>3</sub>) but it was on par with 0.9 IW:CPE (I<sub>4</sub>) and significantly superior as compared to I<sub>1</sub> (Rainfed) and I<sub>2</sub> (0.3 IW:CPE) while, varieties did not differ significantly in respect of NPK uptake.

Water use efficiency decreased with increase in irrigation level from I<sub>1</sub> (Rainfed), to I<sub>4</sub> (0.9 IW:CPE) treatments. Moisture regimes at higher level *i.e.* 0.9 IW:CPE ratio requires more water compared to other lower levels. The lowest water use was recorded under I<sub>4</sub> (0.9 IW:CPE) treatment.

Moisture regimes I<sub>4</sub> (0.9 IW:CPE) resulted in higher crop coefficient value at all crop stages *viz.*, early vegetative, vegetative, flowering, physiological maturity stages, respectively. The peak crop coefficient was achieved during mid season stage followed by development stage owing to more water loss through transpiring surface.

The interaction effects of irrigation and varieties has not shown any significant difference among growth, yield and quality parameters.

## Chapter I

# INTRODUCTION

Pulses are commonly known as food legumes which are secondary to cereals in production and consumption in India. Pulses are the most valuable and naturally occurring sources of protein, vitamins, minerals and calories. Pulses play an important role in Indian agriculture as they restore soil fertility by fixing atmospheric nitrogen (approximately 20 kg ha<sup>-1</sup>) through their nodules. Some pulses are drought resistant and some are having erosion resisting property due to their deep root system and good ground coverage. Because of these good characters, pulses are called as ‘marvel of nature’ (Parihar and Sandhu,1987). Pulses can also be referred to as “mini fertiliser factory”, as they fix atmospheric nitrogen through symbiosis. Pulses are the most important components of the balanced diet in vegetarian countries like India.

Chickpea (*Cicer arietinum* L.) is a *rabi* pulse crop, grown on a wide range of soils from medium to heavy black soils, with a rainfall of 400-700 mm and optimum temperature of 24-30°C. Chickpea (*Cicer arietinum* L.) is the largest produced food legume in South Asia and the third largest produced food legume globally. Across the world, chickpea is grown in 10.5 m ha with a total production of 7.5 m t. Important countries growing chickpea are Pakistan, India, Turkey, Mexico, Burma and Ethiopia. India ranks first in production and consumption in the world. In India, chickpea is grown in an area of 8 m ha with a production of about 7 m t and with a productivity of 895 kg ha<sup>-1</sup>. In India, the crop is largely grown in Madhya Pradesh, Rajasthan, Maharashtra, U.P, Karnataka and Andhra Pradesh. In Andhra Pradesh, chickpea is grown in area of 6.1 m ha with a production of about 8.6 m t and with a productivity of 1410 kg ha<sup>-1</sup>.

There are several important factors responsible for the low production of pulses in general and chickpea in particular in India, *viz.*, cultivation being restricted mainly to rainfed areas or cultivated under residual moisture situation during post-rainy season, lack of high yielding varieties, instability of yield, low harvest index, inadequate management practices and poor quality seeds used for sowing.

Chickpea response to irrigation regimes and increases the yield. The increase in yield due to irrigation regimes is due to increase in number of pods per plant. Maintaining

of soil moisture at an adequate level produces more grain yield in chickpea (Singh *et al.*, 2006).

In *rabi*, chickpea is grown under rainfed conditions. The timely availability of assured irrigation is one of the factors determining the success of the crop especially during the critical stages of the crop growth i.e. branching, development stages and pod formation. Availability of moisture in the soil enhances the efficiency of applied nutrients. Any reduction of soil moisture at critical stages will considerably reduce the grain yield. Therefore, it is necessary to evaluate irrigation scheduling so as to realize higher yield and economic returns.

Water is a crucial input for augmenting crop production towards sustainability in agriculture. Scientific water management aims to provide suitable soil moisture environment to the crop to obtain optimum yield commensurate with maximum economy in irrigation water and maintain soil productivity.

During the winter season less water is required at early stage of crop while, at later crop growth stages water requirement increases due to rapid increase in evapotranspiration demand. Amongst the various irrigation approaches, climatological approach has been found to be better, since it integrates all the weather parameters giving them their natural weightage in given climatic-water-plant continuum (Parihar and Sandhu, 1987). A more practicable and understandable approach based on the ratio of fixed amount of irrigation water (IW) to cumulative pan evaporation (CPE) is much desired. Moreover, a close relationship exists between the rate of consumptive use of crop and the rate of evaporation.

On account of cited facts above, the following objectives are proposed under the **research topic, “Influence of moisture regimes on growth, yield and quality of chickpea (*Cicer arietinum* L.) cultivars”**.

### **Objectives**

1. To study the effect of varying IW/CPE ratios on growth, yield, quality and water productivity of chickpea cultivars.
2. To determine the field crop coefficients for chickpea cultivars.
3. To optimise the crop water requirement of chickpea cultivars.

## Chapter II

# REVIEW OF LITERATURE

Chickpea (*Cicer arietinum* L.) is the largest produced food legume in South Asia and the third largest produced food legume globally. Chickpea is a *rabi* pulse crop, mostly grown in conserved moisture. Irregular rainfall and moisture stress at critical stages of crop results in low yield. Hence higher productivity can be achieved by scheduling irrigation at critical stages (Singh *et al.*, 2006). Most of the earlier work on irrigation is based either on critical growth stages or on soil moisture depletion without including the climatic parameters into consideration. The information on performance of chickpea under different moisture regimes of Southern Telangana is meagre.

Hence, an attempt has been made in this chapter to review the research work done by various workers on varying irrigation schedule and their effect on growth, yield, nutrient content and uptake by chickpea.

### 2.1 Effect of Moisture regimes on Growth and Yield of Chickpea

#### 2.1.1 Growth Parameters

Irrigation scheduled at 0.4 or 0.6 IW:CPE ratio or at branching and pod formation had no effect on nodule dry weight of chickpea recorded at 45 DAS (Roy and Tripathi, 1985).

Parihar (1990) observed significantly higher plant height and branches plant<sup>-1</sup> in chickpea with irrigation scheduling at 0.8 IW:CPE ratio (five irrigations) compared to 0.6 (four irrigations) and 0.4 (three irrigations) IW:CPE ratios.

Prabhakar and Saraf (1990) noticed highest dry matter of chickpea with two irrigations at 0.4 IW:CPE ratio compared to one irrigation at 0.4 or 0.2 IW:CPE ratio and no irrigation. Also, noticed significantly higher plant height and no. of branches plant<sup>-1</sup> of chickpea with two irrigations at 0.4 IW:CPE ratio compared to one irrigation at 0.4 or 0.2 IW:CPE ratio and no irrigation.

Pal and Lal (1993) noticed increased nodule number and their dry weight plant<sup>-1</sup> of greengram with the increasing frequency of irrigation over no post sowing irrigation.

Srivastava and Srivastava (1994) revealed that highest plant height and branches plant<sup>-1</sup> of chickpea with two irrigations at branching and pod-filling stages and also have better influence on rooting pattern of the crop.

Chaudhary *et al.* (1998) conducted experiment at Devataj, Gujarat and opined that there was no significant effect of irrigation on plant height and number of primary and secondary branches plant<sup>-1</sup> of chickpea in comparison with no irrigation.

Dabhi *et al.* (1998) reported that irrigation scheduling based on IW:CPE ratio has showed pronounced effect on growth attributes and revealed that irrigation at 0.75 IW:CPE ratio recorded appreciably higher plant height, number of branches, dry matter accumulation in greengram over 0.30, 0.45 and 0.60 IW:CPE ratio.

Patel *et al.* (1998) confirmed from their study that higher number of branches plant<sup>-1</sup> and nodules plant<sup>-1</sup> in summer greengram can be obtained by irrigating the crop at 0.7 (five irrigations) or 0.9 (six irrigations) IW:CPE ratio compared to 0.5 IW:CPE ratio (three irrigations) .

Reddy and Ahlawat (1998) reported that plant height, dry matter accumulation per plant, LAI, dry weight of nodules and nodules plant<sup>-1</sup> of chickpea were significantly increased with two irrigations at branching and pod initiation compared to no irrigation.

Arif Ullah *et al.* (2002) reported that maximum emergence unit area<sup>-1</sup>, pods plant<sup>-1</sup> and plant height of chickpea was recorded with two irrigations (at 40 and 80 DAS) when compared with other treatments (control, irrigation at 40 DAS and three irrigations at 40, 80 and 120 DAS).

Agrawal *et al.* (2003) revealed that chickpea irrigated at IW:CPE of 0.4 ratio has recorded highest plant height, dry matter and number of branches than IW:CPE of 0.8 ratio.

Arya *et al.* (2005) reported that irrigation at CPE of 60 mm produced significantly higher mean plant height & dry matter plant<sup>-1</sup> of chickpea than CPE of 80 mm but significantly reduced the number and dry weight of root nodules .

Bakhsh *et al.* (2007) observed that chickpea genotypes responded positively to irrigation with 48% increase in number of pods plant<sup>-1</sup>, 36% in total dry weight but the number of primary and secondary branches remained unaffected.

Krishna Murthy and Ramulu (2007) reported highest plant height, number of pods plant<sup>-1</sup>, number of branches plant<sup>-1</sup>, dry matter production with two irrigations at 35 and 55 DAS of chickpea when compared with irrigation at 35 DAS and rainfed condition.

Mustafa *et al.* (2008) reported highest plant height of chickpea with four irrigations scheduled at sowing, branching, flowering and pod filling stage when

compared with irrigation at sowing, irrigation at sowing & pod filling and irrigation at sowing, branching & pod filling stages.

Reddy *et al.* (2008) reported that higher plant height of *rabi* pigeonpea is obtained with 0.9 IW:CPE ratio which is at par with 0.6 IW:CPE and irrigation at critical stages over 0.3 IW:CPE ratio whereas branches plant<sup>-1</sup> was not influenced by irrigation scheduling.

Pramanik *et al.* (2009) conducted experiment at Kanpur, reported that irrigation at 30 and 45 mm depths recorded significantly higher nodulation, root growth, branching and podding in chickpea when compared with irrigation at 15 and 60 mm depth.

Abraham *et al.* (2010) observed that application of two irrigations (pre-flowering + pod formation) recorded highest dry matter accumulation in chickpea when compared with irrigation at pre-flowering, irrigation at pod formation and no irrigation.

Ahlawat and Gangaiah (2010) noticed that irrigation at 0.2 IW:CPE showed significant increase in plant height (both chickpea + linseed), over no irrigation and on par with 0.4 IW:CPE ratio.

Mansur *et al.* (2010) reported that chickpea recorded highest growth attributes such as plant height and dry matter production at treatment 0.8 IW:CPE ratio which is at par with 0.6 IW:CPE ratio when compared with other treatments of 0.4 IW:CPE ratio and control (rainfed).

Thenua *et al.* (2010) observed that irrigation at peak vegetative growth and pod filling stage recorded significantly higher plant height, dry matter accumulation, nodules plant<sup>-1</sup> and number of branches plant<sup>-1</sup> in chickpea at harvest when compared with irrigation at peak vegetative growth + flowering and irrigation at flowering + pod filling stage.

### **2.1.2 Yield Attributes**

Irrigation schedule to chickpea at 0.3, 0.4 or 0.5 IW:CPE ratio did not influence the yield parameters such as no. of pods plant<sup>-1</sup> and seed weight plant<sup>-1</sup> (Dobariya *et al.*, 1985).

Naresh *et al.* (1985) reported that irrigation to chickpea at 90 DAS significantly increased the number of pods plant<sup>-1</sup> over irrigation at 120 DAS, 90 + 120 DAS and no irrigation. But number of grains per pod, test weight and seed yield plant<sup>-1</sup> were not influenced by above irrigation treatments.

Irrigation to chickpea at 0.8 IW:CPE ratio (six irrigations) recorded significantly higher no. of pods plant<sup>-1</sup> and grains plant<sup>-1</sup> compared to 0.3 IW:CPE ratio (two irrigations). Both 0.3 and 0.8 IW:CPE ratios did not influence the test weight (Palled *et al.*, 1985).

Roy and Tripathi (1985) recorded significantly increased number of pods plant<sup>-1</sup>, grains plant<sup>-1</sup> and test weight of chickpea when irrigation was scheduled at 0.4 or 0.6 IW:CPE ratio compared to two irrigations at branching and pod formation.

Borgohain and Agarwal (1986) concluded that the number of fruiting branches plant<sup>-1</sup>, pods plant<sup>-1</sup> and grains pod<sup>-1</sup> of kabuli chickpea increased significantly to the tune of 3.5, 2.5 and 5.0 per cent and 19.0, 15.0 and 29.2 per cent with irrigation at 0.2 and 0.4 IW:CPE ratio respectively over no irrigation. Test weight did not differ significantly due to irrigation treatments.

Chickpea produced significantly higher number of developed pods plant<sup>-1</sup> and test weight with irrigation to the crop at 20 or 40 percent available soil moisture compared to no irrigation (Javiya *et al.*, 1989).

Patel *et al.* (1989) observed that chickpea recorded significantly higher grain weight plant<sup>-1</sup> with irrigation scheduling at 0.4 or 0.5 IW:CPE ratio compared to 0.3 IW:CPE ratio. However test weight was not influenced by irrigation treatments.

Parihar (1990) noticed significantly higher number of pods plant<sup>-1</sup> and grains plant<sup>-1</sup> of chickpea with irrigation at 0.4 or 0.6 IW:CPE ratio compared to 0.8 IW:CPE ratio. However, test weight was significantly influenced by 0.8 IW:CPE ratio compared to 0.4 or 0.6 IW:CPE ratio.

Nimje (1991) noticed significantly higher number of pods plant<sup>-1</sup>, grains plant<sup>-1</sup> and test weight of chickpea with three irrigations at pre-sowing, branching and pod filling over only pre-sowing irrigation, irrigation at pre-sowing + branching and no irrigations.

Vasvelia *et al.* (1991) conducted experiment on clayey soil at Navsari on mustard crop. Results revealed that scheduling irrigation at an IW:CPE ratio of 0.6 has gave highest branches per plant, siliquae plant<sup>-1</sup> and test weight which is at par with 0.8 IW:CPE ratio when compared with 0.4 IW:CPE ratio and control.

Singh and Dixit (1992) reported maximum values of yield attributes (pods plant<sup>-1</sup> grains pod<sup>-1</sup> and test weight) of chickpea with irrigation scheduled at 0.4 IW:CPE ratio compared to 0.2 and 0.6 IW:CPE ratios and under rainfed condition.

Dixit *et al.* (1993) reported that number of pods plant<sup>-1</sup> of chickpea were significantly increased with irrigation at 0.6 or 0.8 IW:CPE ratio compared to 0.4 IW:CPE ratio and no irrigation; whereas the number of grains pod<sup>-1</sup> and test weight were highest with irrigation at 0.8 IW:CPE ratio.

Srivastava and Srivastava (1994) revealed that highest pods plant<sup>-1</sup> and 100 seed weight of chickpea with two irrigations at branching and pod-filling stages when compared with irrigation at branching, irrigation at pod filling and control (no irrigation).

Chaudhary *et al.* (1998) observed that the no. of pods per plant, seeds per pod and test weight of chickpea were not influenced by two irrigations scheduled at flowering and pod development over no irrigation.

Dabhi *et al.* (1998) reported were of the opinion that number of pods and grains plant<sup>-1</sup> of green gram were significantly highest with the irrigation scheduling at 0.45, 0.60 or 0.75 IW:CPE ratio over 0.3 IW:CPE ratio. However, 0.75 IW:CPE ratio recorded significantly highest values of above parameters over other ratios. Test weight was not affected by any of the irrigation schedules.

Reddy and Ahlawat (1998) recorded significantly higher number of pods plant<sup>-1</sup> of chickpea with two irrigations scheduled at branching and pod initiation compared to no irrigation. However, grains per pod and test weight were not affected by two irrigations.

Agrawal (2003) revealed that irrigation at IW:CPE of 0.4 ratio has recorded highest yield attributes of pod number, seed pod<sup>-1</sup> & test weight of chickpea at IW:CPE of 0.4 than IW:CPE of 0.8 ratio.

Golezanik *et al.* (2008) revealed that when water sources are limited, irrigation after 140 mm evaporation from class A pan could be a suitable irrigation regime for chickpea cultivar to provide highest mean grain plant<sup>-1</sup>, 1000 grain weight and grain yield per unit area.

Mustafa *et al.* (2008) found that highest number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup>, 100 seed weight of chickpea was obtained with four irrigation scheduled at sowing, branching, flowering and pod filling stage when compared with irrigation at

sowing, irrigation at sowing & pod filling and irrigation at sowing, branching & pod filling stages.

Patel *et al.* (2010) conducted experiment at Gujarat in order to study the response of frenchbean to different levels of moisture regimes. Results revealed that number of pods plant<sup>-1</sup>, seeds pod<sup>-1</sup>, 100-seed weight were increased with increasing levels of irrigations. Scheduling of irrigation at an IW:CPE ratio of 1.0 was recorded maximum followed by 0.8 IW:CPE.

Reddy *et al.* (2010) conducted field experiment during rabi season in sandy loam soil on frenchbean. They reported that highest number of pods per plant, number of seeds per pod and 100-seed weight was obtained with irrigation scheduled at 1.0 IW:CPE ratio over 0.6 and 0.8 IW:CPE ratio and irrigation at pre flowering and pod development stage.

Thenua *et al.* (2010) reported that irrigation at peak vegetative growth and pod filling stage showed better results in terms of number of pods plant<sup>-1</sup>, number of grains pod<sup>-1</sup> and 100-seed weight of chickpea.

Chauhan and Yadav (2012) reported that yield attributing characters like number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup> and test weight also increased upto 6 cm depth of irrigation water per irrigation through sprinkler.

### **2.1.3 Grain and straw yield**

Sharma and Yadav (1976) noticed significantly increased grain and straw yield of chickpea with irrigation at 0.16 (one irrigation) or 0.32 (two irrigation) IW:CPE ratio over no irrigation.

Singh *et al.* (1980) observed significant increase in grain yield (22.45 and 16.06%) of chickpea with one post sowing irrigation at 45 DAS over no post sowing irrigation and irrigation once at 75 DAS, respectively. Increasing the number of irrigations to two had no significant effect on the production of chickpea.

The results of Poonia (1984) have shown the significant increase in grain yield of chickpea with two irrigations at flowering and pod formation compared to irrigation at flowering or pod formation or no irrigation.

Dobariya *et al.* (1985) stated that seed yield of chickpea did not differ significantly with irrigation schedules at 0.3, 0.4 and 0.5 IW:CPE ratios.

Naresh *et al.* (1985) observed significantly higher grain yield, straw yield and higher harvest index of chickpea with one irrigation at 90 DAS compared to irrigation at 120 DAS, 90 + 120 DAS and no irrigation.

Palled *et al.* (1985) reported that on deep black soil, the grain yield of chickpea was significantly highest with irrigation at 0.8 IW:CPE ratio compared to 0.3 IW:CPE ratio.

Significantly higher grain yield and harvest index of chickpea were noticed with irrigation scheduled at 0.4 or 0.6 IW:CPE ratio compared to irrigation at branching and pod formation stages. But, straw yield was significantly higher with 0.6 IW:CPE ratio (Roy and Tripathi, 1985).

Borgohain and Agarwal (1986) observed significant increase in grain yield of kabuli chickpea (15.2 and 28.0%) when the irrigations were scheduled at 0.2 and 0.4 IW:CPE ratios, respectively over no irrigation. The straw yield and harvest index were also significantly increased with the same ratios.

Javiya *et al.* (1989) observed significantly higher grain yield of chickpea by irrigating the crop at 20 or 40 percent available soil moisture compared to no irrigation.

Patel *et al.* (1989) obtained significantly higher grain and haulm yields of chickpea by irrigating the crop at 0.5 IW:CPE ratio compared to 0.3 and 0.4 IW:CPE ratios.

Parihar (1990) found that grain yield of chickpea was significantly increased with irrigation scheduling at 0.4 IW:CPE ratio (three irrigations) compared to 0.6 (four irrigations) and 0.8 (five irrigations) IW:CPE ratios. But, the straw yield was significantly higher with 0.6 and 0.8 IW:CPE ratios.

Nimje (1991) observed significant increase in grain and haulm yields of chickpea with two irrigations at pre-sowing and pod filling over no irrigation.

Two irrigations to chickpea at 0.4 IW:CPE ratio increased the grain yield significantly over one irrigation at 0.4 or 0.2 IW:CPE ratio and no irrigation (Prabhakar and Saraf, 1991).

Singh *et al.* (1991) observed significantly higher grain yield of chickpea with one irrigation at pre-flowering over no irrigation and increased number of irrigations resulted in no significant increase in grain yield.

Vasvelia *et al.* (1991) conducted experiment on clayey soil at Navsari on mustard crop. Results revealed that scheduling irrigation at an IW:CPE ratio of 0.6 has gave highest grain yield which is at par with 0.8 IW:CPE ratio when compared with 0.4 IW:CPE ratio and control.

Singh and Dixit (1992) noticed higher grain yield of chickpea with irrigation at 0.4 IW:CPE ratio over 0.2 and 0.6 IW:CPE ratios. This moisture regime (0.4 IW:CPE ratio recorded 54.1, 15.6 and 25.5 per cent higher grain yield over no irrigation, 0.2 and 0.6 IW:CPE ratios, respectively.

Dixit *et al.* (1993) indicated that grain yield of chickpea was significantly higher with the irrigation at 0.8 IW:CPE ratio compared to 0.4 and 0.6 IW:CPE ratios and control.

Srivastava and Srivastava (1994) revealed that highest seed yield of chickpea obtained with two irrigations at branching and pod-filling stages when compared with irrigation at branching, irrigation at pod filling and control treatments.

Two irrigations at flowering and pod development of chickpea produced significantly higher grain yield and harvest index as compared to no irrigation. But, haulm yield was not affected by irrigation (Choudhary *et al.*, 1998).

Dabhi *et al.* (1998) reported that irrigation scheduling based on IW:CPE ratio has showed pronounced effect on yield. He revealed that irrigation at 0.75 IW:CPE ratio recorded appreciably higher grain and stover yield in green gram over 0.3 IW:CPE ratio.

Kaswala *et al.* (1998) revealed that application of irrigation either at 0.5, 0.7 or 0.9 IW:CPE ratio gave significantly higher grain yield of rabi pigeonpea over no irrigation.

Reddy and Ahlawat (1998) reported that the irrigation at branching and pod initiation produced significantly higher grain and straw yield of chickpea compared to no irrigation.

Patil *et al.* (2002) observed that irrigation at 0.4 IW:CPE ratio gave maximum grain yield (1804 kg ha<sup>-1</sup>) than no irrigation (1572 kg ha<sup>-1</sup>), 0.2 IW:CPE (1593 kg ha<sup>-1</sup>).

Arif Ullah *et al.* (2002) reported that highest grain, biological yield and harvest index were recorded in the chickpea which were given two irrigation at 40 and 80 DAS.

Arya *et al.* (2005) revealed that the higher grain and straw yield of chickpea was obtained at CPE of 60 mm of 29.2% , 15.2% compared with that of 80mm .

Singh *et al.* (2005) revealed that two irrigation at pre flowering and pod initiation stage has recorded highest seed and straw yield when compared with control and irrigation at pre flowering stage.

Krishna Murthy and Sree Ramulu (2007) showed that the highest seed yield was obtained at irrigation given 35 and 55 DAS when compared with irrigation at 35 DAS and rainfed.

Pal (2007) conducted experiment on French bean at Nadia during winter season revealed that grain yield was significantly influenced by irrigation regime. The maximum grain yield was observed when the crop is irrigated at 0.04 MPa at 15 cm depth when compared with irrigation at 0.04 MPa at 20 and 25 cm depth.

Mustafa *et al.* (2008) revealed that yield of chickpea highest was obtained with four irrigation scheduled at sowing, branching, flowering and pod filling stage when compared with irrigation at sowing, irrigation at sowing and pod filling and irrigation at sowing, branching and pod filling stages.

Reddy *et al.* (2008) reported that higher seed yield of *rabi* pigeonpea is obtained with 0.9 IW:CPE ratio which is at par with 0.6 IW:CPE and irrigation at critical stages over 0.3 IW:CPE ratio.

Munirathnam and Sangita (2009) noticed that yield of chickpea was high when irrigated at 35 and 55 DAS over rainfed condition.

Pramanik *et al.* (2009) found that irrigation at 30 mm recorded maximum grain yield of chickpea which was at par with 45 mm but significantly higher than 15 and 60 mm irrigation.

Abraham *et al.* (2010) observed that highest seed & straw yield and harvest index in chickpea by providing irrigation at preflowering and pod formation comparing with no irrigation , irrigation at preflowering and irrigation at pod formation.

Mansur *et al.* (2010) reported that irrigation with 0.8 IW:CPE (1619 kg ha<sup>-1</sup>) recorded 11% higher yield of chickpea over control (rainfed) 1454 kg ha<sup>-1</sup>.

Patel *et al.* (2010) conducted experiment at Gujarat on frenchbean to study the response of crop under different moisture regimes. They opined that seed yield

increased significantly with increasing frequency of irrigations. Highest seed yield (1828 kg ha<sup>-1</sup>) was obtained with irrigation at 1.0 IW:CPE ratio over irrigation at 0.6 IW:CPE ratio (1103 kg ha<sup>-1</sup>).

Chauhan and Yadav (2012) reported that highest seed yield of chickpea was obtained under sprinkler irrigation with increase in irrigation level upto IW:CPE 0.6.

#### **2.1.4 N P K uptake**

Srivastava and Srivastava (1994) observed that irrigation levels significantly increased the N, P and K uptake of chickpea. Among irrigation levels highest N, P and K uptake of chickpea with two irrigations at branching and pod-filling stages when compared with irrigation at branching, irrigation at pod filling and control-no irrigation.

Arya *et al.* (2005) observed that higher N, P and K uptake by rice and chickpea with CPE ratio of 60 mm compared to CPE of 80 mm.

Abraham *et al.* (2010) reported that irrigation at preflowering and pod filling stages of chickpea recorded significantly higher total uptake of N, P and S as compared with other treatments: no irrigation ,irrigation at preflowering at pod filling.

