

“INFLUENCE OF IRRIGATION SCHEDULES BASED ON CRITICAL GROWTH STAGES AND GROWTH REGULATORS ON GROWTH, YIELD ATTRIBUTES AND SEED YIELD OF CHICKPEA (*Cicer arietinum* L.) UNDER MIDDLE GUJARAT CONDITIONS.”

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ABSTRACT

A field experiment was conducted during *rabi* season of the year 2009-2010 at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat to study the “Influence of irrigation schedules based on critical growth stages and growth regulators on growth, yield attributes and seed yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions.” The soil of the experimental plot was loamy sand in texture having good drainage, low in available nitrogen, medium in available phosphorus and high in available potash with 7.7 soil pH. Sixteen treatment combinations, consisting of four levels of irrigation schedules based on critical growth stage viz., I₁ – irrigation at branching, I₂ – irrigation at branching and at flowering, I₃ – irrigation at branching, at flowering and at pod formation, I₄ – 0.6 IW: CPE ratio as relegated into main plot treatments and four growth regulators viz., GR₀ – Control- water spray, GR₁ – NAA @ 25 ppm at 40 DAS, GR₂ – IBA @ 25 ppm at 40 DAS, and GR₃ – Ascorbic Acid @ 20 ppm at 40

DAS were relegated in sub plot treatments tested under split plot design with four replications.

The results indicated that the seed yield and dry gotar yield as well as most of the growth and yield attributes of chickpea were significantly influenced due to different irrigation schedules. The results revealed that treatment I_3 irrigation at branching, at flowering and at pod formation recorded the higher plant height at 60 DAS and significantly highest at harvest also. The no. of days to maturity, average no. of branches per plant (103.75 and 7.68, respectively) found significantly higher under treatment I_3 irrigation at branching, at flowering and at pod formation, Treatment I_3 recorded significantly the highest average no. pods per plant (89.75), secured the significantly higher seed yield and dry gotar yield (2570 and 4633 Kg/ha, respectively) of chickpea, Test weight (19.94g). Significantly the highest protein content (21.84%) was also observed under treatment I_3 . The consumptive use of water was increased with increase in number of irrigation in the treatment I_3 (199.68 mm), where, as water use efficiency was higher with lower irrigation. The highest gross (Rs.79417 ha⁻¹) and net realization (Rs.69837 ha⁻¹) was secured under treatment I_3 .

Among the various growth regulators, application of NAA @ 25 ppm at 40 DAS (GR_1) resulted in the maximum growth and yield attributes and, which ultimately resulted in to higher seed yield of chickpea. Application of NAA @ 25 ppm at 40 DAS secured significantly higher seed yield 2404 Kg ha⁻¹ with increase at the extent of 8.6 % over control i.e. GR_0 (Water spray). Apart from this, application of NAA @ 25 ppm at 40 DAS (GR_1) also obtained the highest consumptive use of water and maximum water use efficiency. The

higher value of gross (Rs, 74062 ha⁻¹) and highest net realization (Rs, 66128 ha⁻¹) was observed under treatment GR₁ (NAA @ 25ppm at 40 DAS).

During the course of investigation, interaction effect of irrigation schedules and plant growth regulators revealed that the treatment combination I₃GR₁ (I₃ irrigation at branching, at flowering and at pod formation along with GR₁ application of NAA @ 25 ppm at 40 DAS) recorded significantly the highest plant height at 60 DAS and