Thenua *et al.* (2010) revealed that total P-uptake was increased significantly by irrigation at peak vegetative growth and pod filling stage of chickpea.

#### **2.1.5 Water use Studies**

##### **2.1.5.1 Soil Moisture Content**

Mandal *et al.* (1990) found that safflower + chickpea both as sole crop and intercrops extracted higher amount of moisture from deeper layers, i.e. up to 90cm, due to their deeper systems of rooting.

Samarthia and Muldooi (1995) reported that amount of moisture present in the soil throughout the crop growth increased with increasing irrigation schedules in safflower.

##### **2.1.5.2 Crop coefficient (k<sub>c</sub>)**

Singh and Singh (1980) obtained that peak value of K<sub>c</sub> of at Kota was 1.00 in the month of January under 60%, 40% ASM and control, but under 20% ASM the peak value of K<sub>c</sub> attained in the month of February, respectively.

Savani *et al.* (1994) revealed that the K<sub>c</sub> values of mustard were maximum during flowering (1.18) to pod development stage (1.27) of the crop.

Reddy *et al.* (1998) studied the irrigation scheduled for post-rainy season pigeonpea at Jagityal and observed that the ratio of actual to maximum evapotranspiration ( $E_a/E_{tm}$ ) of 1.0 supplied throughout crop growing period and irrigation scheduled at 0.9 of any growth stages (crop development or flowering and grain formation – maturity stages) resulted in ideal yields.

Reddy *et al.* (1999) studied the irrigation scheduled for winter maize at Jagityal and observed that the ratio of actual to maximum evapotranspiration ( $E_a/E_{tm}$ ) of 0.9 during crop development stage and 1.0 during tasseling – silking , grain formation – maturity was ideal for higher productivity of winter maize.

Tyagi *et al.* (2000) reported that in sunflower the  $K_c$  values as 0.52, 1.1, 1.32 and 0.41 at initial, development, mid and late stages, respectively.

Vijay Kumar and Praveen Rao (2001) showed that  $K_c$  values of sunflower was highest (Flowering-1.041 and seed formation stages-1.057) under irrigation scheduled at  $E_a/E_{tm}=1$  throughout the crop growing season (W-W-W) treatment during first and second years.

### **2.1.5.3 Soil moisture extraction pattern**

Chickpea extracted more moisture from upper 0-15 and 15-30 cm soil layers (32 and 20.5% and 24.2 and 24.6%, respectively) when the irrigation was scheduled at 0.32 and 0.16 IW:CPE ratios respectively; chickpea extracted more moisture from deeper layers of 30-60 and 60-90 cm (23.0 and 24.1%, respectively) when the irrigation was not given to the crop (Sharma and Yadav, 1976).

Singh *et al.* (1980) observed that the surface layer of soil (0-30 cm) contributed more water for the growth of chickpea (49.8, 46.0, 46.7 and 51.7%) when no irrigation was given to the crop, one irrigation at 45 DAS or 75 DAS or two irrigations at 45 DAS and 75 DAS than deeper layer (30-60 cm) (32.8, 33.6, 27.0 and 24.9%) respectively.

Nayar and Singh (1985) stated that chickpea extracted more soil moisture from top 30 cm layer and relatively less moisture form deeper layers (30-60>60-90>90-120 cm) when different levels of irrigations were given to the crop.

Parihar (1990) reported that chickpea extracted more moisture from upper 30 cm soil layer (25-35%) in all the three ratios of IW:CPE (30-60 cm) was comparatively more under 0.4 IW:CPE ratio than under 0.6 and 0.8 IW:CPE ratios.

More moisture was extracted from the upper 30 cm soil layer (103.5-179.4 mm) by chickpea, when irrigation was given at 0.4 (one irrigation) or 0.4 (two irrigations) or 0.2 (one irrigation) IW:CPE ratio or no irrigation compared to 30-60 cm soil layer (39.3-58.0 mm) (Prabhakar and Saraf, 1991).

Singh *et al.* (1991) reported that moisture extraction pattern by kabuli chickpea showed that the relative contribution of water to the crop from upper 30 cm soil layer increased with increase in number of irrigation and the contribution from lower layers increased with the reduction in number of irrigations.

Dixit *et al.* (1993) noticed more soil moisture extraction from 0-15 and 15-30 cm soil layers (19.8-33.1 and 34.3-41.3 cm) by chickpea compared to 30-45 and 45-60 cm soil layers (18.7-21.9 and 13.8-16.9 cm).

#### **2.1.5.4 Water use efficiency**

Roy and Tripathi (1985) observed that highest WUE was recorded by irrigating the chickpea at IW:CPE at 0.4 when compared with 0.6 and irrigation at branching and pod formation.

The experiment conducted by Nimje (1991) on deep vertisol at Bhopal (MP) revealed that the water use efficiency of chickpea was highest ( $7.5 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) when only pre-sowing irrigation was given followed by two irrigations at pre-sowing and branching ( $7.1 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) and was lowest when three irrigation were given at pre-sowing, branching and pod filling stages ( $6.6 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ).

Water use efficiency of chickpea was highest when two irrigations were scheduled at 0.4 IW:CPE ratio ( $7.7 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) compared to one irrigation at 0.4 ( $7.6 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) or 0.2 ( $7.2 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) IW:CPE ratio and no irrigation ( $7.1 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) on alluvial sandy loam soil at IARI, New Delhi (Prabhakar and Saraf 1991).

Singh *et al.* (1991) noticed higher water use efficiency of chickpea ( $83.4 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) with one irrigation at pre-flowering followed by one irrigation at pod development ( $70.3 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ), two irrigations at pre-flowering and pod development ( $65.1 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) and lowest ( $58.3 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) was noticed with irrigation at 0.5 IW:CPE ratio.

Higher water use efficiency of chickpea was noticed with irrigation at 0.2 IW:CPE ratio ( $28.2 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) on silty clay loam soil at Faizabad (U.P) as compared to irrigation at 0.4 ( $25.3 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) and 0.6 ( $20.4 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) IW:CPE ratios (Singh and Dixit, 1992).

Srivastava and Srivastava (1994) observed that water use efficiency decreased with the increase in levels of irrigation. The maximum WUE ( $30.2 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ) was recorded under no irrigation, whereas the lowest under two irrigations at branching and pod filling stages ( $11.2 \text{ kg ha}^{-1} \text{ cm}^{-1}$ ).

Nagarajan and Wahab (2001) noticed that in finger millet the higher WUE obtained when irrigated at vegetative stage only whereas least WUE recorded at 0.9 IW:CPE ratio.

Arya *et al.* (2005) revealed that highest WUE of chickpea obtained at irrigation given to CPE of 80 mm compared to CPE 60 mm.

Pal (2007) conducted experiment on french bean at Nadia during winter season opined that WUE was higher ( $11.39 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) with minimum level of irrigation (irrigation at 0.04 MPa at 25 cm depth) and decreased with increase in irrigation level and lowest efficiency ( $8.72 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) at irrigation regime of 0.04 MPa at 15 cm depth.

Reddy *et al.* (2008) reported that higher WUE of *rabi* pigeonpea is obtained with 0.3 IW:CPE ratio (60 mm) followed by irrigation at critical stages (120mm) over 0.6 (180 mm) and 0.9 (300 mm) IW:CPE ratio.

Pramanik *et al.* (2009) reported that maximum WUE was with 30 mm irrigation which was higher by 7.63 and 34.2 % than 45 and 60 mm irrigation respectively.

An experiment conducted on frenchbean at Gujarat revealed that maximum WUE obtained with higher moisture regimes i.e., 1.0 IW:CPE ratio and lowered at 0.6 IW:CPE ratio given by Patel *et al.* (2010).

#### **2.1.5.5 Economics**

Kaswala *et al.* (1998) revealed that application of irrigation either at 0.7 IW:CPE ratio gave significantly higher net returns of *rabi* pigeonpea over no irrigation, 0.5 and 0.9 IW:CPE ratio.

Patil *et al.* (2002) found that chickpea irrigated at 0.4 IW:CPE ratio gave maximum net returns ( $\text{₹ } 27,060 \text{ ha}^{-1}$ ) when compared with other treatments 0.2 and 0.6 IW:CPE ( $\text{₹ } 23,580 \text{ ha}^{-1}$  and  $\text{₹ } 26,295 \text{ ha}^{-1}$ ), respectively.

Singh *et al.* (2005) reported that maximum gross returns ( $\text{₹ } 37,575 \text{ ha}^{-1}$ ), net returns ( $\text{₹ } 26,340 \text{ ha}^{-1}$ ) and B:C ratio (2.35) of chickpea were obtained with the

treatment consisting of two irrigation at pre-flowering and pod initiation stage when compared with control and irrigation at pre-flowering stage.

Arya *et al.* (2005) reported that chickpea irrigated at CPE of 60 mm recorded maximum net returns and B : C ratio than CPE of 80 mm .

Mustafa *et al.* (2008) found that highest net returns and B:C ratio of chickpea was obtained with four irrigation scheduled at sowing, branching, flowering and pod filling stage when compared with irrigation at sowing, irrigation at sowing and pod filling and irrigation at sowing, branching and pod filling stages.

Reddy *et al.* (2008) reported that higher net returns of *rabi* pigeonpea is obtained with 0.9 IW:CPE ratio which is at par with 0.6 IW:CPE over irrigation at critical stages and 0.3 IW:CPE ratio.

Pramanik *et al.* (2009) revealed that irrigation at 30 mm in chickpea recorded higher net returns by ₹ 2037 ha<sup>-1</sup> and ₹ 7,241 ha<sup>-1</sup> over 45 mm irrigation respectively.

Abraham *et al.* (2010) revealed that highest gross and net returns obtained in chickpea by providing irrigation at pre-flowering and pod formation but high B:C ratio is seen in treatment of one irrigation at pod formation.

Mansur *et al.* (2010) observed that irrigation at 0.6 IW:CPE ratio has recorded highest seed yield, net returns (₹ 32000 ha<sup>-1</sup>) and B:C ratio (2.80) in chickpea.

Patel *et al.* (2010) reported that higher net returns and B:C ratio of French bean obtained under irrigation at higher moisture regimes (1.0 IW:CPE) over 0.6 IW:CPE ratio.

Thenua *et al.* (2010) showed that net returns and B:C ratio were significant higher with irrigation at flowering and pod filling stages when compared with peak vegetative growth + flowering , at peak vegetative growth + pod filling stages of chickpea.

#### **2.1.5.6 Protein content**

The experiment conducted by Nimje (1991) on deep vertisol at Bhopal (MP) revealed that the protein content of chickpea was highest when three irrigation were given at pre-sowing, branching and pod filling stages followed by two irrigations at pre-sowing and branching and was lowest when only pre-sowing irrigation was given.

Pawar *et al.* (1992) conducted experiment at Rahuri reported that the highest protein content and protein yield of chickpea obtained with three irrigations at branching, flowering and pod development when compared with no irrigation (control).

## **2.2 Effect of Varieties on Growth and Yield of Chickpea**

### **2.2.1 Effect of varieties on crop growth**

Chaitanya and Chandrika (2003) conducted a field experiment at Tirupati on chickpea genotypes and reported that highest plant height and number of branches plant<sup>-1</sup> was recorded with genotype ICCV-10 when compared with ICCV-2 and Annegiri.

Reddy and Ahlawat (1998) noticed that significantly higher plant height, dry matter plant<sup>-1</sup> and LAI in *desi* variety BG-261 compared to *Kabuli* variety ICCV-32.

### **2.2.2 Effect of varieties on yield components and grain yield**

Chaitanya and Chandrika (2003) conducted a field experiment at Tirupati on chickpea genotypes and reported that highest number of pods plant<sup>-1</sup> and seed yield was recorded with genotype ICCV-10 when compared with ICCV-2 and Annegiri.

Naik *et al.* (2012) reported that highest number of pods plant<sup>-1</sup> and seed yield was obtained with JG-11 when compared with Annegiri whereas test weight has remained non significant.

Rao *et al.* (2012) conducted experiment on chickpea at Rajendranagar, Hyderabad. Through this experiment, they opined that highest number of pods plant<sup>-1</sup>, test weight and seed yield was obtained with variety KAK-2 when compared with JG-11 and Annegiri.

*Desi* variety BG-261 recorded significantly higher number of pods plant<sup>-1</sup>, grains pod<sup>-1</sup>, grain yield and haulm yield compared to *kabuli* variety ICCV-32. But, *kabuli* out crossed *desi* with respect to test weight (Reddy and Ahlawat, 1998).

## **2.3 Interaction Effect of Irrigation Schedules and Varieties on Growth and Yield of Chickpea**

Dixit *et al.* (1993) conducted experiment at Powarkheda, M.P. on chickpea response to irrigation schedules and planting date. They reported that irrigation at 0.6 and 0.8 IW:CPE ratio resulted highest yield when compared with 0.4 IW:CPE ratio whereas among genotypes Radhey is superior to Ujjain 21. But their interaction is non significant.

An experiment was conducted during *rabi* on twenty five genotypes of chickpea under irrigated and unirrigated conditions. The results revealed that there is significant differences between genotypes and genotypes X irrigation for characters (plant height, number of branches plant<sup>-1</sup>, test weight and seed yield) reported by Durga *et al.* ( 2005).

Naik *et al.* (2012) reported that seed yield was obtained with JG-11 when compared with Annegiri and irrigation through ridge and furrow has shown higher yield attributes and yield. But the interaction between them is non significant.

To study the effect of different irrigation levels on chickpea, an experiment was conducted at Peshawar. Statistical analysis of the data revealed that different irrigation levels and varieties had significant effect on grain yield, while interaction among irrigation levels and different varieties was non significant reported by Bakhsh *et al.* (2007).

## Chapter III

# MATERIAL AND METHODS

A field experiment was conducted to investigate the “Influence of moisture regimes on growth, yield and quality of chickpea cultivars” during *rabi*, 2013-2014. The details of the experimental materials used and methods adopted in the present investigation are elucidated in this chapter under appropriate headings.

### 3.1 GEOGRAPHICAL LOCATION OF THE EXPERIMENTAL SITE

The research work was carried out at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.3m above mean sea level on 17° 19'N latitude and 78° 28'E longitude and falls under the Southern Telangana Agroclimatic Regions of Andhra Pradesh.

### 3.2 CLIMATE

#### 3.2.1 Weather conditions during crop growth period.

The meteorological parameters were recorded from ‘B’ class meteorological observatory located at Agricultural Research Institute, Rajendranagar and presented in Appendix A and illustrated in Fig.1. This data was also used as weather input data in scheduling of irrigation.

The mean daily maximum temperature during the crop period ( 3<sup>rd</sup> Nov 2013 – 13<sup>th</sup> Feb 2014) ranged from 27.4°C to 32.8°C with an average of 28.9°C, while the daily mean minimum temperature ranged from 7.51°C to 18.53°C with an average of 13.9°C. The bright sunshine hours based on the mean standard days varied from 2.57 to 9.41 hours per day with an average of 7.82 hours per day.

The mean daily wind velocity ranged from 0.69 to 3.53 km hr<sup>-1</sup> with an average of 2.20 km h<sup>-1</sup> during the crop period.

The mean relative humidity during the crop growing period varied from 51.57 to 86.64 per cent with an average of 63 per cent. The mean pan evaporation (USWB- class A pan) recorded during the crop period ranged from 1.73 to 4.51 mm

day<sup>-1</sup> with an average of 3.19 mm day<sup>-1</sup>. In general, the weather was congenial for the cultivation of chickpea during *rabi*, 2013-2014.

### 3.3 CHARACTERISTICS OF THE EXPERIMENTAL FIELD

#### 3.3.1 Physical and chemical properties (Table 3.2)

Soil samples were drawn from 0-15 cm and 0-30 cm depth in experimental field (Plot no. A-6) and analysed for their physical and chemical properties by adopting standard procedures and the results are summarized in Table 3.2. The texture of the soil is sandy loam.

#### 3.3.2 Moisture holding properties (Table 3.3)

The moisture retention at – 0.03 MPa and 1.50 MPa ( pressure plate method) and bulk density ( core sampler method) of the experimental field was estimated for each 15 cm soil depth upto 45 cm ( Dastane, 1967) and are presented in Table 3.3.

### 3.4 IRRIGATION WATER ANALYSIS (Table 3.4)

Water from well no.1 near the experimental site in college farm was used for irrigation. The water was analysed for important parameters using standard method and are furnished in Table 3.4.

### 3.5 PREVIOUS CROPPING HISTORY

The cropping history of the experimental site for the previous seasons (Table 3.1).

**Table 3.1 Previous cropping history of the experimental site**

S.No.	Year	<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
1.	2011	Maize	Maize	Fallow
2.	2012	Maize	Safflower	Fallow
3.	2013	Maize	Chickpea	

**Table 3.2 Physico – chemical properties of the experimental site**

<i>Particulars</i>	<i>Results</i>	<i>Method</i>
<b>A. MECHANICAL ANALYSIS</b>		
Soil fraction	% composition	Bouyoucos Hydrometer method ( Piper, 1966)
Coarse sand	32.0	
Fine sand	43.0	
Silt	9.6	
Clay	15.0	
Textural class	Sandy loam	
<b>B. CHEMICAL ANALYSIS</b>		
Soil reaction (pH) (1:2.5 soil : water)	7.8	Glass electrode pH meter ( Jackson, 1967)
Electrical conductivity (dS m <sup>-1</sup> )	0.21	Solubridge method & Digital EC ( Jackson, 1967)
Organic Carbon (%)	0.36	Wet oxidation method (Walkley and Black, 1934)
Available Nitrogen (kg N ha <sup>-1</sup> )	226	Alkaline permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg P <sub>2</sub> O <sub>5</sub> ha <sup>-1</sup> )	18.5	Olsen's method (Muhr <i>et al.</i> , 1965)
Available Potassium (kg K <sub>2</sub> O ha <sup>-1</sup> )	235	Neutral Ammonium Acetate method using flame photometer (Jackson, 1967)

**Table 3.3 Moisture retention characters of the experimental soil**

Soil depth (cm)	Moisture percentage at		Bulk density (g cm <sup>-3</sup> )	Available soil moisture (mm)
	Field capacity (-0.03 MPa)	PWP (-1.5MPa)		
0-15	17.40	5.76	1.57	27.1
15-30	16.12	5.24	1.64	26.8
30-45	15.22	5.28	1.67	25.5
0-45	16.43	5.45	1.62	79.6

**Table 3.4 Water quality parameters**

<i>Sl.No.</i>	<i>Parameters</i>	<i>Value</i>	<i>Method followed</i>
1	pH	7.6	Digital pH meter
2	Electrical conductivity (dS m <sup>-1</sup> )	2.05	Digital conductivity bridge
3	Carbonates, me l <sup>-1</sup>	Nil	Titration with 0.02 N H <sub>2</sub> SO <sub>4</sub> using Phenolphthalein indicator
4	Bicarbonates, me l <sup>-1</sup>	8.3	Titration with 0.02 N H <sub>2</sub> SO <sub>4</sub> using Methyl orange indicator
5	Chlorides, me l <sup>-1</sup>	13.1	Titration with standard AgNO <sub>3</sub> using K <sub>2</sub> CrO <sub>4</sub> as indicator
6	Sodium, me l <sup>-1</sup>	9.4	Flame photometer
7	Potassium, me l <sup>-1</sup>	7.7	Flame photometer
8	Calcium, me l <sup>-1</sup>	18.3	Titration with standard EDTA using murexide indicator and NaOH buffer
9	Magnesium, me l <sup>-1</sup>	10.8	Titration with standard EDTA using EBT indicator and

			Ammonia buffer
<b>10</b>	Sodium adsorption ratio	3.08	
<b>11</b>	Residual Sodium Carbonate, me l <sup>-1</sup>	Nil	

### **3.6 EXPERIMENTAL DETAILS**

#### **3.6.1 Design and layout**

The experiment was laid out in Randomized Block Design (factorial) , replicated thrice with thirty six treatments. The details of the treatments are given below and presented in Fig.2.

#### **3.6.2 Treatment details**

Design	:	“Randomized Block Design” (Factorial)
Replications	:	3
Gross Plot Size	:	6m x 4 m
Net Plot Size	:	4.2m x 2.2m
Spacing	:	30 cm × 10 cm
Cultivar	:	1) JG-11
		2) Annegiri
I <sub>1</sub>	:	Rainfed check
I <sub>2</sub>	:	Irrigation scheduling at 0.3 IW : CPE
I <sub>3</sub>	:	Irrigation scheduling at 0.6 IW : CPE
I <sub>4</sub>	:	Irrigation scheduling at 0.9 IW : CPE

#### **3.6.3 Layout of the experimental field (Fig.2)**

The details of layout of experimental field has shown in Figure 3.2.

## **3.7 CULTIVATION DETAILS**

### **3.7.1 Preparatory tillage**

The experimental field was prepared thoroughly by working with tractor mounted disc plough followed by tractor drawn cultivar twice and finally harrowing to achieve optimum tilth subsequently, leveling was carried out and the plots were laid out according to the plan.

### **3.7.2 Variety**

The duration of the varieties JG-11 and Annegiri is 90-100 and 100-110 days, respectively grown during *rabi* season, it is suitable for rainfed situations. JG-11 is an early maturing variety with semi spreading nature having attractive large seed and resistant to fusarium wilt whereas Annegiri is a bushy plant with medium to large sized seed of amber color.

### **3.7.3 Sowing**

Chickpea was sown on 3<sup>rd</sup> November, 2013, after treating the seed with Rhizobium (*Cicer rhizobium*). Seeds were hand dibbled @ 2 seeds hill<sup>-1</sup> at a depth of 6 cm and sowing was carried out in N-S direction leaving 10 cm space between two hills with a row to row gap of 30 cm.

Immediately after sowing irrigation equivalent to 60 mm was applied uniformly to all the treatments through surface irrigation except for T<sub>1</sub> (Rain fed treatment).

### **3.7.4 Fertilizer application**

Immediately after sowing basal application of N-20, P<sub>2</sub>O<sub>5</sub>-50, K<sub>2</sub>O-40 kg ha<sup>-1</sup> was applied.

### **3.7.5 Irrigation**

Irrigations were given as per the cited treatments as described below:

A pre-sowing irrigation was given to all the experimental plots. In a treatment

under IW:CPE ratio of 0.3, 0.6 and 0.9 i.e. I<sub>2</sub>, I<sub>3</sub> and I<sub>4</sub> respectively, irrigation was applied on the basis of cumulative pan evaporation (CPE) which is obtained by recording the open pan evaporimeter reading every day and irrigation was scheduled accordingly.

IW:CPE ratio	CPE (mm)	No. of irrigations	Total quantity of water given ( litres)	Effective rainfall (mm)
0.3	200	1	1440	31
0.6	100	3	4320	31
0.9	66.66	4	5760	31

The quantity of irrigation water given for plot size of 24m<sup>2</sup> at 6 cm depth of irrigation water:

$$\frac{6}{100} \times 24 \times 1000 = 1440 \text{ litres}$$

Thus calculated irrigation water was delivered to each experimental plot by installing water meter in the field water course at the channel outlet.

### 3.7.5 Gap filling and thinning

Gap filling was done one week after sowing to maintain the desired plant population. Thinning was carried out one week after gap filling so as to achieve one plant per hill.

### 3.7.6 Weed control

Weeds were controlled by pre-emergence spraying of Pendimethalin @ 1.3 kg *a. i.* per acre. It was followed by manual hand weeding at 35 and 55 DAS, respectively.

### 3.7.7 Plant protection

To control wilt and pod borer, Carbendazim @ 2.5 g per litre water and Quinolphos @ 2.5 ml per litre water was sprayed at 35 and 55 DAS, respectively.

### **3.7.8 Harvesting**

Chickpea crop is harvested when leaf turns to reddish brown and starts shedding.

The plants of border rows of each were harvested and separated first and the plants from net plot were harvested later.

### **3.7.9 Threshing**

After sun drying , it is threshed by beating with sticks. Later the grains were sun dried to a moisture content of 14 per cent, cleaned and weighed separately for each plot. The stover yield was recorded after sun drying the plant to a constant weight.

## **3.8 OBSERVATIONS**

### **3.8.1 Initial and final plant stand**

In each net plot, the initial emergence count at 10 DAS and final plant stand at harvest were recorded and the per cent crop stand was computed as follows.

$$\text{Plant stand (\%)} = \frac{\text{Observed plant stand}}{\text{Theoretical plant stand}} \times 100$$

### **3.8.2 GROWTH ATTRIBUTING CHARACTERS**

#### **3.8.2.1 Plant height (cm)**

From the randomly tagged five plants, the plant height was recorded at 30, 60, 90 DAS and at harvest. The measurement was taken from the base of the stem to the last ligule and measurement was taken up to the tip of the leaf. Subsequently, the mean plant height was taken and expressed in centimeter.

#### **3.8.2.2 Number of Branches Plant<sup>-1</sup>**

From the randomly tagged five plants, the no. of branches per plant was recorded at each 30, 60 and 90 DAS and at harvest.

### **3.8.2.3 Dry matter production (g plant<sup>-1</sup>)**

Five plants samples were collected from the sampling rows selected next to border rows at 30, 60, 90 DAS and at harvest. The plant samples after sun drying were dried at 60-65°C for 48 hours in hot air oven till constant weights were obtained and weight were recorded and expressed as dry matter production in gram per plant.

### **3.8.2.4 Root nodules**

Root nodules count is taken from five plant samples collected at each 30, 60 and 90 DAS and at harvest

## **3.9 YIELD ATTRIBUTING CHARACTERS**

### **3.9.1 Number of Pods Plant<sup>-1</sup>**

Number of pods from five randomly selected chickpea plants was counted and the mean value was computed to indicate the number of pods plant<sup>-1</sup>.

### **3.9.2 Number of Seeds Pod<sup>-1</sup>**

Number of seeds from five randomly selected chickpea plants was counted and the mean value was computed to indicate the number of seeds pod<sup>-1</sup>.

### **3.9.3 Test weight (g)**

Hundred seeds were randomly picked up from the shelled pods of selected five plants, weighed and expressed in grams.

## **3.10 YIELD**

### **3.10.1 Seed yield (kg ha<sup>-1</sup>)**

The seed yield of each net plot including the yield from selected five plants were cleaned, sun dried till constant weight was obtained and computed as seed yield in kg ha<sup>-1</sup>.

### 3.10.2 Haulm yield (kg ha<sup>-1</sup>)

Haulm yield of chickpea from each plot including that of five selected plants after threshing was recorded after sun drying till the produce attained constant weight and expressed as kg ha<sup>-1</sup>.

### 3.10.3 Harvest index (%)

Harvest index is defined as the ratio of economic yield to the biological yield. It was calculated by using the formula given by Donald (1962).

$$\text{Harvest index} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Biological (Seed + Haulm) yield (kg ha}^{-1}\text{)}} \times 100$$

## 3.11 Quality parameters

### 3.11.1 Protein content (%)

Nitrogen content in grain samples of chickpea were estimated by modified micro Kjeldahl method after digesting the powdered plant sample with H<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>O<sub>2</sub> (Piper, 1966).

This nitrogen content of grain samples was multiplied with a factor 6.25 and protein content of grain samples of chickpea was obtained (Piper, 1966).

## 3.12 WATER USE STUDIES

### 3.12.1 Soil moisture content (%)

Soil moisture content was estimated before and after giving irrigation following gravimetric method (Richards, 1959). The following was used in computing moisture content in percentage.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight of the soil sample} - \text{Oven dry weight of the soil sample}}{\text{Oven dry weight of the soil sample}} \times 100$$

### 3.12.2 Water use (mm)

Water used was calculated as detailed below.

Water use (mm) = Soil moisture depletion (mm) + effective rainfall (mm)

### 3.12.3 Water use efficiency (kg ha<sup>-1</sup> mm<sup>-1</sup>)

The weight of economic yield per unit of water used is referred to as water use efficiency and was calculated by using the formula given by Viets (1962).

$$\text{WUE (kg ha}^{-1} \text{ mm}^{-1}\text{)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Water used (mm)}}$$

### 3.12.4 Actual Evapotranspiration (Crop Et<sub>a</sub>)

Actual evapotranspiration was calculated on the basis of the soil moisture measurements taken by the gravimetric method. The difference in moisture content before and after irrigation was considered as actual evapotranspiration assuming other losses are minimal. The procedure used for estimation of crop Et<sub>a</sub> was as follows (Praveen Rao, 1993).

$$\text{Crop } Et_a = \sum_{n=1}^{i=n} \left( \frac{M_{1i} - M_{2i}}{10} \right) \times P_{bi} \times D_i$$

Where,

- Et<sub>a</sub> : Crop ET from the effective root zone depth within one irrigation cycle.
- n : Number of soil layers sampled in the root zone.
- M<sub>1i</sub> : Mass water percentage measured in 24 hours after n<sup>th</sup> irrigation in the i<sup>th</sup> layer.
- M<sub>2i</sub> : Mass water percentage measured one day before the n<sup>th</sup> irrigation in the i<sup>th</sup> layer.
- P<sub>bi</sub> : Bulk density of the soil layer in the i<sup>th</sup> layer.
- D<sub>i</sub> : Depth of i<sup>th</sup> layer of the soil (cm) i.e. 0-15, 15-30 and 30-35 cm.

### 3.12.5 Reference Evapotranspiration (Et<sub>0</sub>)

Et<sub>0</sub> was computed by the following pan evaporation method (Doorenbos and Kassam, 1979).

$$ET_0 = E_{pan} \times K_{pan}$$

E<sub>pan</sub> : Pan evaporation values from class A open pan evaporimeter (mm).

K<sub>pan</sub> : Pan coefficient.

### 3.12.6 Crop Coefficient (K<sub>c</sub>)

The crop growth period was divided into initial stage (20 days), developmental stage (25 days), mid season stage (35 days) and late season stage (25 days) for estimation of K<sub>c</sub> values as per Doorenbos and Kassam, 1979 by the following formula.

$$K_c = \frac{\text{Actual evapotranspiration(Crop } E_a)}{\text{Reference evapotranspiration}(E_0)}$$

## 3.13 ECONOMICS

The prices in rupees of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation.

### 3.13.1 Net return (₹ ha<sup>-1</sup>)

Net return was estimated at harvest by deducting the cost of cultivation from gross return.

$$\text{Net return} = \text{Gross return} - \text{Cost of cultivation}$$

### 3.13.2 Gross return (₹ ha<sup>-1</sup>)

Gross monetary returns were calculated by multiplying the economic yield with prevailing market price ( Perin *et al.*, 1979).

### 3.13.3 Benefit : Cost ratio

$$\text{B:C ratio} = \frac{\text{Gross returns } (\text{₹ ha}^{-1})}{\text{Cost of cultivation } (\text{₹ ha}^{-1})}$$

### 3.14 PLANT ANALYSIS

For estimating nitrogen, phosphorus and potassium content, well dried samples collected for dry matter production were used. Samples collected from each plot were oven dried and used for chemical analysis (Piper, 1950).

The uptake of N, P and K by chickpea plant was computed as follows :

$$\text{Uptake of nutrient } (\text{kg ha}^{-1}) = \frac{\text{Nutrient content } (\%)}{100} \times \text{Total dry matter } (\text{kg ha}^{-1})$$

#### 3.14.1 Nitrogen uptake ( $\text{kg ha}^{-1}$ )

Plant sample (0.2 g) was taken in a test tube and digestion was carried out by using  $\text{H}_2\text{SO}_4$  and  $\text{H}_2\text{O}_2$ . After digestion, nitrogen content in the plant sample was estimated by micro kjeldahl method (Jackson, 1967). The nitrogen uptake was calculated by multiplying the content of nitrogen with respective dry matter production and expressed in  $\text{kg ha}^{-1}$ .

#### 3.14.2 Phosphorus uptake ( $\text{kg ha}^{-1}$ )

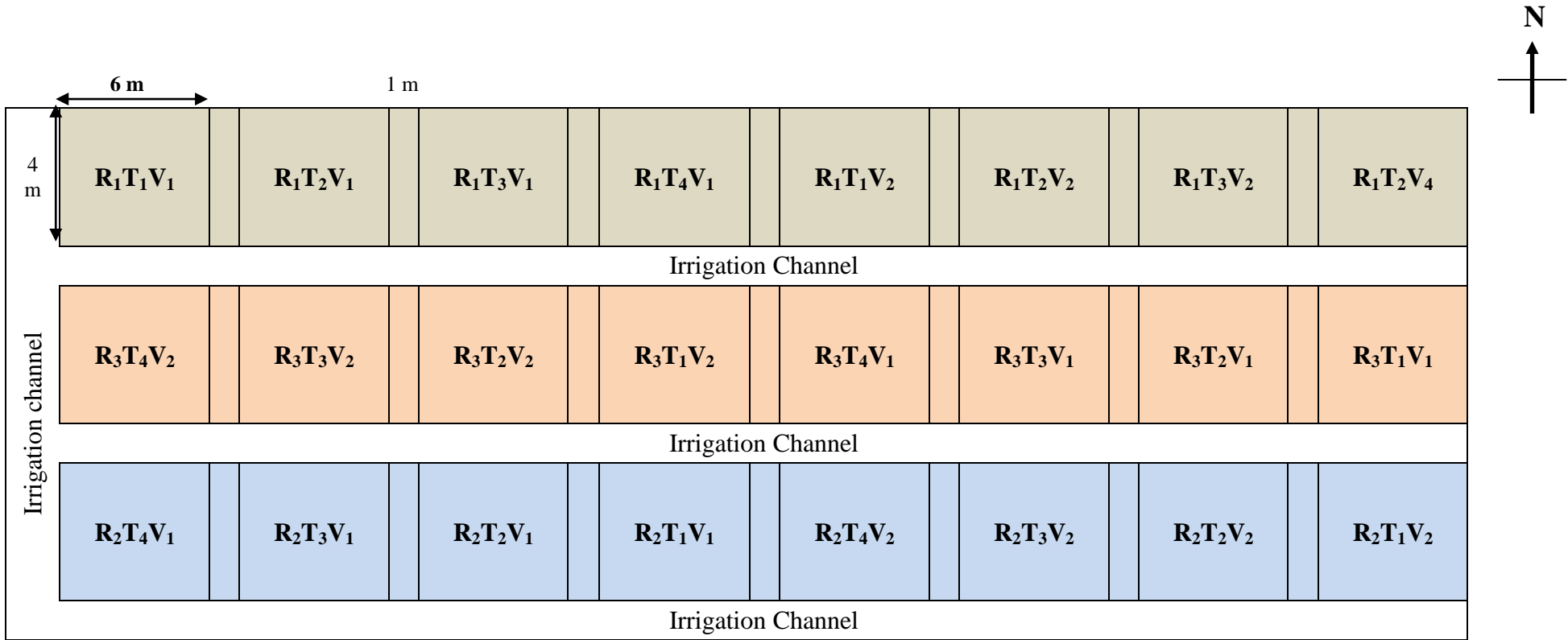
The tri-acid digested plant samples were analysed for phosphorus content by Vanado - molybdo phosphoric acid yellow colour method. The intensity of yellow colour developed was measured using Spectronic – 20 D. The uptake of phosphorus was calculated by multiplying the phosphorus content with the respective dry matter production and expressed in  $\text{kg ha}^{-1}$ .

#### 3.14.3 Potassium uptake ( $\text{kg ha}^{-1}$ )

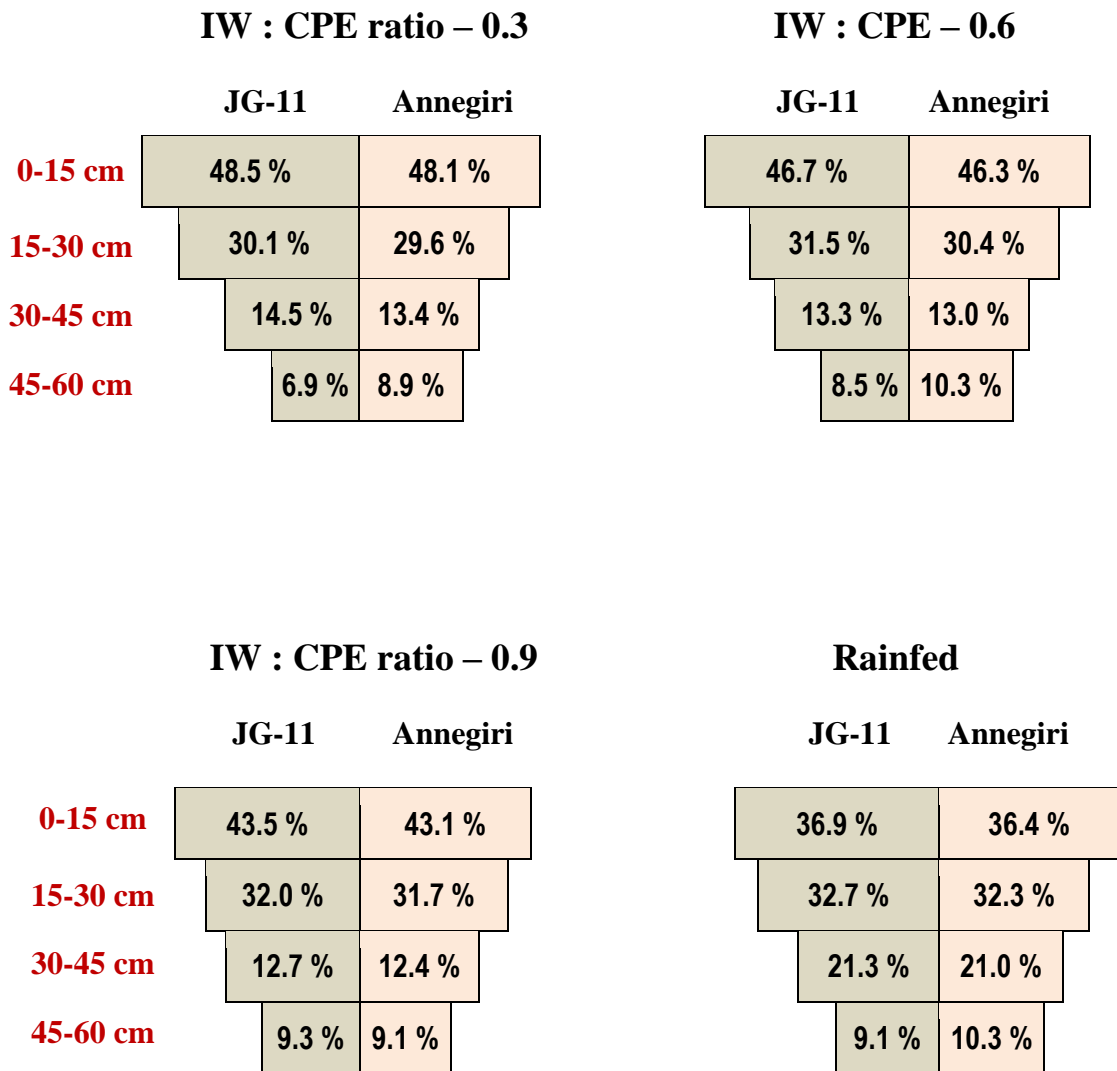
Potassium content of the diluted tri-acid digest was determined by using ELICO flame photometer and the uptake of potassium was estimated by multiplying the K content with the respective dry matter production and presented in  $\text{kg ha}^{-1}$ .

### **3.15 STATISTICAL ANALYSIS**

The data recorded on various parameters during the course of investigation were statistically analyzed duly following the analysis of variance technique for randomized block design as suggested by Panse and Sukhatme (1978). The levels of significance used in 'F' and 't' test was P – 0.05 and 0.01 and critical values were calculated wherever the 'F' test was significance.

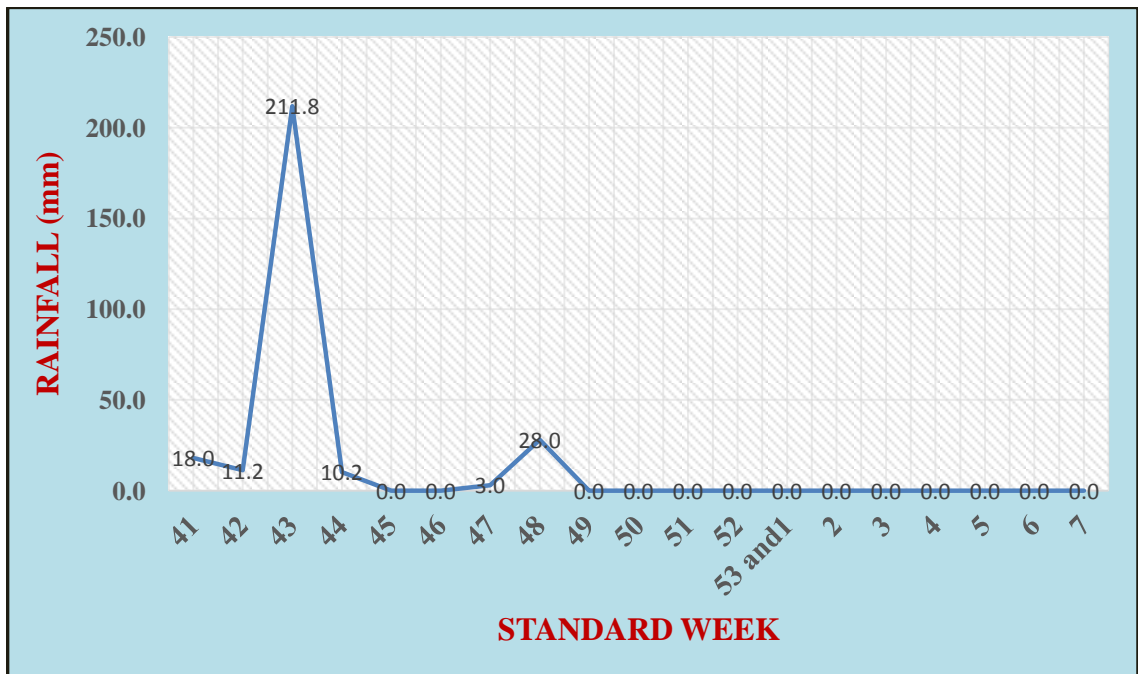
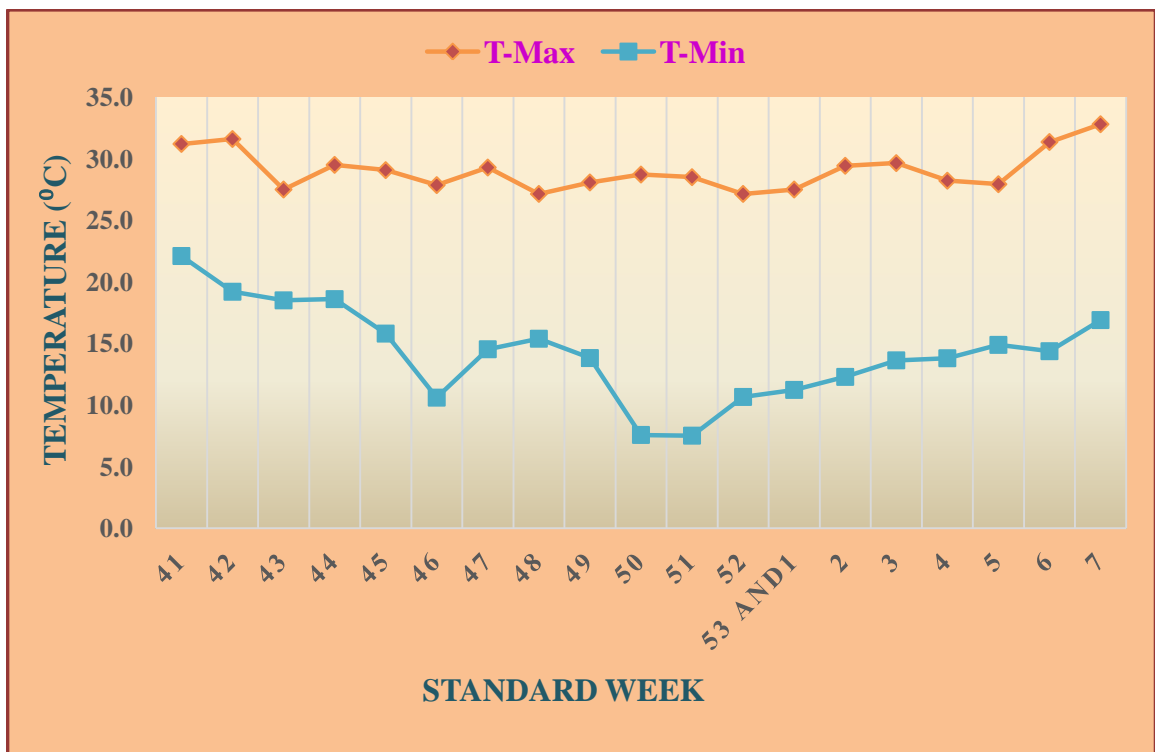


**Figure 3.2. Layout of the Experimental Site**



**Fig 4.17 Soil moisture extraction pattern (%) by chickpea varieties as influenced by moisture regimes.**





**Fig 3.1.1 Weekly mean meteorological data (Temperature and Rainfall) during cropping period *rabi*, 2013-14**

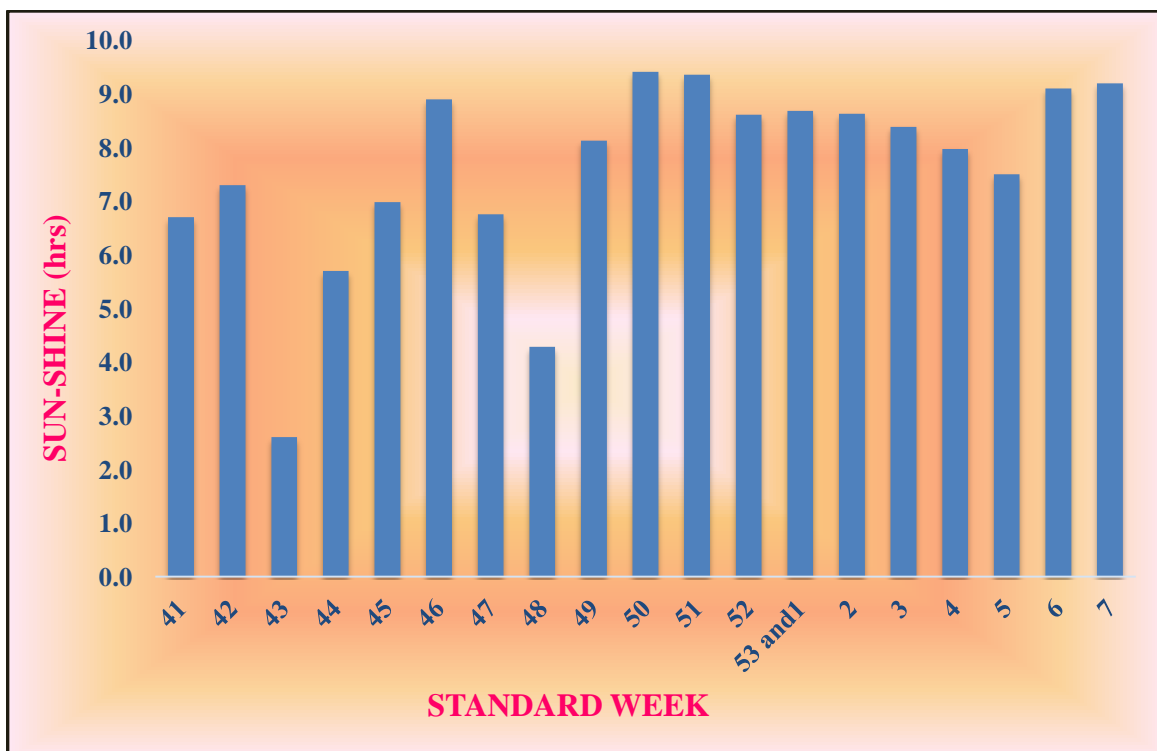
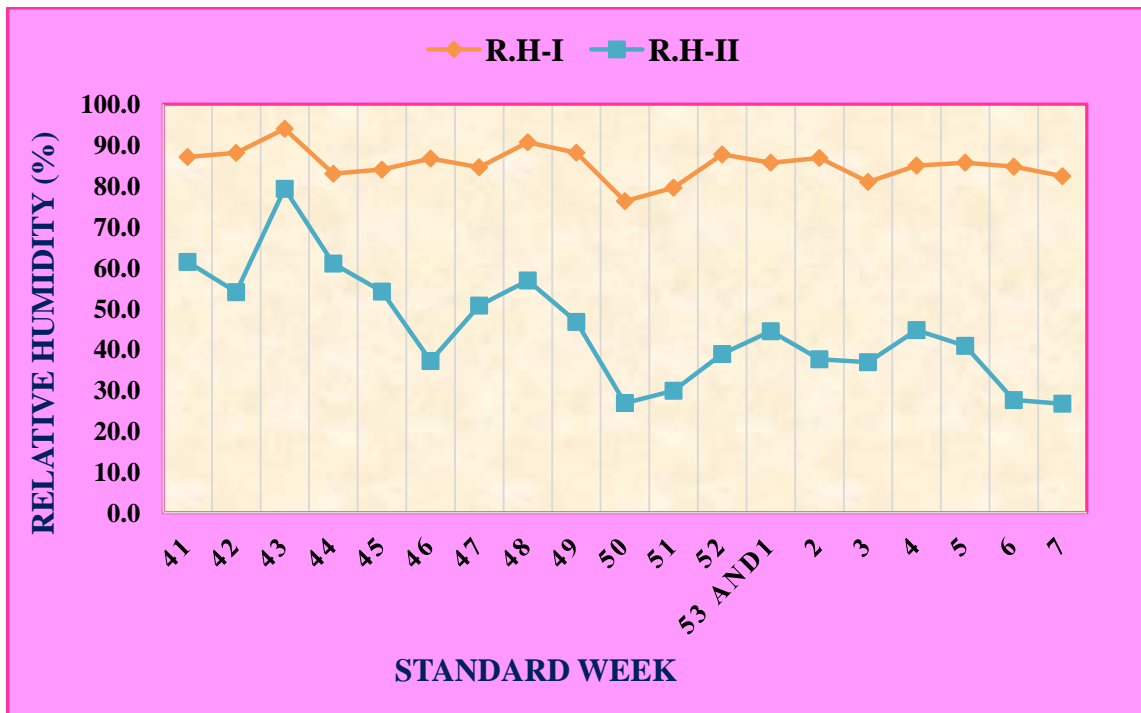


Fig 3.1.2 Weekly mean meteorological data (RH and Sun shine) during cropping period *rabi*, 2013-14

## Chapter IV

# RESULTS AND DISCUSSION

The results of the experiment entitled “**Influence of moisture regimes on growth, yield and quality of chickpea cultivars**” was conducted during *rabi* season, 2013-14, at the College Farm, College of Agriculture, Rajendranagar, Hyderabad are presented and are discussed in this chapter. Experimental data were statistically analyzed apportioned under various heads and subheads, furnished in tables and illustrated through figures wherever necessary. The experimental data on various growth parameters, yield attributes, yield, quality parameters, water use studies, nutrient uptake and economics are interpreted in tables.

The results found were discussed critically with cause and effect relationships under following headings.

1. Growth parameters
2. Yield attributes and yield
3. Quality parameters
4. Water use studies
5. NPK uptake
6. Economics

### 4.1 PLANT POPULATION

The data inscribed in table 4.1 on crop stand of chickpea both at initial (plant population at germination) and the final (plant population at harvest) stages were found to be not influenced by different treatments *viz.*, irrigation scheduling and varieties and their interaction effect.

**Table. 4.1. Crop stand of chickpea varieties as influenced by varied moisture regime**

Treatments	Initial plant stand (m <sup>2</sup> )			Final plant stand (m <sup>2</sup> )		
	V <sub>1</sub>	V <sub>2</sub>	Mean	V <sub>1</sub>	V <sub>2</sub>	Mean
T <sub>1</sub> -Control	14.87	16.38	15.63	12.37	13.22	12.79
T <sub>2</sub> -0.3 IW:CPE	14.47	15.45	14.96	12.56	15.96	14.26
T <sub>3</sub> -0.6 IW:CPE	16.32	16.21	16.27	14.01	14.56	14.29
T <sub>4</sub> -0.9 IW:CPE	16.17	15.95	16.06	12.90	12.81	12.85
Mean	15.46	16.00	15.73	12.96	14.14	13.55
	SE(m)	CD		SE(m)	CD	
Factor A	0.52	NS		0.54	NS	
Factor B	0.73	NS		0.76	NS	
Factor ( A x B)	1.03	NS		1.07	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V<sub>1</sub>- JG-11, V<sub>2</sub>-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

## 4.2 PLANT GROWTH CHARACTERS

The data on growth attributing characters like plant height, No. of branches per plant, dry matter production and root nodules count of plant at different growth stages as influenced by moisture regime were analysed and the results are furnished in table 4.2 to 4.4.

### 4.2.1 Plant height (cm)

Growth was slow up to 30 days after sowing (DAS), thereafter it increased linearly up to 60 DAS and after that although it continued to increase but is at a diminishing rate (table 4.2).

#### 4.2.1.1 Effect of irrigation scheduling on plant height

The data on plant height in table 4.2 clearly indicates that plant height increased progressively with increase in age. The quantum of increase is rapid between

30-60 DAS slowed thereafter. At all the stages of crop growth lowest plant height was observed in control (I<sub>1</sub>), where as the highest plant height was observed in 0.9 IW:CPE ratio (Treatment-I<sub>4</sub>). However, no significant influence on height was observed between other irrigation levels.

A close scrutiny of the data revealed that there is consistency regards to the effect of different moisture regime on plant height at all the growth stages of the crop. However, the plant height throughout the crop growth period was found to respond to irrigation. with increase in volume of irrigation, the plant height has been increased. These findings are in close conformity with those of Dabhi *et al.* (1998).

Under moisture regimes of IW:CPE ratio 0.3, 0.6 and 0.9, the increase in irrigation level, the plant height increased through the grand growth period. Rapid increase in plant height from 30 DAS to 60 DAS might be due to optimum soil moisture availability coupled with higher water potential and turgidity of the plant cells and leaf expansion which ultimately lead to higher assimilation as compared to control crop. Similar findings were also reported by Dabhi *et al.*(1998), Chandrasekhar and Saraf (2005), Mustafa *et al.*(2008).

#### **4.2.1.2 Effect of varieties on plant height**

A close scrutiny of the data revealed that there is inconsistency among the varieties on plant height (Naik *et al.*,2012). However, variety JG-11 (V<sub>1</sub>) recorded higher plant height at all stages of growth except at harvest as compared to Annegiri (V<sub>2</sub>).

#### **4.2.1.3 Interaction effect**

Interaction effect of irrigation scheduling and varieties on plant height was non significant at all the stages of crop growth (Naik *et al.*, 2012).

#### **4.2.2 No. of Branches Plant<sup>-1</sup>**

The data on number of branches plant<sup>-1</sup> at various stages of chickpea are presented in table 4.3

##### **4.2.2.1 Effect of irrigation scheduling on no. of branches plant<sup>-1</sup>**

A perusal of the data (table 4.3) revealed that the number of branches plant<sup>-1</sup> increased significantly due to influence of varied moisture regime except at 30 DAS.

Lowest number of branches plant<sup>-1</sup> was recorded in control treatment and a significant increase was observed with irrigation. However, when compared 0.3 IW:CPE ratio (I<sub>2</sub>) significant increase in number of branches in I<sub>4</sub> was observed. This could be ascribed to the resultant effect of moisture availability and maintained the

water potential and the net assimilation which transformed into vegetative growth i.e. number of branches. Similar views were expressed by Patel *et al.* (1988), Patel *et al.* (1989), Dixit *et al.* (1993), Dabhi *et al.* (1998), Chandrasekhar and Saraf (2005) and Mansur *et al.* (2010).

#### **4.2.2.2 Effect of varieties on no. of branches plant<sup>-1</sup>**

Through this data, it has been revealed that varieties have not shown significant effect on number of branches plant<sup>-1</sup> at any crop growth stage as supported from results of Naik *et al.* (2012).

#### **4.2.2.3 Interaction effect**

There was no significant effect of interaction on number of branches plant<sup>-1</sup> due to irrigation scheduling and varietal variation. The results are in confirmation with those of Naik *et al.* (2012).

### **4.2.3 Total dry matter production (g plant<sup>-1</sup>)**

#### **4.2.3.1 Effect of irrigation scheduling on total dry matter**

Irrigation scheduling had a significant effect on dry matter production at 60 DAS, 90 DAS and at harvest (table 4.4). At 30 DAS, though the effect of irrigation was not significant, the lowest accumulation of dry matter was recorded with I<sub>1</sub> treatment. At 60 DAS, the total dry matter increased significantly with increasing irrigation level from I<sub>2</sub> to I<sub>4</sub> treatment.

Lowest dry matter was recorded in I<sub>1</sub> (control) treatment, highest dry matter accumulation was always recorded with I<sub>4</sub> (0.9 IW:CPE) treatment. There is a significant increase in dry matter production when crop was grown under moisture regime of (0.9 IW:CPE) at all growth stages as compared to control (I<sub>1</sub>) treatment. Both the treatments I<sub>3</sub> and I<sub>4</sub> recorded significantly higher dry matter per plant as compared to I<sub>1</sub> and I<sub>2</sub> treatments. The increase in dry matter production is due to the fact that the availability of soil moisture at critical growth stages of crop growth in I<sub>2</sub>, I<sub>3</sub> and I<sub>4</sub>. Thus, it makes the sense clear that irrigation is imperative for crop growth and accumulation of dry matter production. These findings lead support those of Dabhi *et al.* (1998), Reddy and Ahlawat (1998), Chandrasekhar and Saraf (2005) and Mansur *et al.* (2010).

#### **4.2.3.2 Effect of varieties on total dry matter**

It is apparent from the data (table 4.4) that the genotypes had no significant effect on dry matter production at all the stages of crop (Naik *et al.*, 2012).

#### **4.2.3.3 Interaction effect**

The interaction effect of irrigation scheduling and varieties was non significant at all the stages of observation. This results are in conformity with those of Naik *et al.* (2012).

#### **4.2.4 Root nodules**

##### **4.2.4.1 Effect of irrigation scheduling on root nodules**

Irrigation scheduling had a significant effect on root nodules at all crop stages except 30 DAS (table 4.5). At 30 DAS, though the effect of irrigation was not significant, the lowest nodules were recorded with I<sub>1</sub> treatment. At 60 DAS, the total root nodules increased significantly with increasing irrigation level from I<sub>2</sub> to I<sub>4</sub> treatment.

Highest nodule count was recorded with I<sub>4</sub> (0.9 IW:CPE) treatment. There is a significant increase in nodule number when crop was grown under moisture regime of (0.9 IW:CPE) at all growth stages as compared to control (I<sub>1</sub>) treatment. Both the treatments I<sub>3</sub> and I<sub>4</sub> recorded significantly higher root nodules as compared to I<sub>1</sub> and I<sub>2</sub> treatments. These findings lead support those of Patel *et al.* (1988), Pal and Lal (1993), Reddy and Ahlawat (1998).

##### **4.2.4.2 Effect of varieties on total dry matter**

Number of nodules per plant was not significantly influenced by varieties.

##### **4.2.4.3 Interaction effect**

The interaction effect of irrigation scheduling and varieties was non significant at all the stages of observation.

### **4.3 YIELD ATTRIBUTES**

A close observation of the data on yield attributes mentioned in (table 4.6) clearly reveals the fact that increased moisture availability significantly influences the yield attributes like number of pod plant and test weight (g).

#### **4.3.1 Number of pods plant<sup>-1</sup>**

It is apparent from the data (table 4.6) that both irrigation scheduling and varieties has a significant effect on the number of pods plant<sup>-1</sup>.

##### **4.3.1.1 Effect of irrigation scheduling**

The maximum number of pods plant<sup>-1</sup> (74.27 and 65.30 for JG-11 and Annegiri, respectively) was recorded with I<sub>3</sub> (0.6 IW:CPE) treatment, where as the lowest number of pods plant<sup>-1</sup> (53.20 and 46.25 for JG-11 and Annegiri, respectively) was recorded under I<sub>1</sub> (control). A further increase in the moisture regime failed to influence the number of pods plant<sup>-1</sup> from 0.6-0.9 IW:CPE ratio as supported with

results of Patel *et al.* (1988) and Mansur *et al.* (2010). This could be ascribed to the fact that moisture availability in the root zone increased the nutrient uptake which produces multiple physiological effects and to increase in net assimilation followed by source to sink of the photosynthates. Similar findings were reported by Singh and Dixit (1992), Dixit *et al.* (1993), Dabhi *et al.* (1998), Reddy and Ahlawat (1998), Kaushik and Chaubey (1999), Chandrasekhar and Saraf (2005) and Mustafa *et al.* (2008).

#### **4.3.1.2 Effect of varieties**

The varieties significantly influenced the number of pods plant<sup>-1</sup>. All the treatments differed significantly among themselves. I<sub>3</sub> (74.27 pods plant<sup>-1</sup> of JG-11) recorded highest number of pods which is at par with I<sub>4</sub> treatment (70.17 pods plant<sup>-1</sup> of JG-11), while I<sub>1</sub> put forth the lowest number of pods (53.20 pods plant<sup>-1</sup> of JG-11). JG-11 recorded significantly higher pods (74.27 pods plant<sup>-1</sup>) when compared with Annegiri (61.52 pods plant<sup>-1</sup>). Similar findings were reported by Naik *et al.* (2012) and Rao *et al.* (2012).

#### **4.3.1.3 Interaction effect**

The interaction between irrigation and varieties was found to be non significant (Naik *et al.*, 2012).

#### **4.3.2 No. of seeds pod<sup>-1</sup>**

A perusal of the data presented in table 4.6 on no.of seed pod<sup>-1</sup> in chickpea showed that irrigation schedules, varieties and their interactions has no significant effect . These results are in conformity with those of Dixit *et al.* (1993), Chaudhari *et al.* (1998), Reddy and Ahlawat (1998), Kaushik and Chaubey (1999), Chandrasekhar and Saraf (2005).

#### **4.3.3 Test weight (g)**

Scanning of the data presented in table 4.6 and depicted in Fig 4.6.3 revealed that the 100-seed weight (Test weight) was significantly affected by irrigation scheduling as well as varieties.

##### **4.3.3.1 Effect of irrigation scheduling**

Irrigation treatment I<sub>3</sub> recorded significantly higher test weight (24 g and 20.83 g for JG-11 and Annegiri, respectively) as compared to the rest of the irrigation treatments and was followed, in decreasing order, by I<sub>4</sub> (23.84 g and 20.2 g for JG-11 and Annegiri, respectively), I<sub>2</sub> (21.42 g and 18.13 g for JG-11 and Annegiri, respectively) and I<sub>1</sub> (19.04 g and 17.23 g for JG-11 and Annegiri, respectively)

treatments, respectively. The treatment  $I_4$  and  $I_3$  were on par with each other and were significantly superior to  $I_1$  treatment which recorded the lowest test weight.

The increase in test weight with the increase in irrigation frequency might be due to better growth of the crop, efficient dry matter partitioning and better translocation to the sink, leading to the formation of large sized seeds. On the contrary, the lower in test weight with lower irrigation frequency might be due to the effect of soil moisture stress leading to poor translocation of photosynthates to grain resulting in shrivelled and small sized grains. Similar findings were reported by Singh and Dixit (1992), Dabhi *et al.* (1998), Kaushik and Chaubey (1999), Mustafa *et al.* (2008). In the case of highest irrigation level *i.e.*  $I_4$  treatment, the decrease might be due to too frequent irrigation leading to poor grain filling when compared with  $I_3$ . These results were in conformation with those of Patel *et al.* (1988), Singh and Dixit (1992), Chandrasekhar and Saraf (2005).

#### **4.3.3.2 Effect of varieties**

A scrutiny of the data (table 4.6) revealed that the variety JG-11 has recorded highest test weight (24 g) when compared with Annegiri (20.83 g). Similar results were recorded by of Rao *et al.* (2012). But the interaction effect of varied moisture regime and varieties was non significant (Naik *et al.*, 2012).

### **4.4 YIELD**

#### **4.4.1 Grain yield ( $\text{kg ha}^{-1}$ )**

Data pertaining to the grain yield recorded are presented in table 4.7 and graphically illustrated in Fig 4.7.1. A close scrutiny of the data reveals that irrigation scheduling and varieties has a significant effect on grain yield.

##### **4.4.1.1 Effect of irrigation scheduling**

The highest grain yield was obtained when irrigation was scheduled at an IW:CPE ratio of 0.6 ( $I_3$ ) (1882  $\text{kg ha}^{-1}$  and 1655  $\text{kg ha}^{-1}$  for JG-11 and Annegiri, respectively), but it was on par with  $I_4$  (IW:CPE-0.9) (1722  $\text{kg ha}^{-1}$  and 1542  $\text{kg ha}^{-1}$  for JG-11 and Annegiri, respectively) treatment and  $I_4$  is onpar with  $I_2$  (1567  $\text{kg ha}^{-1}$  and 1322  $\text{kg ha}^{-1}$  for JG-11 and Annegiri, respectively). Both of these treatments were significantly superior to  $I_1$  (1245  $\text{kg ha}^{-1}$  and 1008  $\text{kg ha}^{-1}$  for JG-11 and Annegiri, respectively) treatment, respectively. Irrigation level of  $I_1$  produced the lowest grain yield as compared to  $I_2$  treatment. These findings were in conformation with Palled *et al.*, 1985. Irrigation level of  $I_2$  was significantly superior to  $I_1$  treatment. The higher grain yield with more frequent irrigation might be accounted for their favorable

influence on the growth characters (plant height and number of branches respectively) and yield attributing characters (no. of pods plant<sup>-1</sup> and test weight, respectively). Similar finding also reported by Palled *et al.* (1985), Patel *et al.* (1989), Dixit *et al.* (1993), Dabhi *et al.* (1998), Kaushik and Chaubey (1999), Singh *et al.* (2005), Mustafa *et al.* (2008). In case of I<sub>4</sub> treatment which provide maximum frequency of irrigation (four irrigations), the decrease in grain yield as compared to I<sub>3</sub> treatment might be due to frequent irrigations leading to relatively lesser seed filling as it was evident from the data on test weight. Similar findings were reported by Yusuf *et al.* (1980), Palled *et al.* (1985), Chandrasekhar and Saraf (2005).

#### **4.4.1.2 Effect of varieties**

With an increment in the no. of pods plant<sup>-1</sup> and test weight, the grain yield was significantly increased. The JG-11 variety recorded significantly higher grain yield (1882 kg ha<sup>-1</sup> at 0.6 IW:CPE ratio) as compared to Annegiri (1655 kg ha<sup>-1</sup> at 0.6 IW:CPE ratio). These results were in conformity with Naik *et al.* (2012), Rao *et al.* (2012).

#### **4.4.1.3 Interaction effect**

Interaction effect between irrigation levels and varieties was non significant with regard to the grain yield.

#### **4.4.2 Haulm yield (kg ha<sup>-1</sup>)**

The data presented in table 4.7 and illustrated in Fig 4.7.2. revealed that the haulm yield was significantly influenced by irrigation scheduling and varieties.

##### **4.4.2.1 Effect of irrigation scheduling**

Irrigation level I<sub>3</sub> recorded the maximum haulm yield (893 kg ha<sup>-1</sup> and 794 kg ha<sup>-1</sup> for JG-11 and Annegiri, respectively), but was on par with I<sub>4</sub> treatment (822 kg ha<sup>-1</sup> and 657 kg ha<sup>-1</sup> for JG-11 and Annegiri, respectively). The treatments I<sub>3</sub> and I<sub>4</sub> were superior to the control treatment and I<sub>4</sub> is on par with I<sub>2</sub>. I<sub>1</sub> treatment recorded significantly lower haulm yield (618 kg ha<sup>-1</sup> and 451 kg ha<sup>-1</sup> for JG-11 and Annegiri, respectively) as compared to the rest of the irrigation levels. The increase in haulm yield with increased in irrigation frequency of irrigation might be accounted for high vegetative growth and dry matter production. Similar findings were reported by Dabhi *et al.* (1998) and Singh *et al.* (2005). With further increased in the frequency of irrigation from I<sub>3</sub> to I<sub>4</sub>, it does not resulted in any significant higher yield as supported from results of Chandrasekhar and Saraf (2005).

#### **4.4.2.2 Effect of varieties**

The varieties significantly differ among themselves higher haulm yield was obtained with JG-11 variety (893 kg ha<sup>-1</sup>) when compared with Annegiri (794 kg ha<sup>-1</sup>). Similar findings were reported by Rao *et al.* (2012).

#### **4.4.2.3 Interaction effect**

Interaction effect of irrigation schedules and varieties has shown inconsistency which resulted in non significant.

#### **4.4.2 Harvest index**

The data presented in table 4.7 revealed that the different moisture regime, varieties and their interaction effect has no effect on the harvest index.

### **4.5 NPK UPTAKE (AT HARVEST)**

Meager water supply or excessive irrigation can result in unavailability or leaching of a major part of nutrients resulting in insufficiency of nutrient and low yields. Proper water management will hold these losses to a bare minimum. Likewise, the amount and movement of water in soil influence the availability of nutrients to plant roots.

Varied moisture regime had a significant influence on N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O uptake of plants at harvest (table 4.8).

Increasing irrigation frequency resulted in increase in total uptake of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O (table 4.8). The highest uptake was obtained with I<sub>3</sub> treatment. With additional increase in the frequency of irrigation upto I<sub>4</sub>, nitrogen uptake was lower due to leaching losses and lower yield levels. The lowest uptake was obtained with I<sub>1</sub> (control) treatment. But as a whole, the increase in irrigation frequency resulted in higher solubility of nutrients and higher uptake. Similar findings were reported by Roy and Tripathi (1985), Dixit *et al.* (1993), Srivastava and Srivastava (1994), Reddy and Ahlawat (1998).

The highest K uptake was obtained with I<sub>3</sub> treatment. With additional increase in the frequency of irrigation upto I<sub>4</sub>, P uptake has been not influenced by irrigation.

Varieties and interaction effect of varied moisture regime and varieties has shown significant effect. Among varieties, JG-11 has showed more N and K upake but P uptake remained non significant.

### **4.6 QUALITY PARAMETER**

#### 4.6.1 Protein content (%)

It was evident from the data in (table 4.8) that the protein content of chickpea was significantly influenced by varied moisture regime. The treatment I<sub>3</sub> (0.6 IW:CPE) recorded (24.9% and 24.7% for JG-11 and Annegiri, respectively) significantly higher protein content as compared to I<sub>1</sub> - control (19.13 % and 18.67 % for JG-11 and Annegiri, respectively) , I<sub>2</sub> -0.3 IW:CPE (22.50 % and 22 % for JG-11 and Annegiri, respectively) and I<sub>4</sub> -0.9 IW:CPE (23% and 22.9% for JG-11 and Annegiri, respectively). The lowest protein content was observed in I<sub>1</sub> (control) treatment. This finding is conformity with those of Dixit *et al.* (1993).

The varieties as well as the interaction effect of irrigation schedules and varieties has no consistency and finally results in insignificant data.

### 4.7 ECONOMICS

With increase in irrigation levels, the total cost of cultivation increased accordingly (Table 4.9). In treatments viz., I<sub>1</sub> (control), I<sub>2</sub> (0.3 IW:CPE), I<sub>3</sub> (0.6 IW:CPE) and I<sub>4</sub> (0.9 IW:CPE). The gross returns, net returns per hectare and B:C ratio was highest at irrigation level I<sub>3</sub> (0.6 IW:CPE) (₹ 58360 ha<sup>-1</sup>, ₹ 39775 ha<sup>-1</sup> and 3.14 for JG-11 and ₹ 51306 ha<sup>-1</sup>, ₹ 32721 ha<sup>-1</sup> and 2.76 for Annegiri, respectively) and it was minimum under I<sub>1</sub> (control) (₹ 38607 ha<sup>-1</sup>, ₹ 21282 ha<sup>-1</sup> and 2.23 for JG-11 and ₹ 31254 ha<sup>-1</sup>, ₹ 13929 ha<sup>-1</sup> and 1.80 for Annegiri, respectively). The magnitude of increase in yield further increases the net profit which finally results in higher B:C ratio. This finding is conformity with those of Patel *et al.* (1989), Singh *et al.* (2005) and Mustafa *et al.* (2008).

Among the varieties JG-11 has shown more net returns and B:C ratio (₹ 39775 ha<sup>-1</sup> and 3.14) than Annegiri (₹ 32721 ha<sup>-1</sup> and 2.76). This finding is conformity with those of Rao *et al.* (2012).

### 4.8 WATER USE

#### 4.8.1 Water use efficiency (kg ha<sup>-1</sup>mm<sup>-1</sup>)

##### 4.8.1.1 Effect of irrigation scheduling

A scrutiny of the data (table 4.10) reveals that the highest irrigation level I<sub>4</sub> recorded the lowest water use efficiency of 7.83 kg ha<sup>-1</sup>mm<sup>-1</sup> and 4.66 kg ha<sup>-1</sup>mm<sup>-1</sup> for JG-11 and Annegiri respectively. With the increase in irrigation level, the water use efficiency decreases. The I<sub>1</sub> (control) recorded the highest water use efficiency of

9.41kg ha<sup>-1</sup>mm<sup>-1</sup> and 6.68 kg ha<sup>-1</sup>mm<sup>-1</sup> for JG-11 and Annegiri respectively, compared to the other higher levels of moisture regimes. This finding is in conformity with Sharma and Yadav (1976), Singh *et al.* (1980), Yusuf *et al.* (1980), Dobariya *et al.*(1985), Roy and Tripathi (1985), Patel *et al.*(1989), Prabhakar and Saraf (1991), Srivastava and Srivastava (1994), Singh *et al.* (2006), Pramanik *et al.*(2008).

#### 4.8.2 Total Crop Evapotranspiration (mm)

A scrutinized observation of the data presented in (table 4.10) revealed that the water use increased with the increase in an irrigation frequency. The highest amount of water was utilized under I<sub>4</sub> (0.9 IW:CPE) treatment which was to the tune of 220 mm and 204 mm for JG-11 and Annegiri respectively. The water used under I<sub>3</sub> (0.6 IW:CPE) treatment was 200 mm and 182 mm for JG-11 and Annegiri respectively while under I<sub>2</sub> (0.3 IW:CPE) treatment, it was 193 mm and 170 mm for JG-11 and Annegiri respectively. The lowest amount of moisture utilization was recorded under I<sub>1</sub> (Control) treatment which was to the tune of 155 mm and 148 mm for JG-11 and Annegiri respectively (Singh *et al.*, 1991).

The relationship between chickpea crop yield and crop evapotranspiration was established (Fig 4.11 to Fig 4.14) following both linear and quadratic water production functions. The resultant functions and test statistics are as follows:

**Linear**            Y            = 1167.8+ 174.67 Et<sub>c</sub>

R<sup>2</sup>                = 0.6884

F value          = 4.85 for JG-11

**Linear**            Y            = 193.41+ 898.56 Et<sub>c</sub>

R<sup>2</sup>                = 0.768

F value          = 4.647 for Annegiri

**Quadratic**        Y            = 120.53 X<sup>2</sup> + 777.3 X + 565.2

R<sup>2</sup>                = 0.95

F value          = 2.02 for JG-11

$$\begin{aligned} \text{Quadratic } Y &= 106.89 X^2 + 727.88 X + 364.1 \\ R^2 &= 0.956 \\ F \text{ value} &= 4.87 \end{aligned}$$

The test statistics ( $R^2$  and F value) of linear production function indicated that it was statistically significant. The explained total variation ( $R^2$ ) in chickpea grain yield was 68% and 76 % for JG-11 and Annegiri, respectively (Fig 4.11 to Fig 4.14). The positive linear regression coefficient indicated that the chickpea grain yield increased linearly with increase in seasonal evapotranspiration. On the other hand, the test statistics and  $R^2$  pertaining to quadratic water production did not exhibit any significant improvement over linear water production function. The  $R^2$  and F values were marginally higher in quadratic function as compared to linear function. Hence, the optimization of water was not possible due to linear response of chickpea crop yield to seasonal evapotranspiration in the present study (Dogan *et al.*, 2013).

#### 4.8.3 Crop coefficient ( $K_c$ )

Crop coefficient  $K_c$  is the best known approach for explaining yield as a function of  $Et_a$ . In other words, it is the prediction of  $Et_a$  requirement of the crop ( $Et_a = K_c Et_o$ ) not just as a simple value for the season, but as a cumulative value over time which shows the differential  $Et_a$  needs in each individual crop growth sub phase. Initially, the crop coefficient value was low (table 4.11 and 4.12, Fig 4.15 and 4.16) due to incomplete canopy cover which may be accounted occurrence for the maximum water loss through evaporation from the bare soil. With the advancement of the crop age, the ratio increased accordingly upto mid season stage, which represent the peak value of crop coefficient throughout the crop growth cycle. This reflects the increased water loss due to increased transpiring surface as a consequence of rapid leaf development and also indicates the maximum water need of the crop as a consequence of full canopy cover intercepting maximum incident photosynthetically active radiation (PAR). In contrast, the crop coefficient value decreased towards late season stage, which reflects the senescence of the leaf.

Perusal of the variation in the  $K_c$  values ( $Et_a / Et_o$  rates) with time in different treatments indicated that the highest  $K_c$  values of 1.08 and 1.00 for JG-11 and Annegiri, respectively was registered by  $I_4$  ( 0.9 IW:CPE) treatment at flowering and

development stage. Likewise, the treatment  $I_3$  (0.6 IW:CPE) attained a peak value of 0.98 and 0.89 for JG-11 and Annegiri, respectively at flowering and development stage. The treatment  $I_1$  (control) registered lower  $K_c$  values than all the treatment at all the stages of crop growth. The variation in  $K_c$  values of  $I_4$  treatment was similar to  $I_{3+}$  treatment whereas the variation in  $I_1$  and  $I_2$  showed a similar fashion of Nayar and Singh (1985), Reddy *et al.* (1998).

#### **4.8.4 Soil Moisture Extraction Pattern (%)**

A scrutinized observation of the data presented in (Fig 4.17) revealed that the percentage of soil moisture extracted from 0-15 cm layers under all moisture regime followed by the next consecutive layers of 15-30 cm and 30-45 cm layers. This trend is similar in all moisture regimes. However, under control conditions the moisture extraction from 0-15 cm layer was lowest (36.9 % and 10.3 % for JG-11 and Annegiri respectively) as compared to other moisture regimes (0.3, 0.6 and 0.9 IW:CPE ratio). Similarly, as root goes more deeper layer under control conditions at 15-30 and 30-45 cm layers were also higher as when compared to other moisture regimes. These observed results are in confirmity with those reported by Singh *et al.* (1980), Prabhakar and Saraf (1991), Singh *et al.* (1991), Dixit *et al.* (1993), Singh *et al.* (2006), Pramanik *et al.* (2008).

Since the crop is under control conditions and as well as varied moisture regimes the root distribution also varied. Since root growth system are heirarthial, each lower ordered class of roots (as root goes deeper) has less mass per length unit area than the higher roots (shallow layers). The moisture extraction pattern also varies accordingly. Increased moisture regimes leading to more shallow depth root distribution might have lead to higher percentage of moisture extraction from shallow depths as compared to the crop under control. These views are supported by the experimental findings Dixit *et al.* (1993).

**Table 4.2 Plant height (cm) of chickpea varieties influenced by varied moisture regimes**

TREATMENTS	30DAS			60DAS			90DAS			At Harvest		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	18.23	19.56	18.89	25.80	25.10	25.45	29.00	27.87	28.44	29.60	28.89	29.25
T2-0.3IW:CPE	19.13	19.62	19.37	29.01	28.60	28.81	31.40	30.60	31.00	32.60	31.80	32.20
T3-0.6 IW:CPE	18.21	19.22	18.72	32.60	32.20	32.40	34.30	33.80	34.05	35.40	35.30	35.35
T4-0.9 IW:CPE	19.47	19.08	19.27	33.20	33.10	33.15	36.20	35.40	35.80	37.30	37.90	37.60
Mean	18.76	19.37	19.06	30.15	29.75	29.95	32.73	31.92	32.32	33.73	33.47	33.60
	SE(m)	CD		SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	0.34	NS		0.70	NS		0.47	NS		0.63	NS	
Factor B	0.49	NS		0.99	3.00		0.66	2.00		0.90	2.72	
Factor ( A x B)	0.69	NS		1.40	NS		0.93	NS		1.27	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.4 Dry matter production (g plant<sup>-1</sup>) of chickpea varieties influenced by varied moisture regime**

TREATMENTS	30DAS			60DAS			90DAS			At Harvest		
	V <sub>1</sub>	V <sub>2</sub>	Mean	V <sub>1</sub>	V <sub>2</sub>	Mean	V <sub>1</sub>	V <sub>2</sub>	Mean	V <sub>1</sub>	V <sub>2</sub>	Mean
T1-CONTROL	3.73	4.53	4.13	5.64	5.43	5.54	13.92	13.53	13.73	12.28	12.12	12.20
T2-0.3IW:CPE	4.67	4.27	4.47	7.00	6.80	6.90	15.80	15.50	15.65	14.23	14.03	14.13
T3-0.6 IW:CPE	4.27	4.27	4.27	8.50	8.20	8.35	17.81	17.48	17.65	16.52	16.08	16.30
T4-0.9 IW:CPE	4.40	3.87	4.13	9.30	9.40	9.35	18.21	18.13	18.17	17.30	17.16	17.23
Mean	4.27	4.23	4.25	7.61	7.46	7.53	16.44	16.16	16.30	15.08	14.85	14.97
	SE(m)	CD		SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	0.14	NS		0.30	NS		0.41	NS		0.40	NS	
Factor B	0.19	NS		0.43	1.29		0.58	1.76		0.56	1.71	
Factor ( A x B)	0.27	NS		0.60	NS		0.82	NS		0.80	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V<sub>1</sub>- JG-11, V<sub>2</sub>-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.5 Root nodules of chickpea varieties influenced by varied moisture regime**

TREATMENTS	30DAS			60DAS			90DAS			At Harvest		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	10.77	11.23	11.00	23.12	24.24	23.68	37.07	38.11	37.59	31.67	32.20	31.94
T2-0.3IW:CPE	11.10	11.43	11.27	26.67	27.67	27.17	40.33	41.67	41.00	34.66	34.86	34.76
T3-0.6 IW:CPE	11.80	12.07	11.93	30.48	31.82	31.15	43.93	44.94	44.44	37.95	38.23	38.09
T4-0.9 IW:CPE	12.53	12.33	12.43	32.72	33.36	33.04	44.87	45.42	45.15	40.08	40.42	40.25
Mean	11.55	11.77	11.66	28.25	29.27	28.76	41.55	42.54	42.04	36.09	36.43	36.26
	SE(m)	CD		SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	0.59	NS		0.78	NS		0.72	NS		0.61	NS	
Factor B	0.84	NS		1.11	3.36		1.01	3.07		0.87	2.63	
Factor ( A x B)	1.18	NS		1.57	NS		1.43	NS		1.23	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.3 No. of branches of chickpea varieties influenced by varied moisture regimes**

TREATMENTS	30DAS			60DAS			90DAS			At Harvest		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	2.40	2.07	2.23	3.94	3.82	3.88	4.11	4.01	4.06	4.40	4.20	4.30
T2-0.3 IW:CPE	2.27	2.73	2.50	4.96	4.79	4.88	5.26	5.16	5.21	5.31	5.24	5.28
T3-0.6 IW:CPE	2.13	1.80	1.97	6.00	5.78	5.89	6.32	6.25	6.29	6.47	6.32	6.40
T4-0.9 IW:CPE	2.93	2.07	2.50	6.21	5.95	6.08	6.48	6.32	6.40	6.68	6.58	6.63
Mean	2.43	2.17	2.30	5.28	5.09	5.18	5.54	5.44	5.49	5.72	5.59	5.65
	SE(m)	CD		SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	0.12	NS		0.22	NS		0.24	NS		0.16	NS	
Factor B	0.17	NS		0.31	0.95		0.34	1.03		0.23	0.37	
Factor ( A x B)	0.24	NS		0.45	NS		0.48	NS		0.32	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.6 Yield attributes of chickpea varieties influenced by varied moisture regime**

TREATMENTS	No. of pods plant <sup>-1</sup>			No. of seeds pod <sup>-1</sup>			Test weight (g)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	53.20	46.25	49.73	1.00	1.07	1.03	19.04	17.23	18.14
T2-0.3IW:CPE	62.07	54.13	58.10	1.00	1.00	1.00	21.42	18.13	19.78
T3-0.6 IW:CPE	74.27	65.30	69.78	1.00	1.07	1.03	24.00	20.83	22.42
T4-0.9 IW:CPE	70.17	61.52	65.85	1.13	1.00	1.07	23.84	20.2	22.02
Mean	63.18	55.23	59.20	1.03	1.03	1.03	22.08	19.10	20.59
	SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	1.64	4.97		0.02	NS		0.55	1.68	
Factor B	2.32	7.03		0.03	NS		0.78	2.37	
Factor ( A x B)	3.28	NS		0.04	NS		1.11	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.7 Yield of chickpea varieties influenced by varied moisture regime**

TREATMENTS	Grain yield (kg ha <sup>-1</sup> )			Haulm yield (kg ha <sup>-1</sup> )			Harvest index (%)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	1245	1008	1127	618	451	535	65.02	68.62	66.82
T2-0.3IW:CPE	1567	1323	1445	750	583	667	64.33	70.73	67.53
T3-0.6 IW:CPE	1882	1655	1769	893	794	844	65.93	65.97	65.95
T4-0.9 IW:CPE	1722	1542	1632	822	657	740	65.77	67.09	66.43
Mean	1604	1382	1493	771	621	696	65.26	68.10	66.68
	SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	72.05	218.55		29.93	90.81		1.51	NS	
Factor B	101.90	309.07		42.33	128.42		2.13	NS	
Factor ( A x B)	144.10	NS		59.87	NS		3.01	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.8 NPK uptake and protein content of chickpea grain influenced by varied moisture regime**

TREATMENTS	N uptake (kg ha <sup>-1</sup> )			P uptake (kg ha <sup>-1</sup> )			K uptake (kg ha <sup>-1</sup> )			Protein content (%)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	51.06	54.45	52.76	0.32	0.22	0.27	24.54	23.09	23.82	19.13	18.67	18.90
T2-0.3IW:CPE	66.78	58.45	62.62	0.45	0.42	0.37	31.33	29.58	30.46	22.50	22.00	23.30
T3-0.6 IW:CPE	74.92	71.23	73.08	0.51	0.55	0.53	36.44	34.23	35.34	24.90	24.70	24.80
T4-0.9 IW:CPE	70.47	62.34	66.41	0.25	0.35	0.30	33.92	32.16	33.04	23.00	22.90	22.30
Mean	65.81	61.62	63.71	0.38	0.39	0.38	31.56	29.77	30.66	22.82	22.50	22.66
	SE(m)	CD		SE(m)	CD		SE(m)	CD		SE(m)	CD	
Factor A	1.11	3.36		0.04	NS		0.46	1.39		0.63	NS	
Factor B	1.57	4.76		0.06	NS		0.65	1.97		0.89	2.61	
Factor ( A x B)	2.22	6.73		0.08	NS		0.92	2.79		1.25	NS	

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.9 Economics of chickpea varieties as influenced by varied moisture regime**

TREATMENTS	Cost of cultivation (₹ ha <sup>-1</sup> )			Gross return (₹ ha <sup>-1</sup> )			Net return (₹ ha <sup>-1</sup> )			B:C		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
T1-CONTROL	17325	17325	17325	38607	31254	34930.5	21282	13929	17605	2.23	1.80	2.01
T2-0.3IW:CPE	18165	18165	18165	48592	41011	44801.5	30426	22846	26636	2.68	2.26	2.47
T3-0.6 IW:CPE	18585	18585	18585	58360	51306	54833	39775	32721	36248	3.14	2.76	2.95
T4-0.9 IW:CPE	19005	19005	19005	53400	47809	50604.5	34395	28804	31599	2.81	2.52	2.66
<b>Mean</b>	18270	18270	18270	49739	42845	46292	31469	24575	28022	2.71	2.33	2.52

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

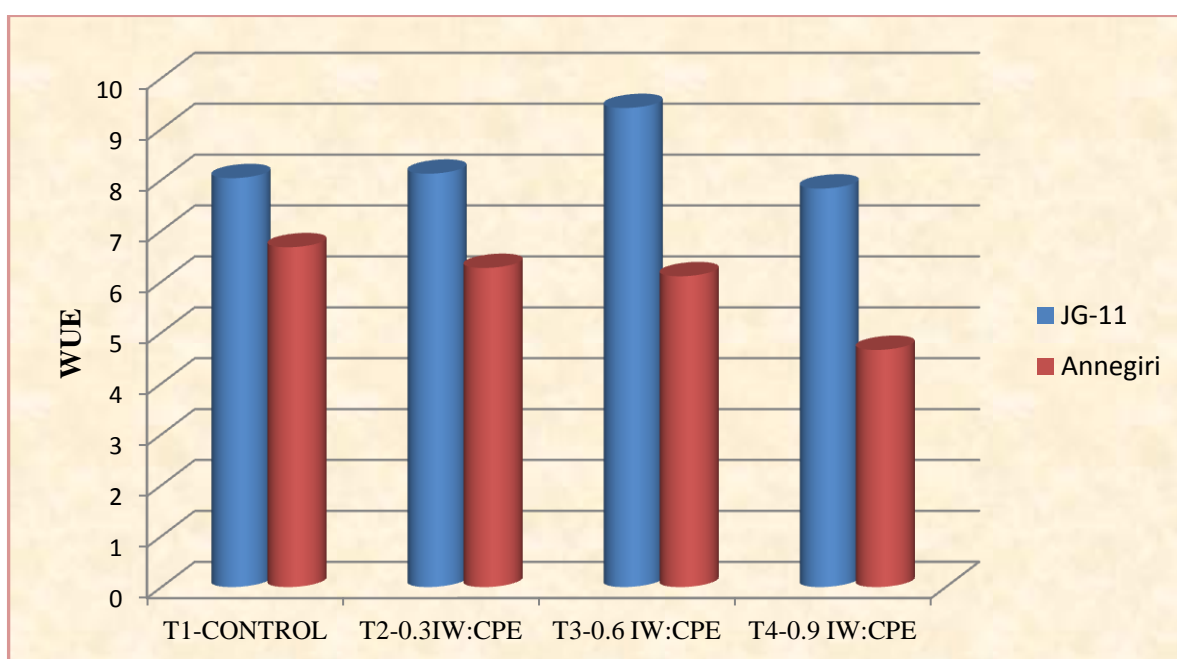
V1- JG-11, V2-Annegiri, Factor A-Varieties, Factor B- Irrigation levels

**Table 4.10 Total water use and water use efficiency (WUE) of chickpea varieties under varied moisture regime**

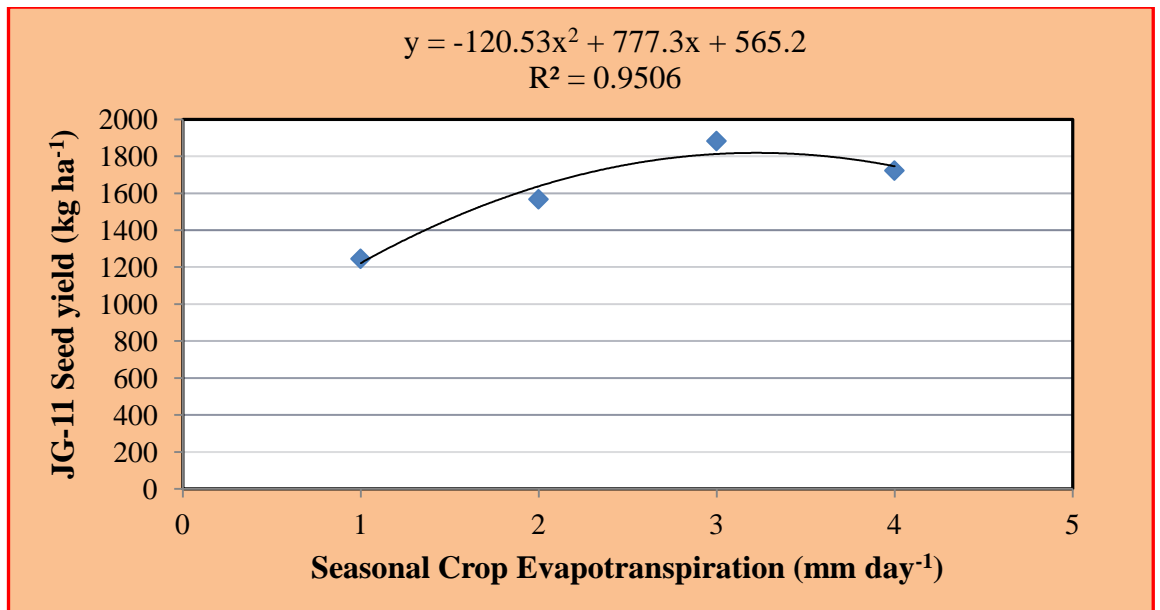
Treatments	Total $E_t$		Etc (mm day <sup>-1</sup> )		WUE (kg ha <sup>-1</sup> mm <sup>-1</sup> )	
	V1	V2	V1	V2	V1	V2
T <sub>1</sub> -Control	155	148	1.55	1.48	9.41	6.68
T <sub>2</sub> -0.3IW:CPE	193	170	1.93	1.70	8.12	6.27
T <sub>3</sub> -0.6IW:CPE	200	182	2.00	1.82	8.03	6.11
T <sub>4</sub> -0.9IW:CPE	220	204	2.2	2.04	7.83	4.66

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

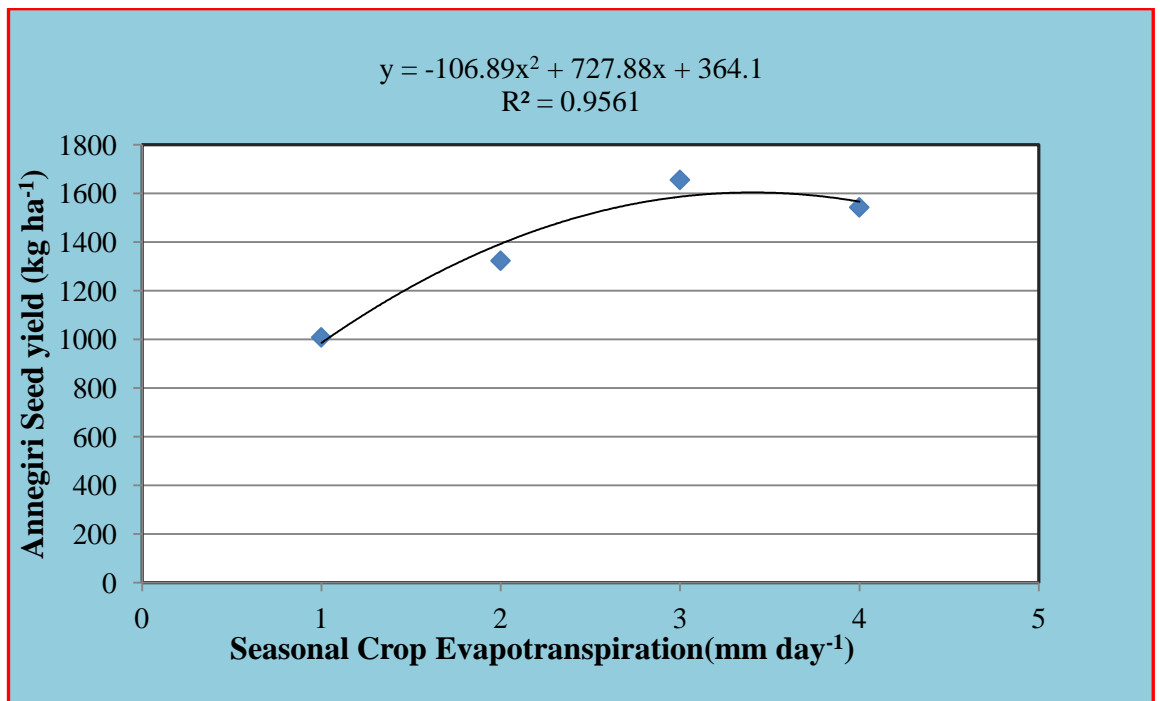
V1- JG-11, V2-Annegiri



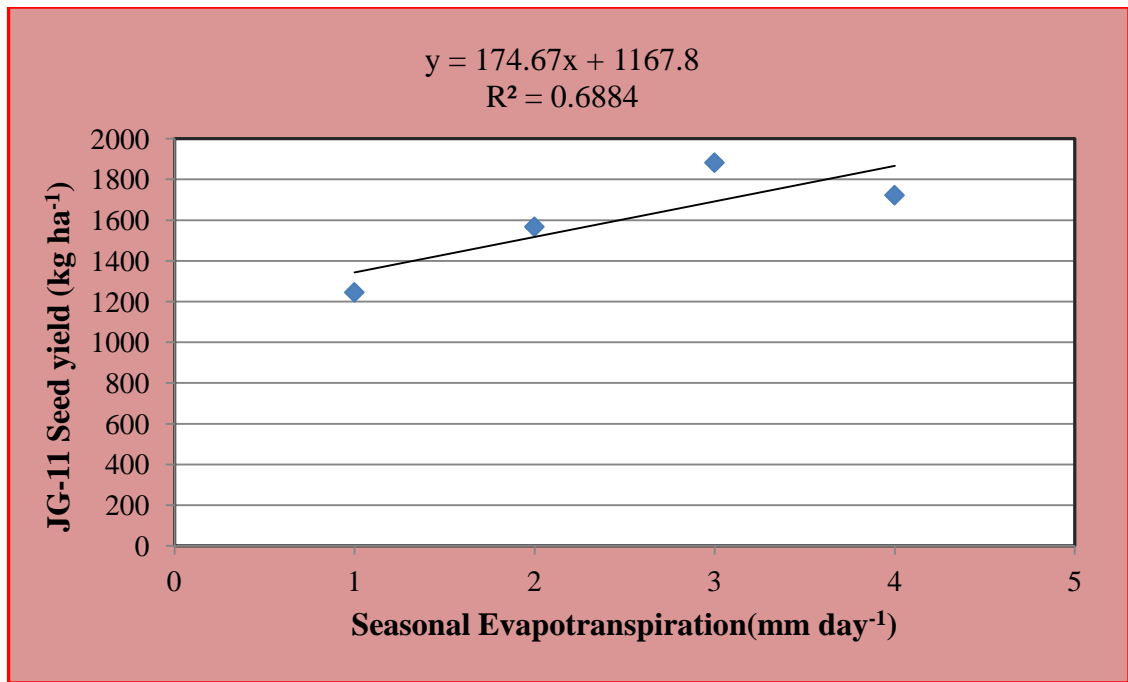
**Fig 4.10 Water use efficiency (WUE) of chickpea under varied moisture regime**



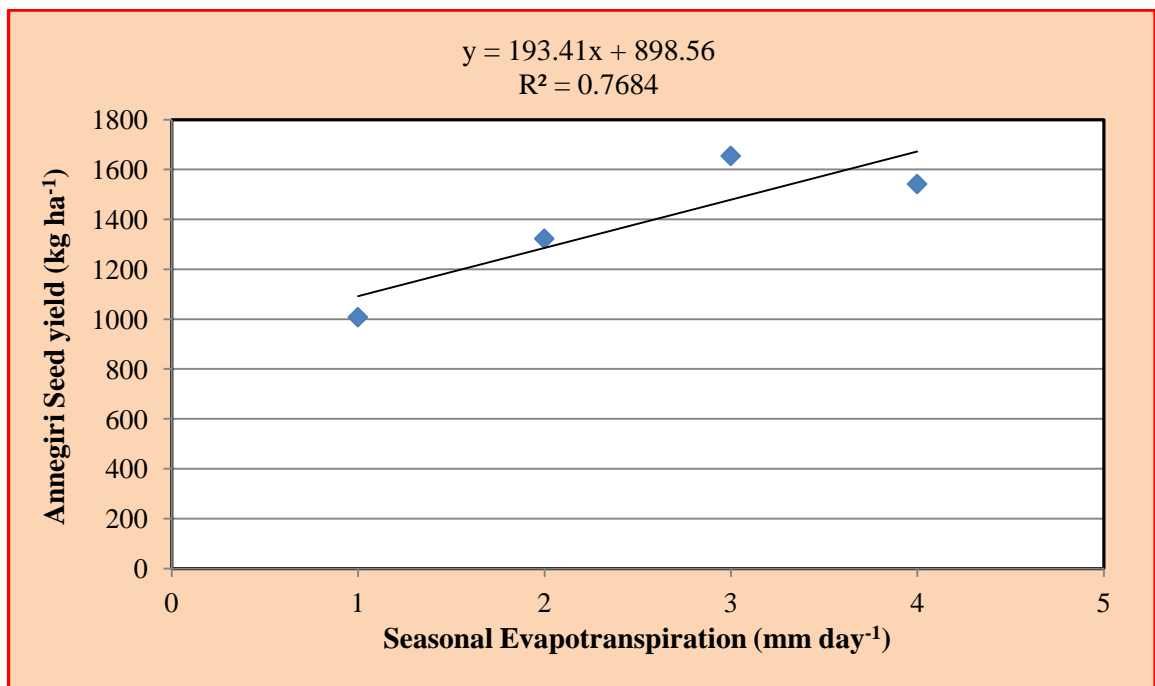
**Fig.4.11 Quadratic water production function between seed yield and seasonal ET of JG -11**



**Fig.4.12 Quadratic water production function between seed yield and seasonal ET of Annegiri**



**Fig 4.13 Linear water production function between seed yield and seasonal ET of JG-11**



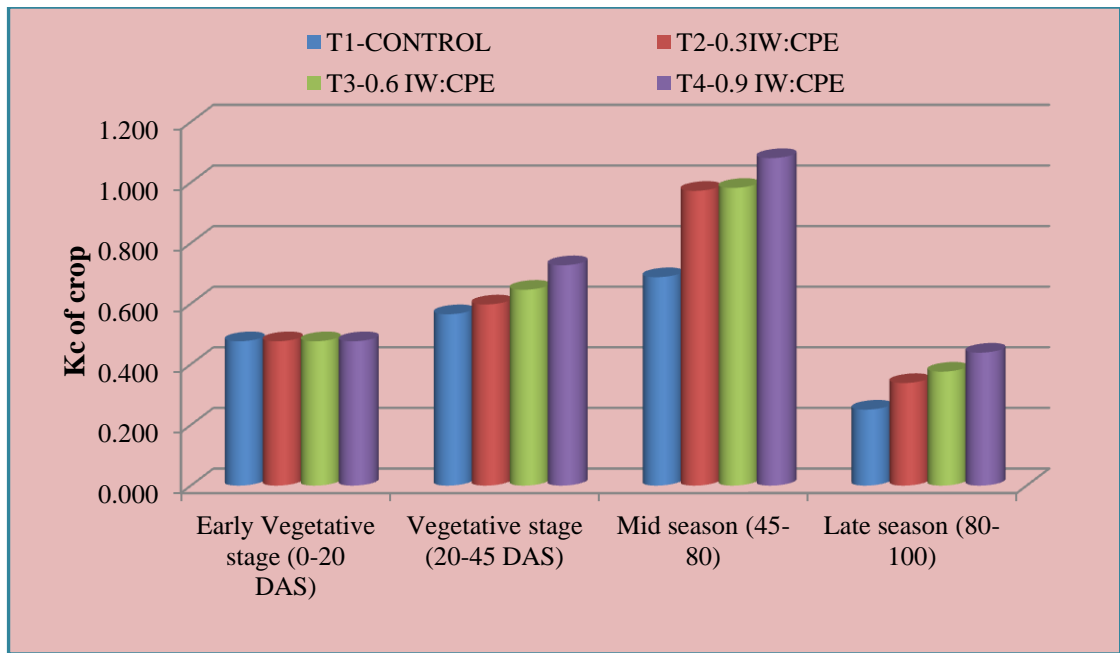
**Fig 4.14 Linear water production function between seed yield and seasonal ET of Annegiri**

**Table 4.11 Crop coefficient of chickpea (JG-11) under varied moisture regime**

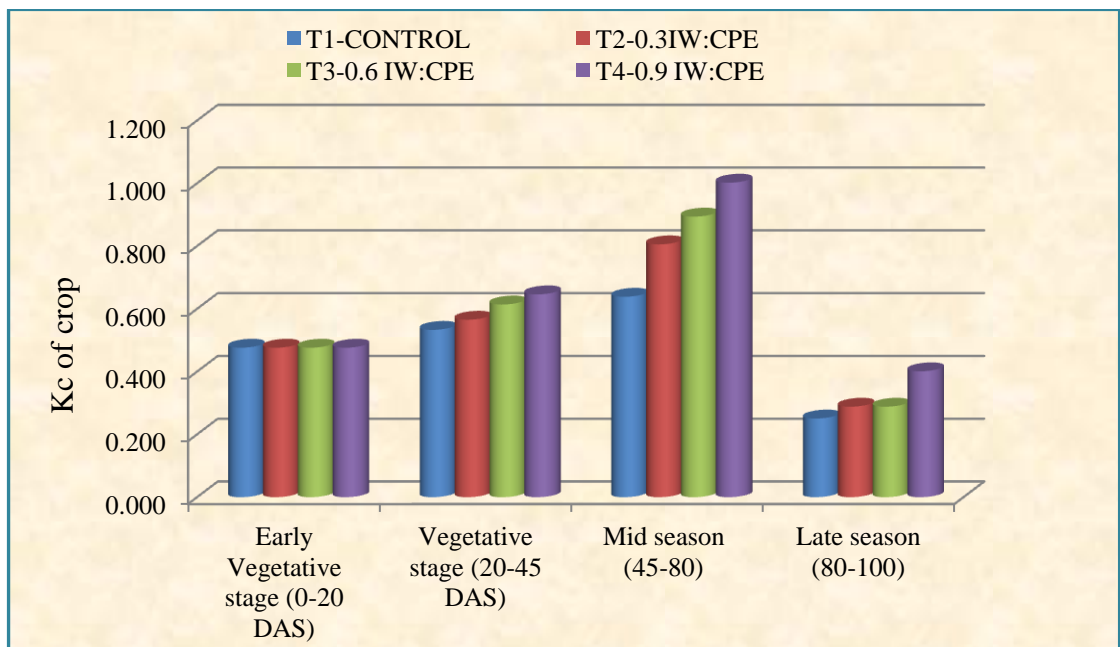
<b>MOISTURE REGIMES</b>	<b>Crop coefficient (<math>K_c</math>)</b>			
	Early Vegetative stage (0-20 DAS)	Vegetative stage (20-45DAS)	Mid season (45-80 DAS)	Late season (80-100 DAS)
T1-Control	0.47	0.56	0.68	0.25
T2-0.3IW:CPE	0.47	0.59	0.97	0.33
T3-0.6 IW:CPE	0.47	0.64	0.98	0.37
T4-0.9 IW:CPE	0.47	0.72	1.08	0.43

**Table 4.12 Crop coefficient of chickpea (Annegiri) under varied moisture regime**

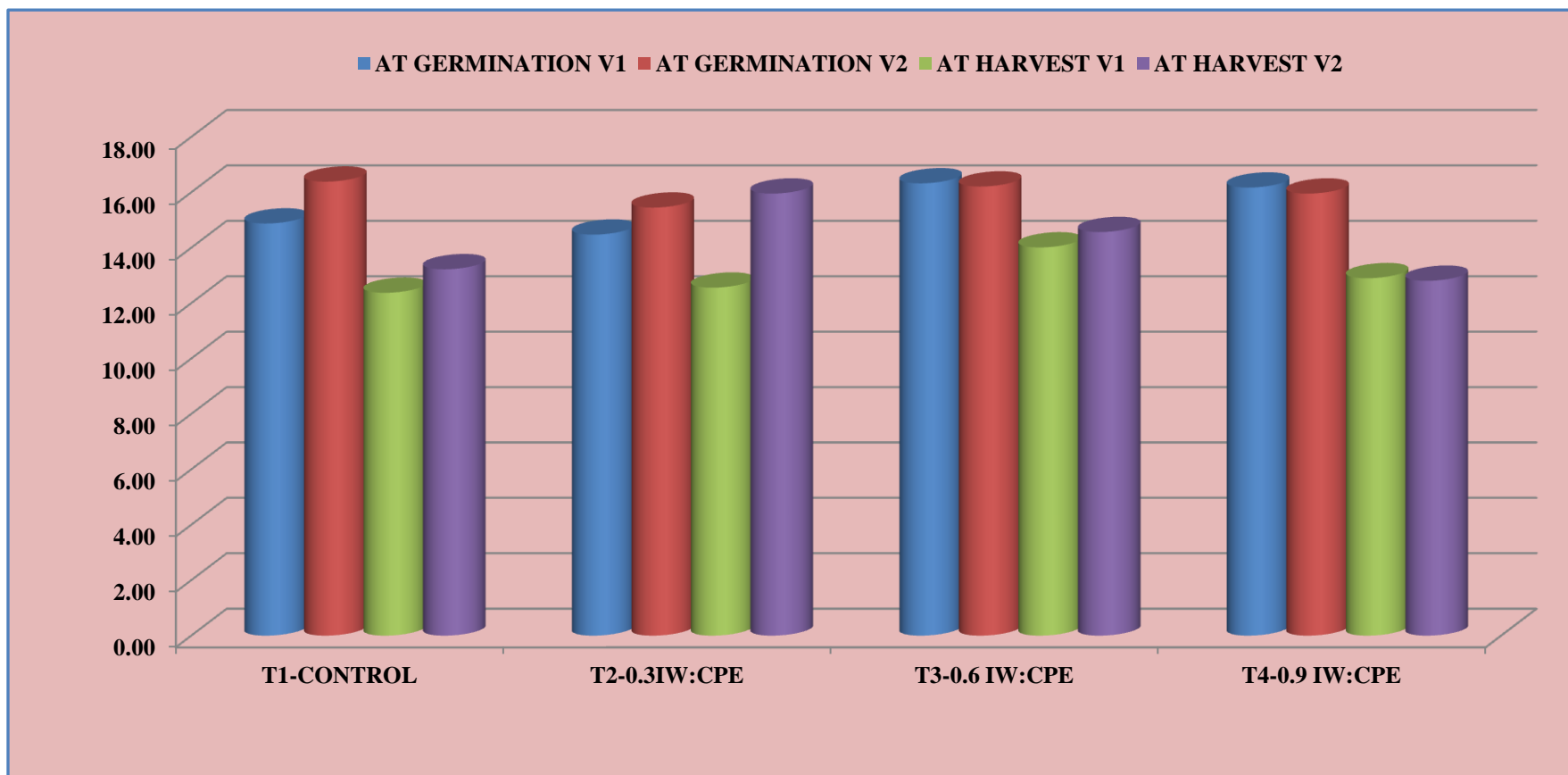
<b>MOISTURE REGIMES</b>	<b>Crop coefficient (<math>K_c</math>)</b>			
	Early Vegetative stage (0-20 DAS)	Vegetative stage (20-45 DAS)	Mid season (45-80 DAS)	Late season (80-100 DAS)
T1-Control	0.47	0.53	0.63	0.25
T2-0.3 IW:CPE	0.47	0.56	0.80	0.28
T3-0.6 IW:CPE	0.47	0.61	0.89	0.28
T4-0.9 IW:CPE	0.47	0.64	1.00	0.40



**Fig.4.15 Crop coefficients of JG-11 as influenced by varied moisture regime**

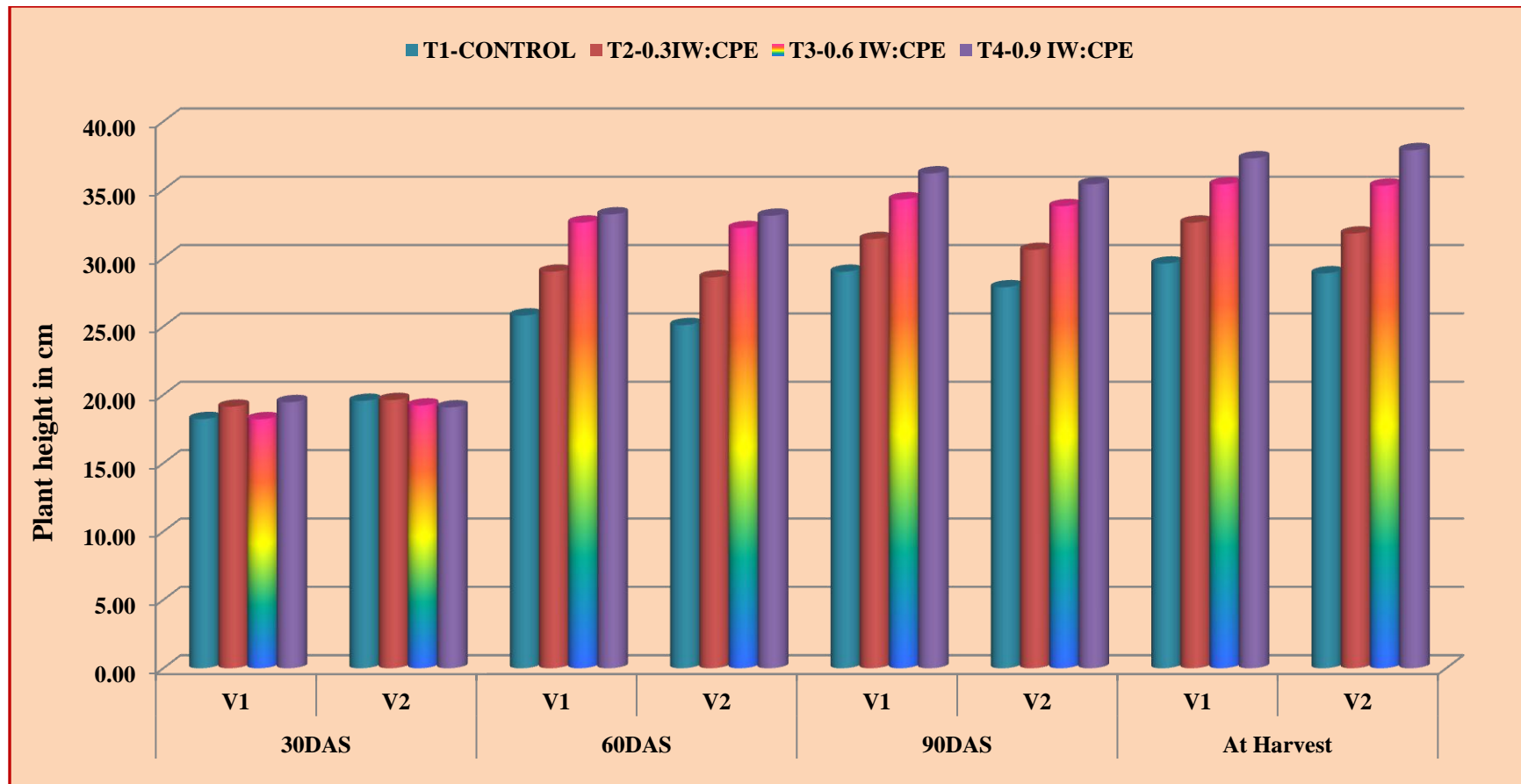


**Fig.4.16 Crop coefficients of Annegiri as influenced by varied moisture regime**



**Fig 4.1. Crop stand of chickpea varieties as influenced by varied moisture regime**

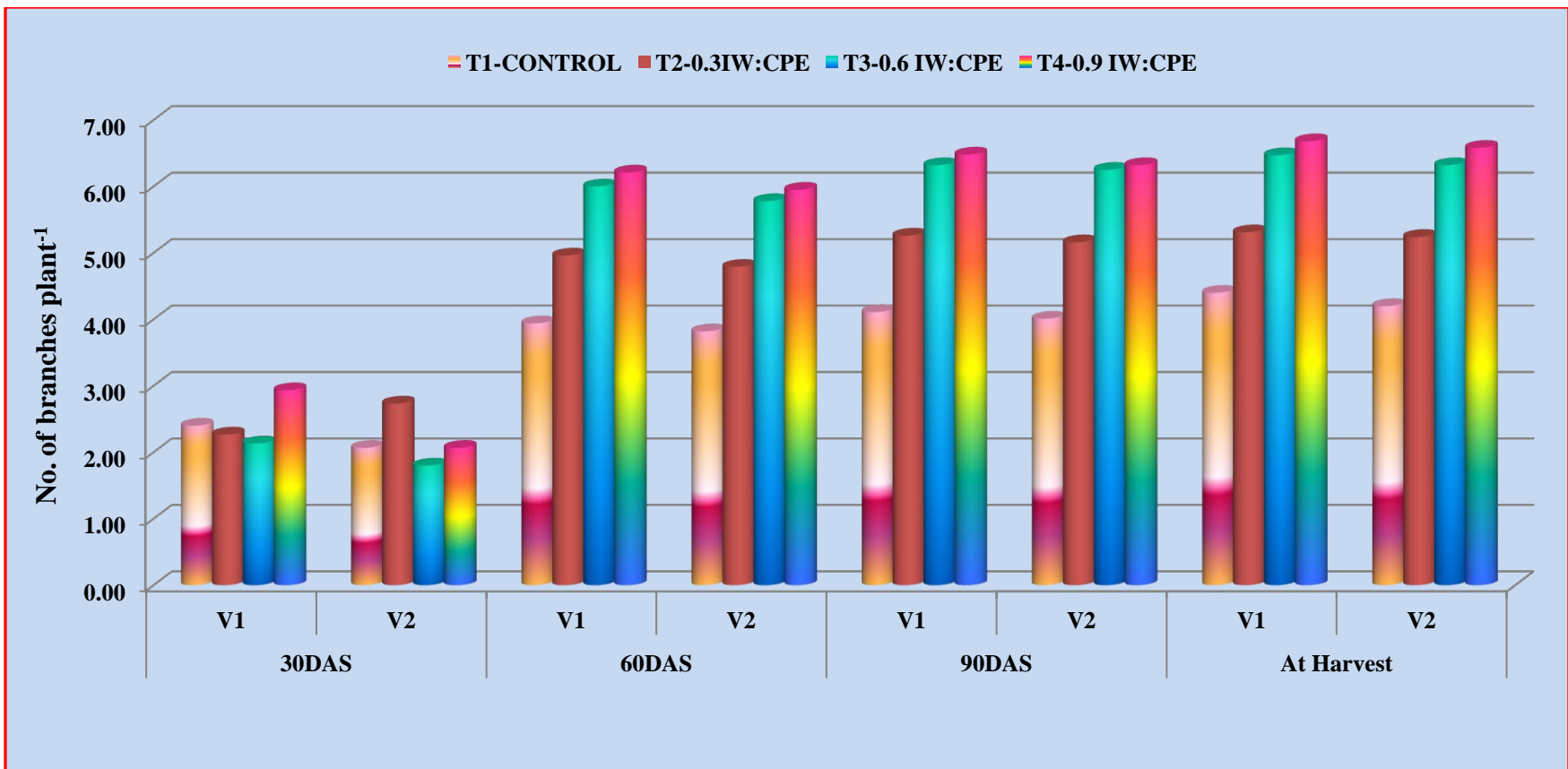
IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



**Fig 4.2. Plant height of chickpea varieties influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

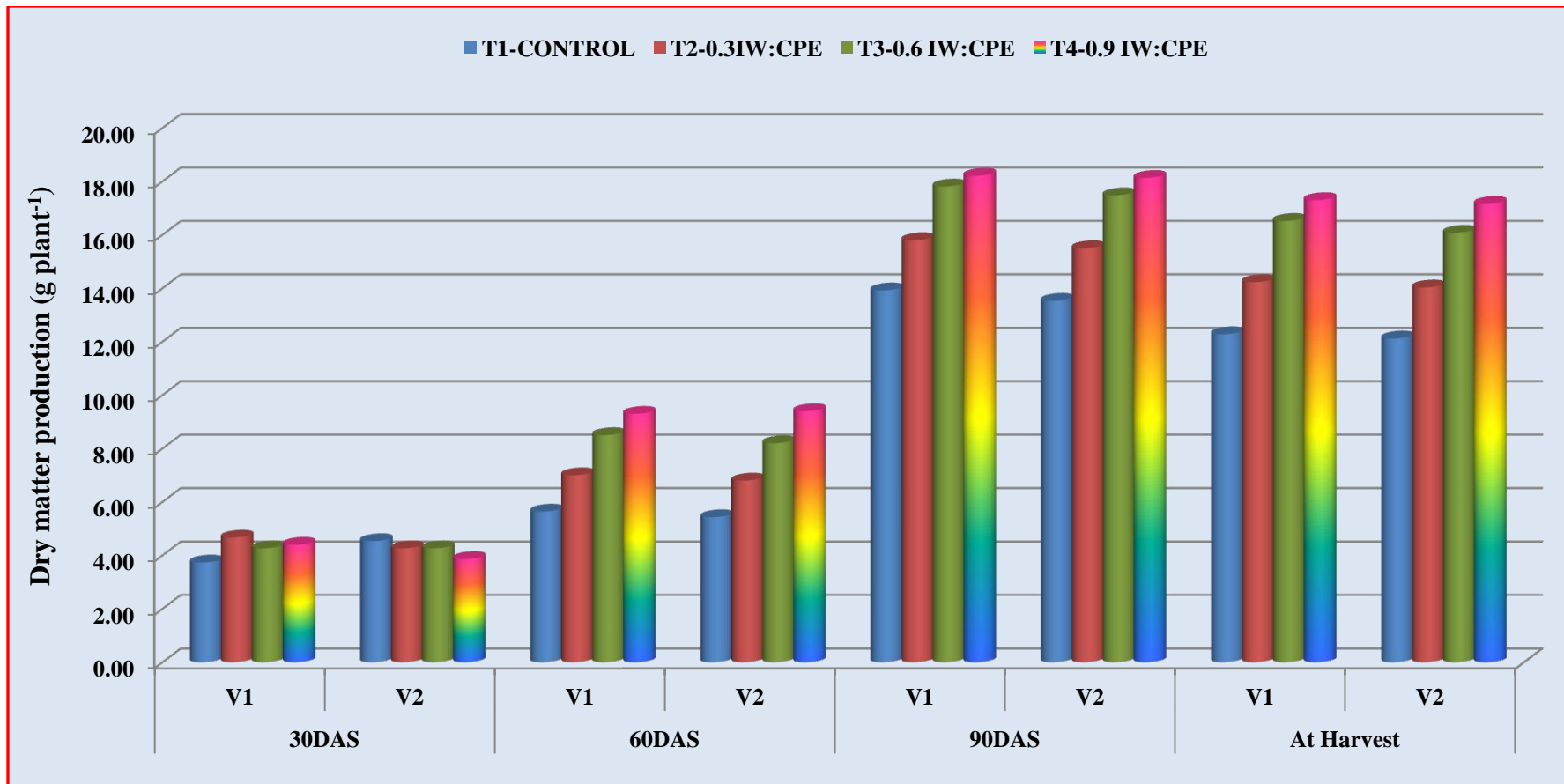
V1- JG-11, V2-Annegiri



**Fig 4.3. No. of branches of chickpea varieties influenced by varied moisture regime**

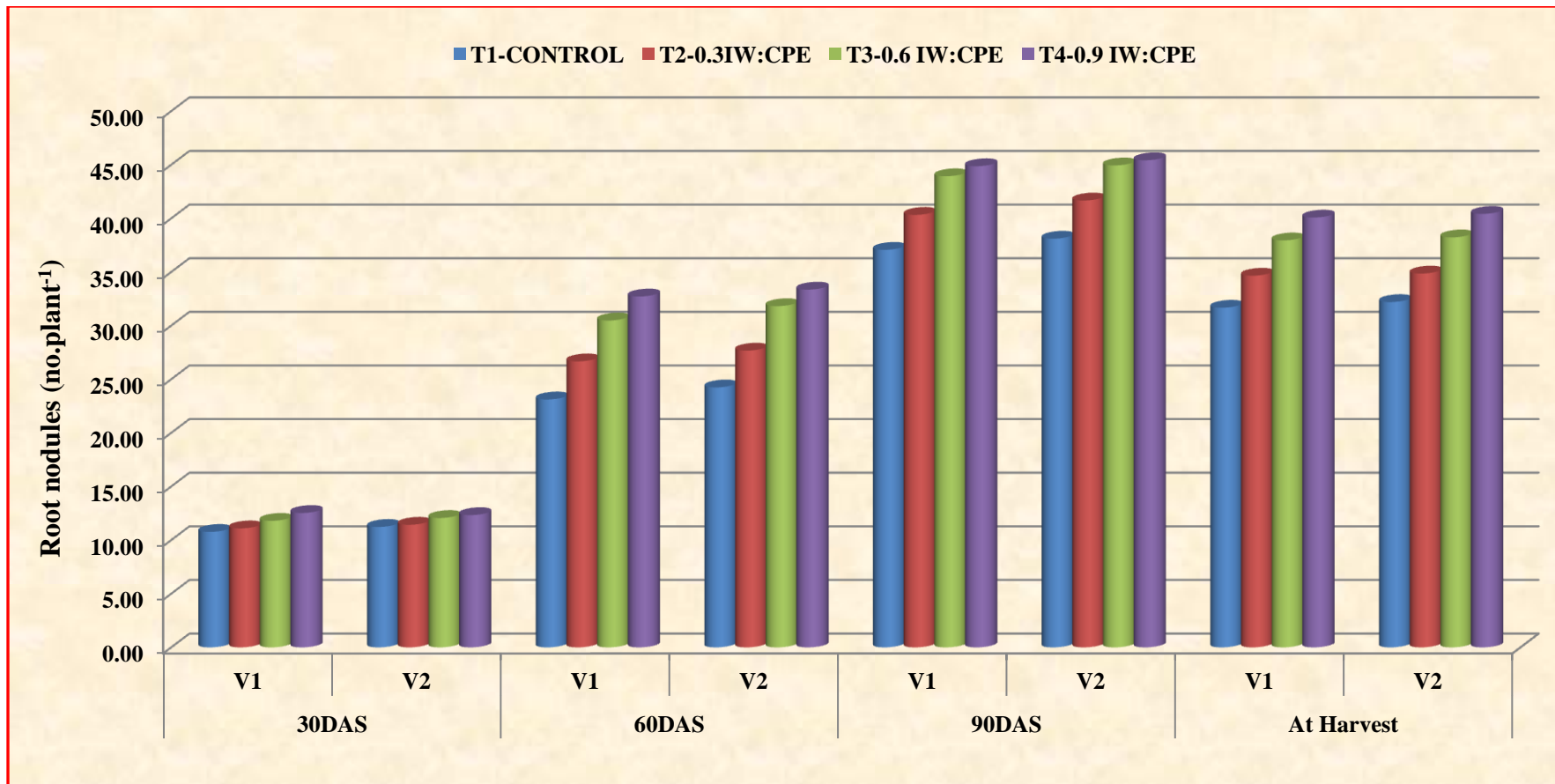
IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri



**Fig 4.4. Dry matter production of chickpea varieties influenced by varied moisture regime**

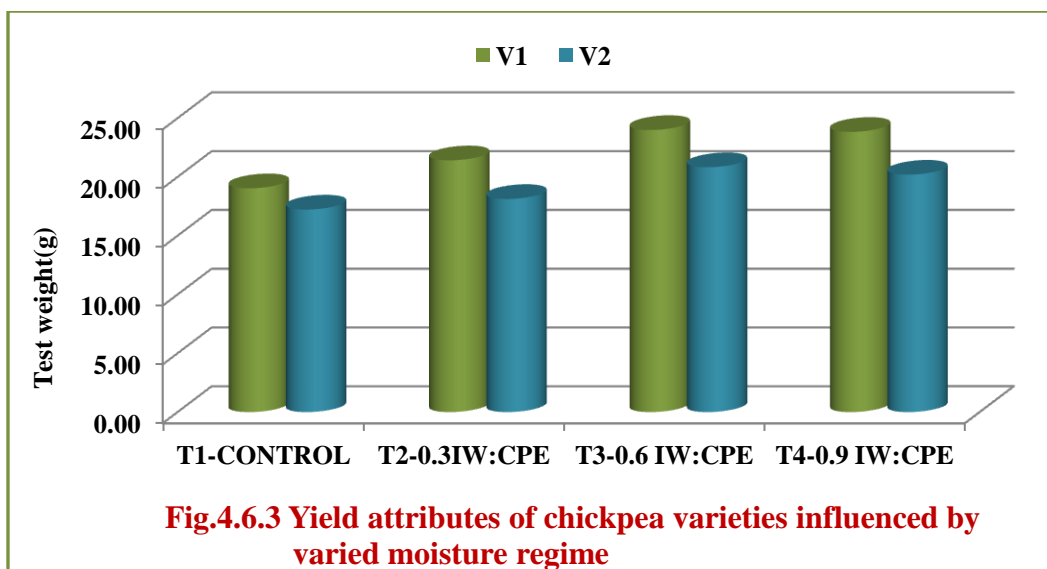
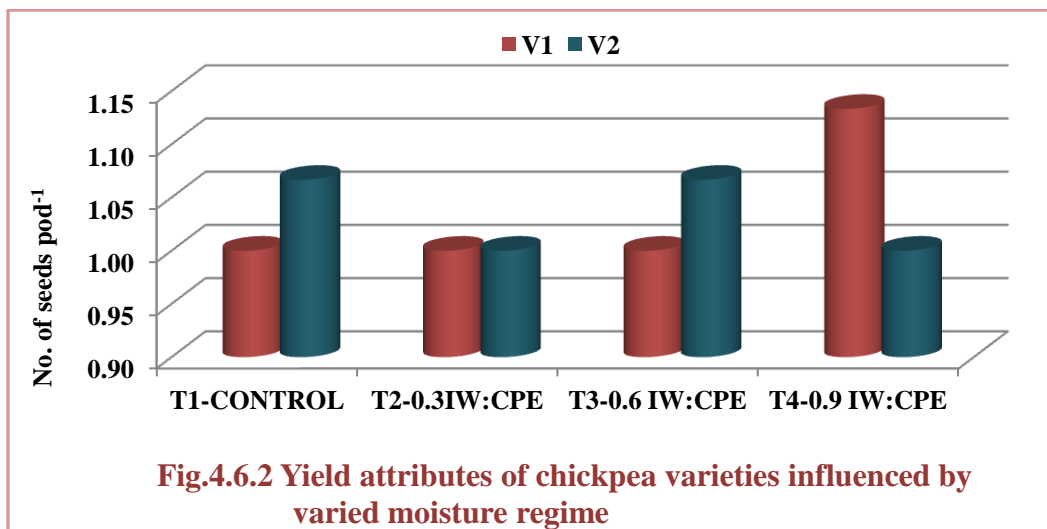
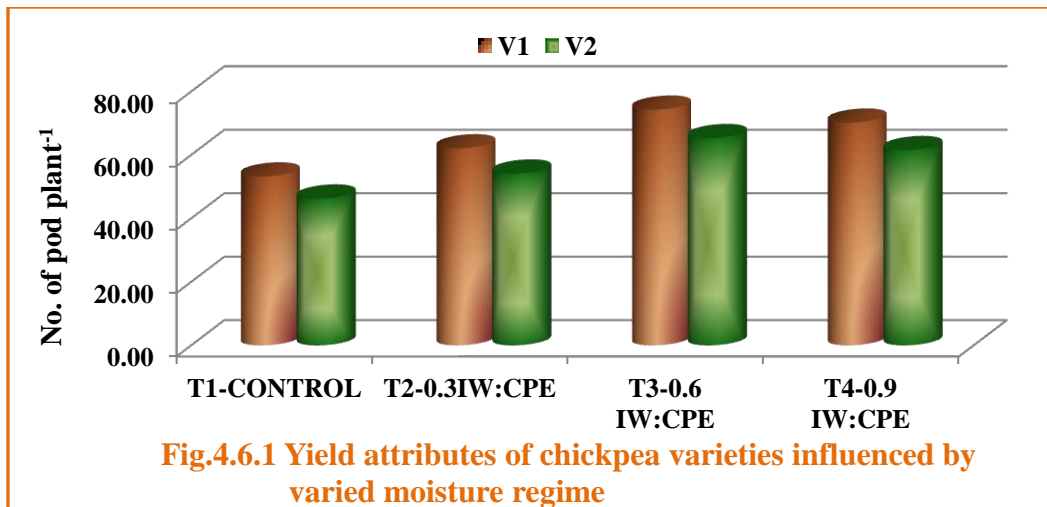
IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



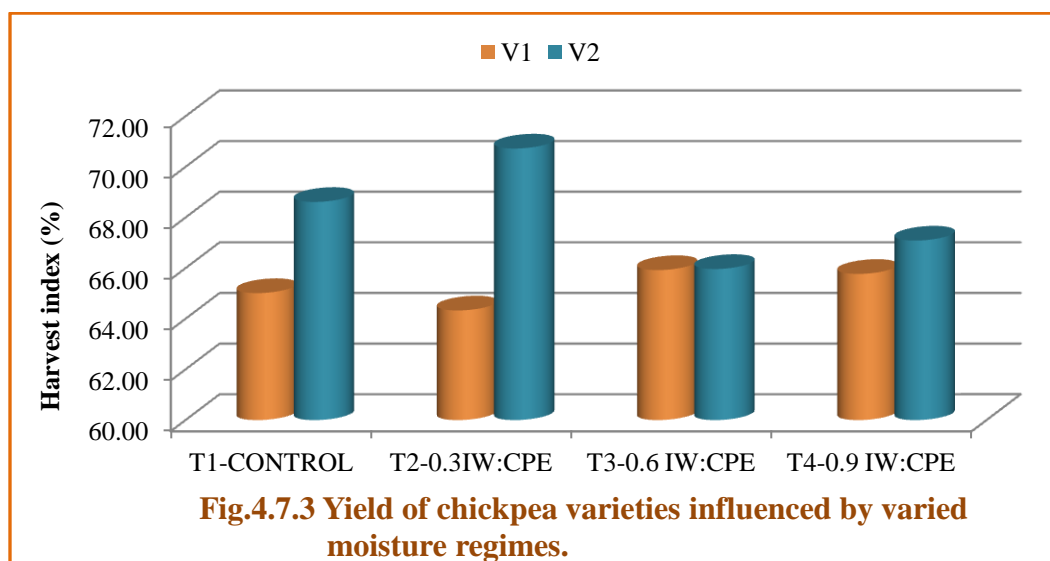
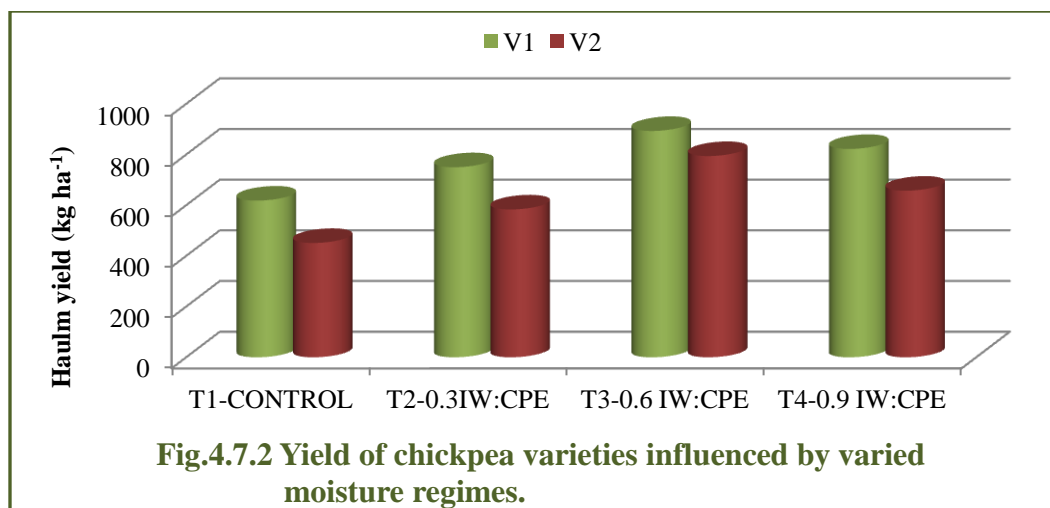
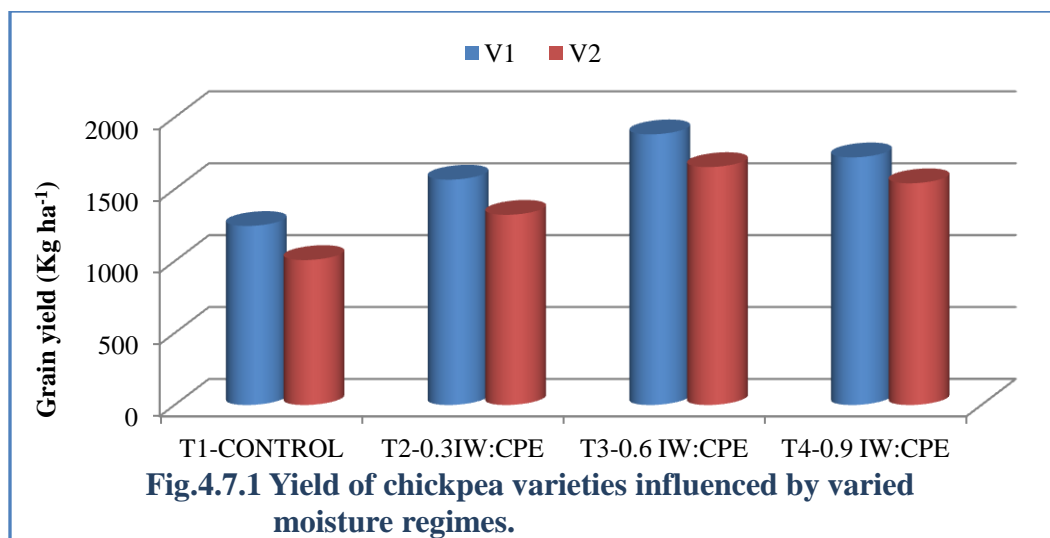
**Fig 4.5. Root nodules of chickpea varieties influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

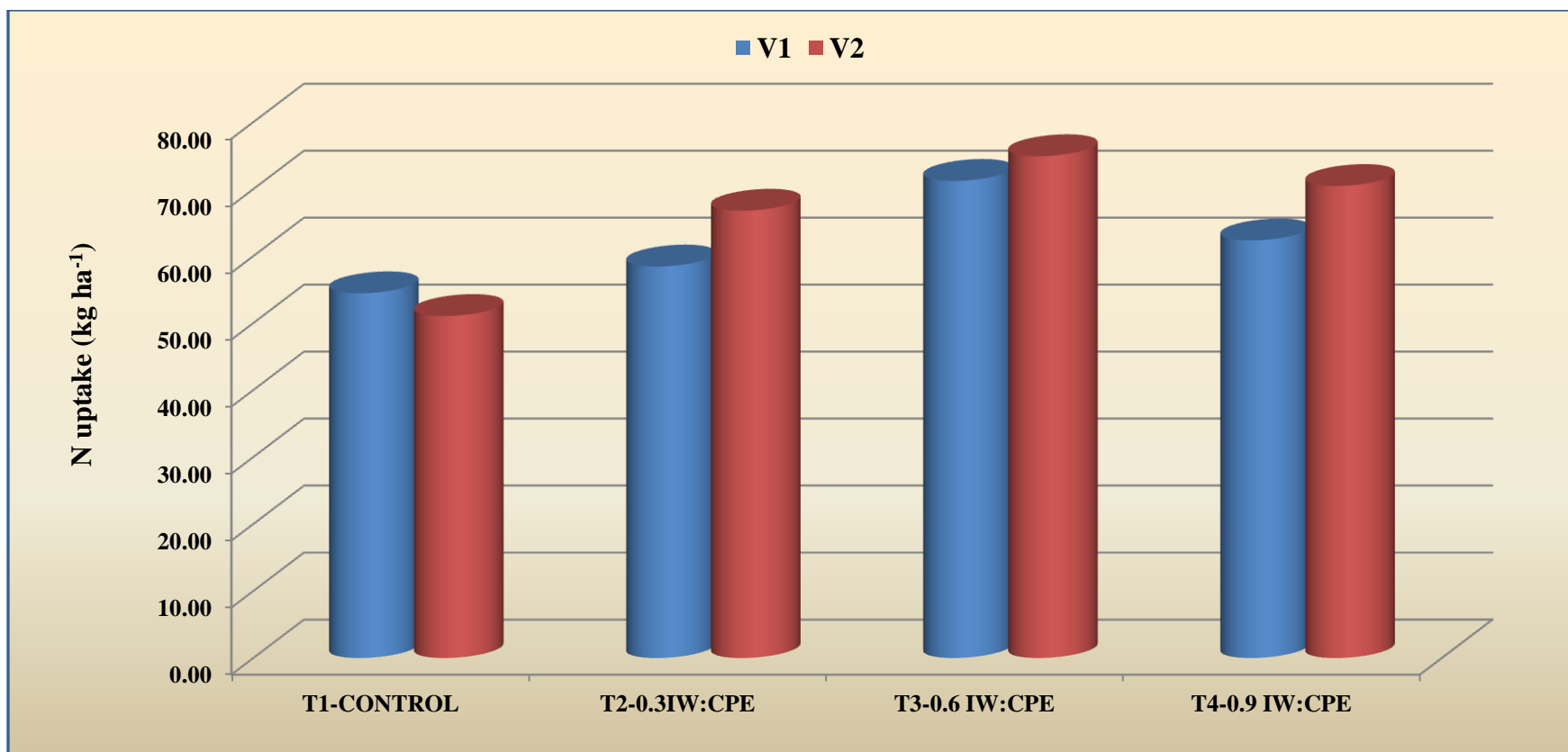
V1- JG-11, V2-Annegiri



IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



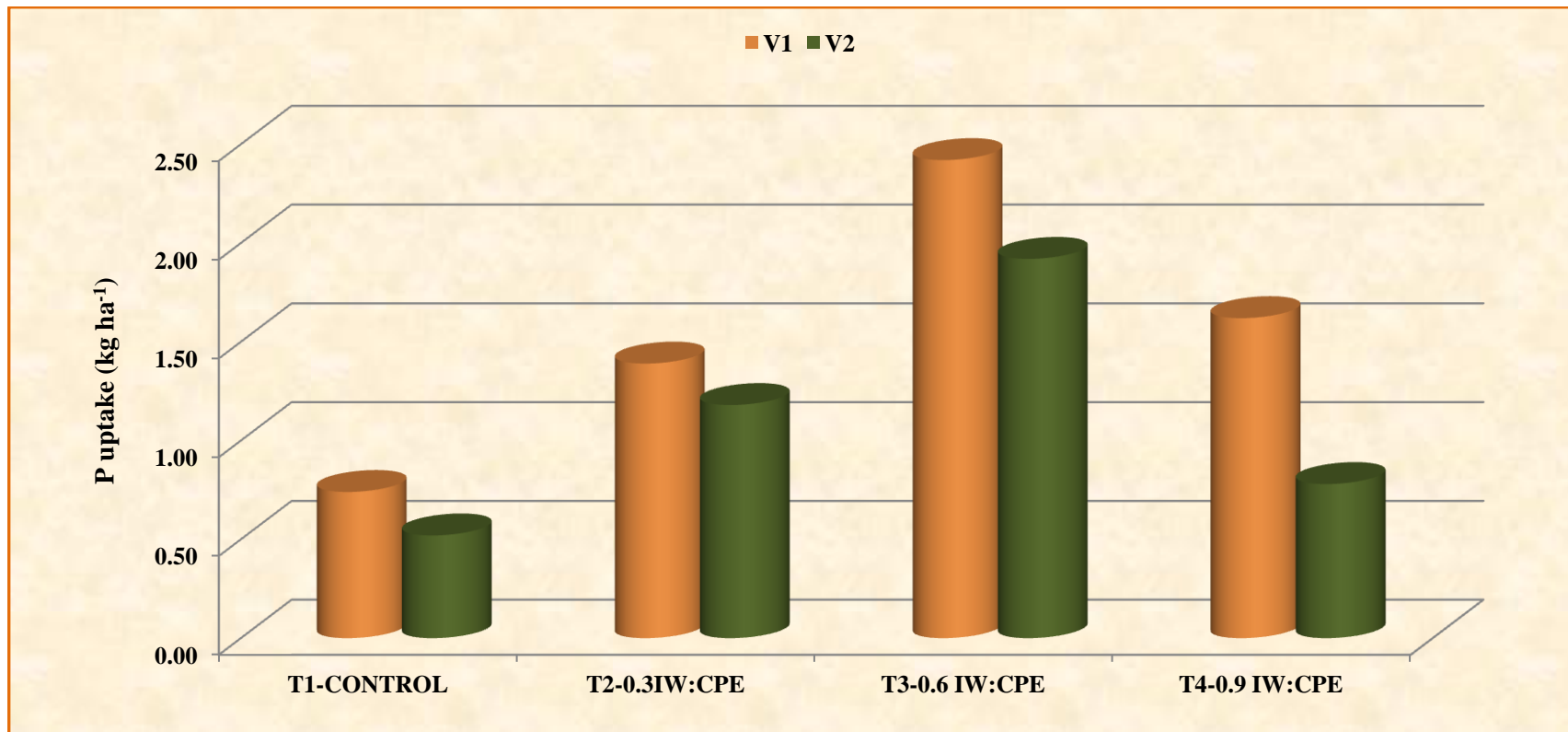
IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



**Fig.4.8.1 N Uptake of chickpea grain influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

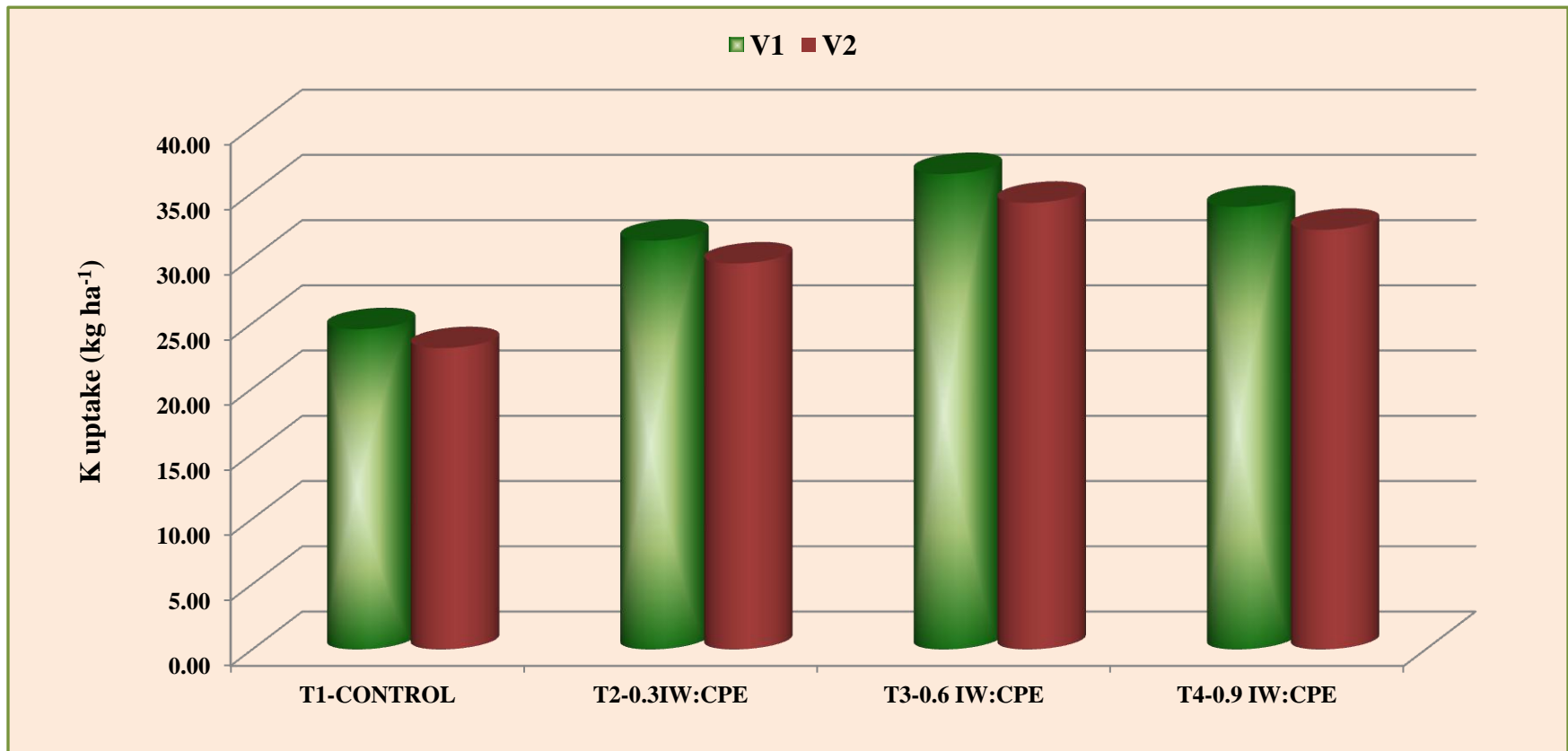
V1- JG-11, V2-Annegiri



**Fig.4.8.2 P Uptake of chickpea grain influenced by varied moisture regime**

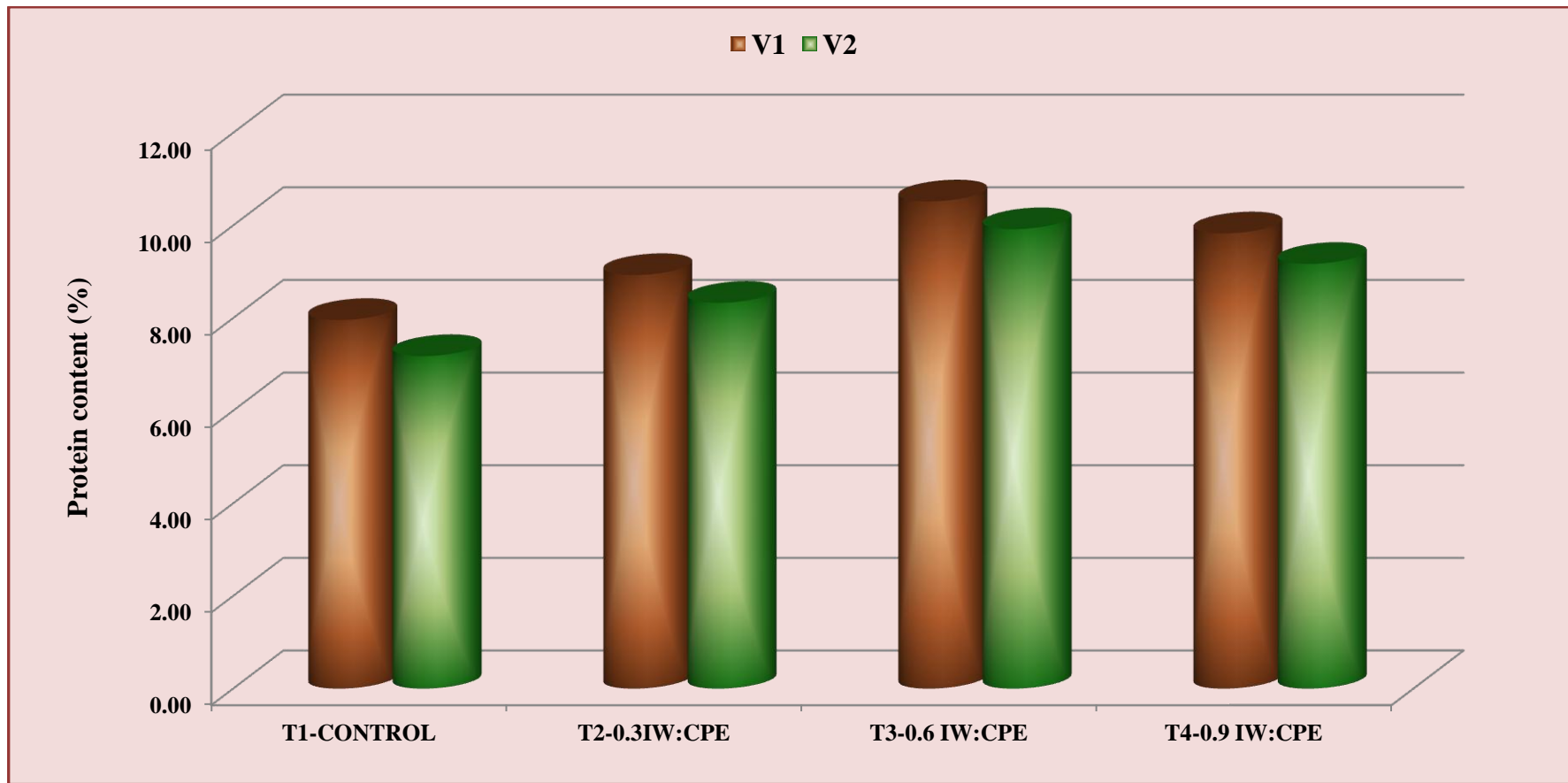
IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri



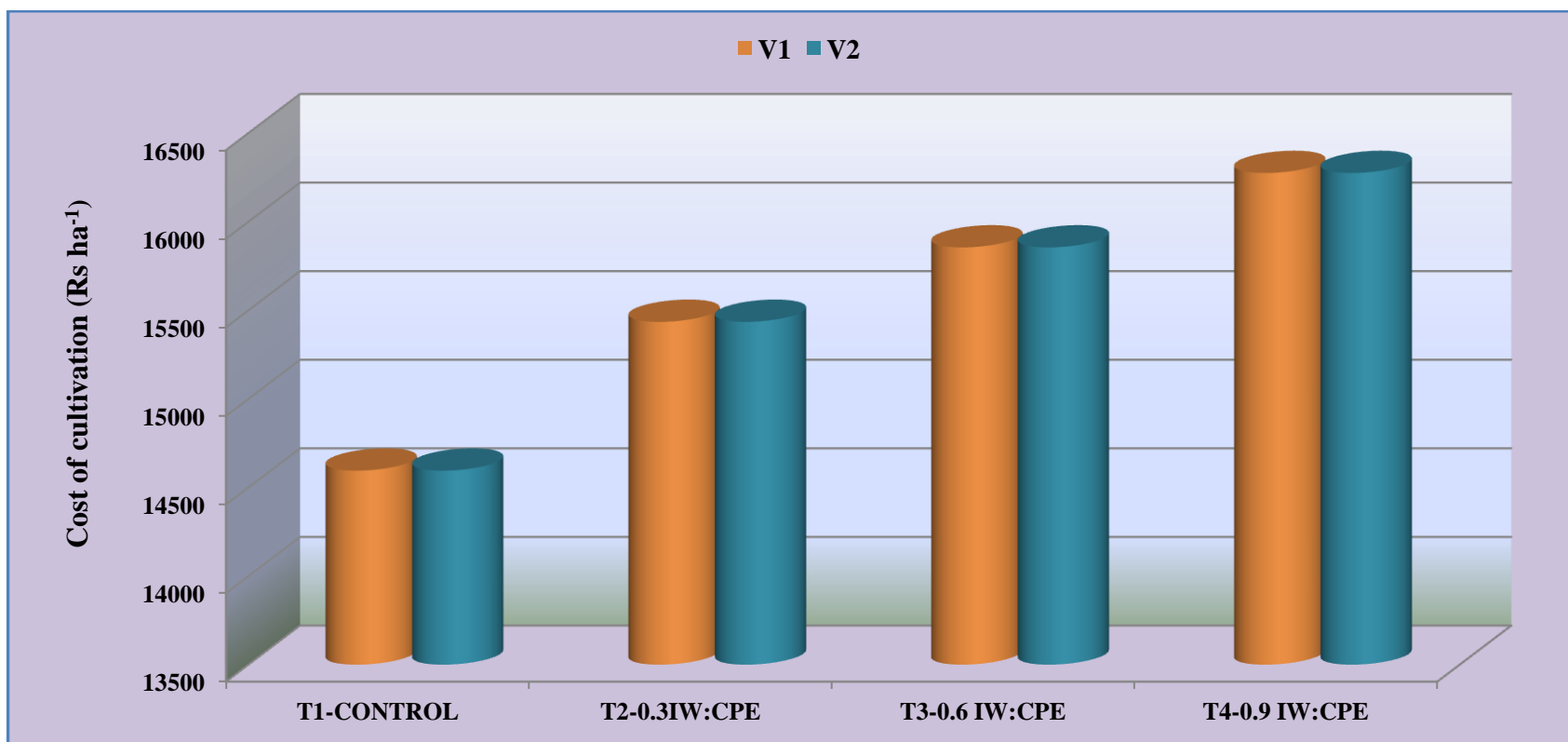
**Fig.4.8.3 K Uptake of chickpea grain influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



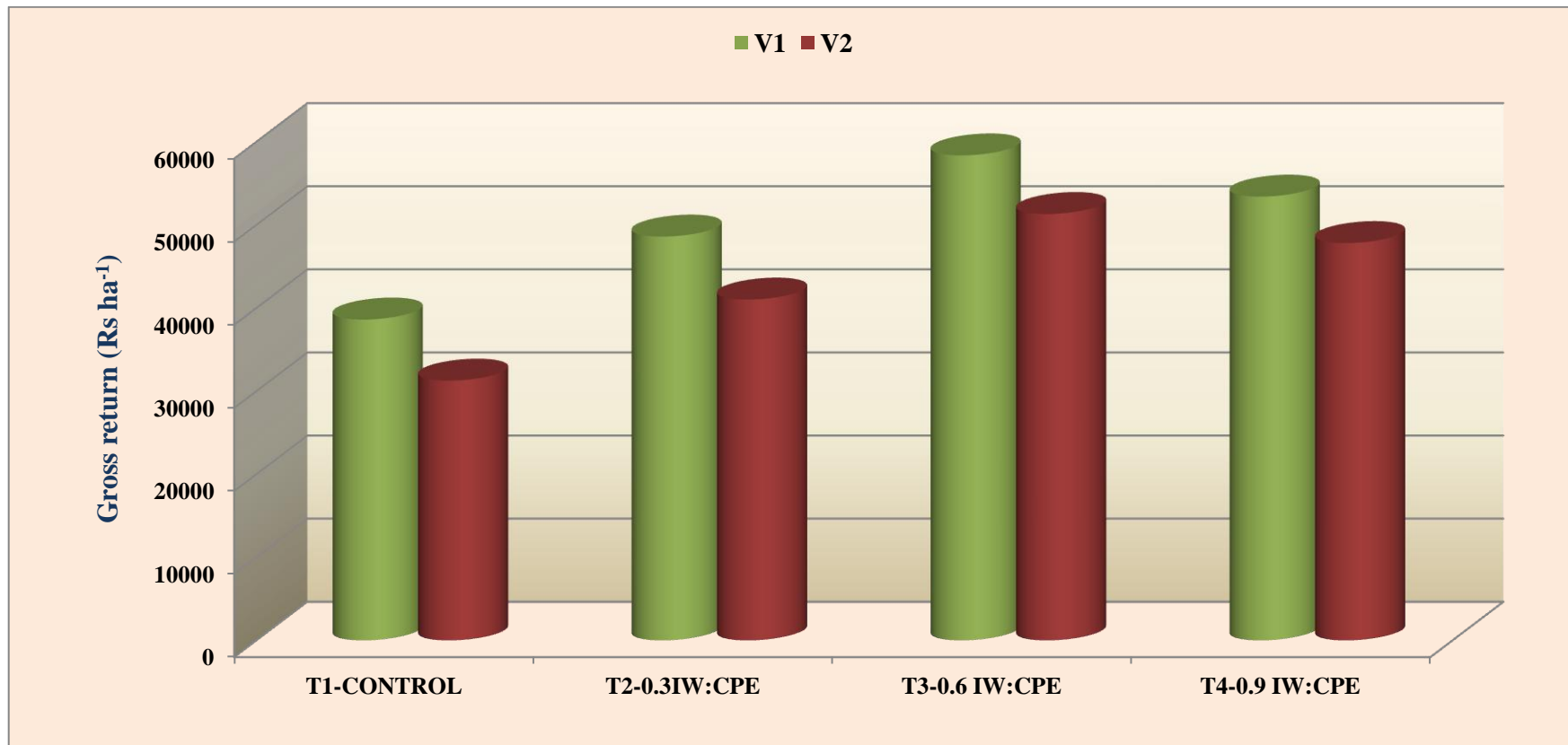
**Fig.4.8.4 Quality parameter of chickpea grain influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



**Fig.4.9.1 Cost of cultivation of chickpea varieties as influenced by varied moisture regime**

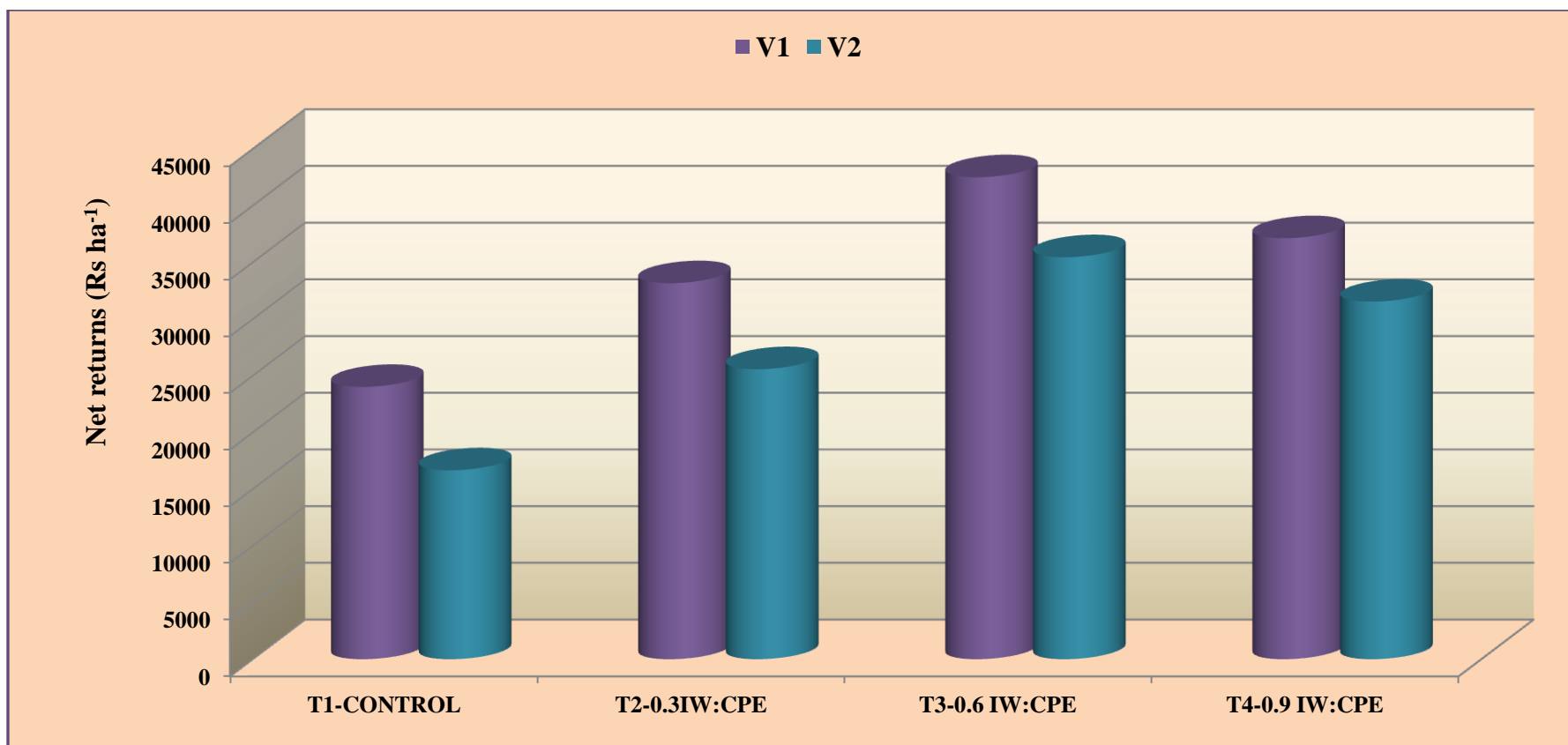
IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



**Fig.4.9.2 Gross returns of chickpea varieties as influenced by varied moisture regime**

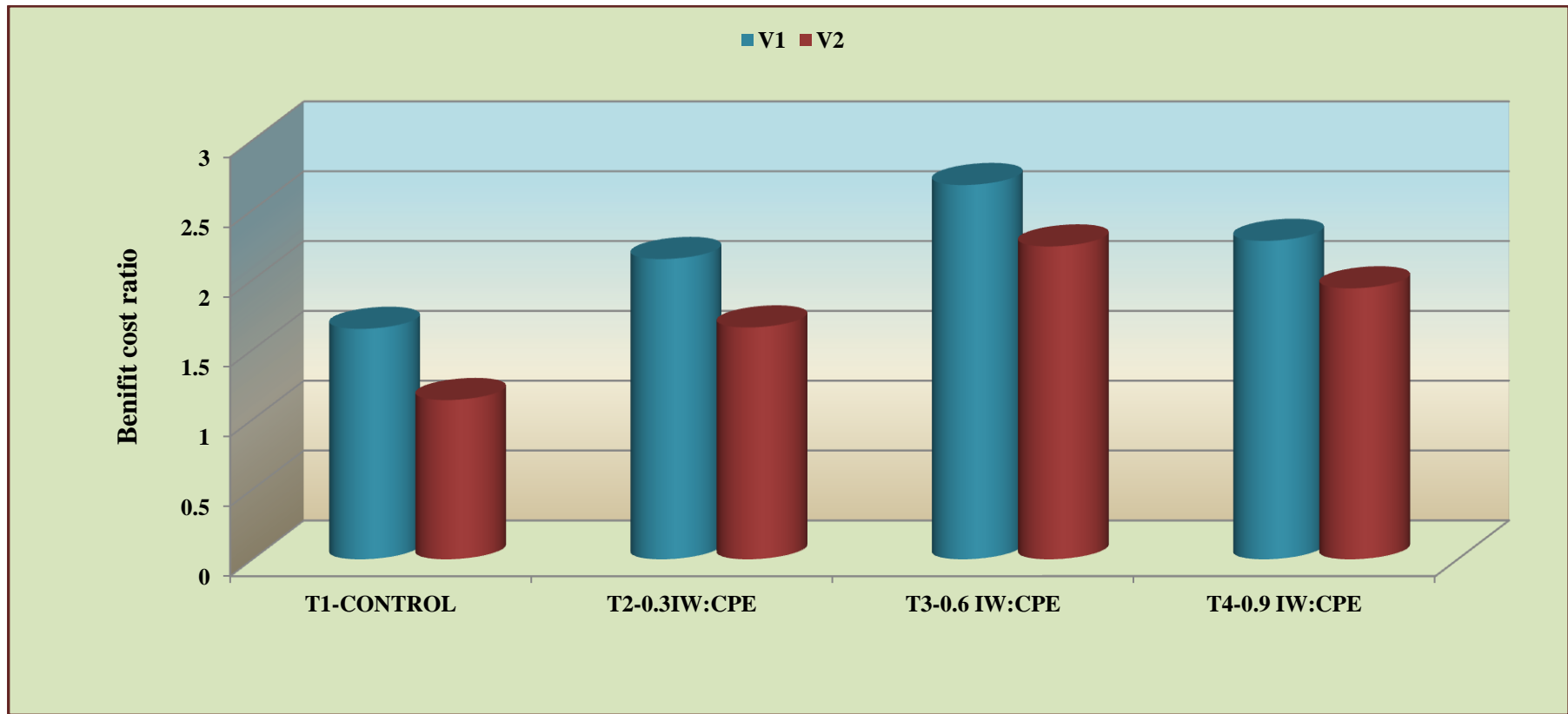
IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri



**Fig.4.9.3 Net returns of chickpea varieties as influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation, V1- JG-11, V2-Annegiri



**Fig.4.9.4 Economics of chickpea varieties as influenced by varied moisture regime**

IW:CPE- Irrigation Water:Cumulative Pan Evaporation

V1- JG-11, V2-Annegiri

## Chapter V

### SUMMARY AND CONCLUSION

The field experiment was conducted in sandy loam soils of College Farm, Acharya N.G. Ranga Agricultural University, Hyderabad during winter season of 2013-2014 in randomized block design and replicated thrice. The treatments consisted of four irrigation levels in namely, rainfed ( $I_1$ ), IW:CPE ratio of 0.3 ( $I_2$ ), IW:CPE ratio 0.6 ( $I_3$ ) and IW:CPE ratio 0.9 ( $I_4$ ) and two varieties; JG-11 and Annegiri. The results are summarized below.

- In general, moisture regimes at an IW:CPE ratio of 0.9 ( $I_4$ ) statistically performed better when the growth characters studied (plant height, no. of branches, dry matter) at different stages of observation was considered. It is statistically on par with IW:CPE ratio 0.6 ( $I_3$ ) and closely followed by IW:CPE ratio of 0.3 ( $I_2$ ). The lower value of these growth parameters were recorded under rainfed ( $I_1$ ) treatment. Genotype variation has not seen.
- The treatment  $I_3$  (IW:CPE ratio 0.6) was significantly superior to other irrigation levels in yield attributes viz., no. of pods plant<sup>-1</sup>, 100 seed weight which is on par with  $I_4$  (IW:CPE ratio 0.9). The treatment  $I_1$  (rainfed) recorded lower yield attributes. JG-11 has recorded superior yield attributes than Annegiri.
- The highest seed and haulm yield were recorded with moisture regime of IW:CPE ratio 0.6 ( $I_3$ ) which were at par with the yield obtained with IW:CPE ratio of 0.9 ( $I_4$ ). The lowest seed and haulm yields were observed in  $I_1$  (rainfed) treatment. Among varieties, JG-11 has recorded highest seed and haulm yield.
- Protein content (%) was highest in 0.9 IW:CPE ( $I_4$ ) but it was on par with 0.6 IW:CPE ( $I_3$ ). Treatment  $I_4$  is significantly superior than  $I_1$  (rainfed) and  $I_2$  (0.3 IW:CPE). The varieties have no influence on protein content.
- The total N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O uptake was lowest with  $I_1$  (rainfed) and increasing frequency of irrigation resulted in higher uptake of nutrient. The treatment 0.6 IW:CPE ( $I_3$ ) has recorded highest uptake. Genotype variation was not seen.

- Total water use as well as evapotranspiration per day and soil moisture content (%) increased with an increasing irrigation regime. I<sub>4</sub> (IW:CPE ratio-0.9) treatment recorded the premier seasonal water requirement and per day moisture consumption, whereas, I<sub>1</sub> (rainfed) treatment accounted the least. In general, total moisture use increased with an increase in regularity of irrigation scheduling. The water use efficiency decreased with an increase in irrigation regime. The highest and lowest water use efficiency were recorded under I<sub>1</sub> (rainfed) and I<sub>4</sub> (IW:CPE ratio-0.9) treatments respectively.
- Irrigation at IW:CPE ratio of 0.9 registered the maximum cost of cultivation, whereas, the rainfed treatment recorded the minimum. The net returns per hectare and B:C ratio increased with increase in the level of irrigation. The maximum net returns and B:C ratio was recorded at irrigation level IW:CPE 0.6 and it is minimum in rainfed treatment.

## **Conclusions**

Keeping in sight the results obtained under the present study and the probable reasons for their unevenness having discussed, the following conclusions were drawn:

Irrigation scheduled at an IW:CPE ratio of 0.6 as compared to other treatments gave improved performance in terms of growth parameters, which influenced the yield attributing characters, leading to a significant increase in grain yield and higher benefit cost ratio.

Chickpea responded linearly to seasonal evapotranspiration upto I<sub>3</sub> (0.6 IW:CPE ratio) and further decreased. Thus optimization of water requirement was possible.

Average crop coefficients of Chickpea were low at initial stages of growth and then gradually increased and reached the peak at flowering and grain formation stages and then decreased towards physiological maturity stage which coincides with the senescence of leaves and reduced root activity.

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## APPENDIX-A

### WEEKLY METEOROLOGICAL DATA RECORDED DURING THE CROP GROWTH PERIOD

Week	DATE	TEMPERATURE (°C)		R.H. (%)		RAIN-FALL (mm)	RAINY DAYS	SUN-SHINE (hrs.)	WIND SPEED (km/hr)	EVAPO-RATION (mm)	MEAN TEMP. (°C)
		MAX.	MIN.	I	II						
43	20-26 OCT	27.54	18.53	94.00	79.29	211.80	5.00	2.57	2.41	2.33	23.04
44	27-02 NOV	29.21	17.66	88.86	55.00	10.20	1.00	6.63	1.04	2.87	23.44
45	03-09 NOV	29.07	15.80	84.00	54.14	0.00	0.00	6.99	2.27	3.19	22.44
46	10-16 NOV	27.86	10.60	86.71	37.14	0.00	0.00	8.90	2.07	2.99	19.23
47	17-23 NOV	29.29	14.53	84.57	50.71	3.00	1.00	6.76	0.69	2.83	21.91
48	24-30 NOV	27.14	15.39	90.71	56.86	28.00	1.00	4.29	2.10	1.73	21.26
49	01-07 DEC	28.07	13.81	88.14	46.71	0.00	0.00	8.13	2.26	2.66	20.94
50	08-14 DEC	28.71	7.57	76.29	26.86	0.00	0.00	9.41	1.60	2.71	18.14
51	15-21 DEC	28.50	7.51	79.57	29.86	0.00	0.00	9.36	0.84	2.90	18.01
52	22-28 DEC	27.14	10.66	87.71	38.86	0.00	0.00	8.61	2.17	2.54	18.90
1	29-04 JAN	27.50	11.23	85.71	44.43	0.00	0.00	8.69	1.94	2.56	19.36
2	05-11 JAN	29.43	12.29	86.86	37.57	0.00	0.00	8.63	1.54	3.06	20.86
3	12-18 JAN	29.64	13.63	81.00	36.86	0.00	0.00	8.39	3.06	3.39	21.64
4	19-25 JAN	28.21	13.80	85.00	44.71	0.00	0.00	7.97	3.53	3.13	21.01
5	26-1 FEB	27.93	14.89	85.71	40.86	0.00	0.00	7.50	2.01	3.11	21.41
6	02-08 FEB	31.36	14.37	84.71	27.57	0.00	0.00	9.10	1.60	3.80	22.86
7	09-15 FEB	32.81	16.89	82.43	26.71	0.00	0.00	9.16	2.63	4.51	24.85
8	16-22 FEB	30.00	17.56	68.71	36.00	0.00	0.00	8.27	3.10	5.03	23.78
9	23-1 MAR	31.07	18.39	76.71	41.29	0.00	0.00	9.21	4.89	5.37	24.73

## **APPENDIX-B**

### **Calender of operations**

<b>DATE</b>	<b>OPERATION</b>
2-11-2013	Land preparation
3-11-2013	Sowing + Irrigation + Fertilizer application
5-11-2013	Spraying of Pendimethalin
26-11-2013	Hand weeding
09-12-2013	Irrigation (0.9 IW:CPE)
13-12-2013	Spraying of Chloripyriphos
21-12-2013	Irrigation (0.6 IW:CPE)
03-01-2014	Irrigation (0.9 IW:CPE)
24-01-2014	Irrigation (0.9 IW:CPE)
25-01-2014	Irrigation (0.3 and 0.6 IW:CPE)
11-02-2014	Irrigation (0.9 IW:CPE)
12-02-2014	Irrigation (0.6 IW:CPE)
13-02-2014	Harvesting
16-02-2014	Threshing and Winnowing
20-02-2014	Packing and Marketing

## APPENDIX-C

### Cost of cultivation of *rabi* chickpea (2013-14)

<b>I. Input Cost</b>	<b>Unit cost(Rs)</b>	<b>Quantity</b>	<b>Total cost (Rs)</b>
a) Seeds (kg ha <sup>-1</sup> )	35	87.5	2625
b) Fertilizers			
Urea	295	1 bag	295
SSP	410	6 bag	2460
MOP	880	1 bag	880
c) Weedicides Chemical	450	1 lit	450
d) Pesticides	275	4 lit	1100
<b>II. Labour Cost</b>			
a) Land preparation (Bullock pair + man days)			1010
b) Sowing (7 man days)			1470
e) Irrigation ( 15 man days)			3150
c) Fertilizer application (6 man days)			1260
d) Pesticides application (3 man days)			630
e) Harvesting (8 man days)			1680
f) Packing & Marketing (2 man days)			420

#### Unit cost of input

**Urea : Rs. 295/50kg**

**Pendimethalin : Rs.450/lit**

**Labour : 210/day**

**SSP : Rs. 410/50kg**

**Chloripyriphos : Rs. 275/lit**

**MOP : Rs. 880/50 kg**

**Chickpea seed : Rs.35/kg**

## APPENDIX-D

### Cost of cultivation of chickpea (₹ ha<sup>-1</sup>) as per Treatment

TREATMENTS	₹ ha <sup>-1</sup>
I <sub>1</sub> (RAINFED)	17,325
I <sub>2</sub> (0.3 IW:CPE)	18,165
I <sub>3</sub> (0.6 IW:CPE)	18,585
I <sub>4</sub> (0.9 IW:CPE)	19,005

## APPENDIX-E

### Daily Pan Evaporation Studies

Date	DAS	ET (mm)	IW:CPE 0.3	IW:CPE 0.6	IW:CPE 0.9	Control
03.11.2013	1	3.5				
04.11.2013	2	3.5				
05.11.2013	3	3.8				
06.11.2013	4	3.6				
07.11.2013	5	3.0				
08.11.2013	6	2.5				
09.11.2013	7	2.4				
10.11.2013	8	3.0				
11.11.2013	9	2.9				
12.11.2013	10	3.0				
13.11.2013	11	3.0				
14.11.2013	12	3.0				
15.11.2013	13	3.0				
16.11.2013	14	3.0				
17.11.2013	15	2.8				
18.11.2013	16	2.5				
19.11.2013	17	3.0				
20.11.2013	18	2.9				
21.11.2013	19	3.1				
22.11.2013	20	3.2				
23.11.2013	21	2.3				
24.11.2013	22	1.3				
25.11.2013	23	1.7				
26.11.2013	24	2.0				
27.11.2013	25	2.0				
28.11.2013	26	2.1				
29.11.2013	27	1.6				
30.11.2013	28	1.4				
01.12.2013	29	2.0				
02.12.2013	30	2.5				
03.12.2013	31	3.0				
04.12.2013	32	2.8				
05.12.2013	33	2.8				
06.12.2013	34	2.8				
07.12.2013	35	2.7				
08.12.2013	36	2.8				
<b><u>09.12.2013</u></b>	<b><u>37</u></b>	<b><u>2.8</u></b>			<b><u>1</u></b>	

10.12.2013	38	2.5				
11.12.2013	39	2.5				
12.12.2013	40	2.6				
13.12.2013	41	2.8				
14.12.2013	42	3.0				
15.12.2013	43	3.0				
16.12.2013	44	3.0				
17.12.2013	45	3.1				
18.12.2013	46	3.1				
19.12.2013	47	3.0				
20.12.2013	48	2.3				
<b><u>21.12.2013</u></b>	<b><u>49</u></b>	<b><u>2.8</u></b>		<b><u>1</u></b>		
22.12.2013	50	3.0				
23.12.2013	51	2.8				
24.12.2013	52	1.8				
25.12.2013	53	2.0				
26.12.2013	54	2.8				
27.12.2013	55	2.7				
28.12.2013	56	2.7				
29.12.2013	57	2.8				
30.12.2013	58	2.7				
31.12.2013	59	2.5				
01.01.2014	60	2.5				
02.01.2014	61	2.4				
<b><u>03.01.2014</u></b>	<b><u>62</u></b>	<b><u>2.5</u></b>			<b><u>2</u></b>	
04.01.2014	63	2.5				
05.01.2014	64	3				
06.01.2014	65	3				
07.01.2014	66	3				
08.01.2014	67	3				
09.01.2014	68	3				
10.01.2014	69	3.2				
11.01.2014	70	3.2				
12.01.2014	71	3.3				
13.01.2014	72	3.4				
14.01.2014	73	3.4				
15.01.2014	74	3.3				
16.01.2014	75	3.5				
17.01.2014	76	3.4				
18.01.2014	77	3.4				
19.01.2014	78	3.3				
20.01.2014	79	3.4				
21.01.2014	80	3.1				
22.01.2014	81	3.1				

23.01.2014	82	3				
<b><u>24.01.2014</u></b>	<b><u>83</u></b>	<b><u>3</u></b>			<b><u>3</u></b>	
<b><u>25.01.2014</u></b>	<b><u>84</u></b>	<b><u>3</u></b>	<b><u>1</u></b>	<b><u>2</u></b>		
26.01.2014	85	3				
27.01.2014	86	3.1				
28.01.2014	87	3				
29.01.2014	88	3.1				
30.01.2014	89	3				
31.01.2014	90	3.1				
01.02.2014	91	3.5				
02.02.2014	92	3.4				
03.02.2014	93	3.6				
04.02.2014	94	3.8				
05.02.2014	95	3.8				
06.02.2014	96	3.9				
07.02.2014	97	3.9				
08.02.2014	98	4.2				
09.02.2014	99	4.3				
10.02.2014	100	4.3				
11.02.2014	101	4.5				
<b><u>12.02.2014</u></b>	<b><u>102</u></b>	<b><u>4.6</u></b>		<b><u>3</u></b>	<b><u>4</u></b>	
13.02.2014	103	4.7				



**Plate 1. An over view of chickpea crop at 30 DAS**



**Plate 2. An over view of chickpea crop at 75 DAS**



**Plate 3. An over view of chickpea crop at harvest**



**Plate 4. Harvesting of chickpea crop**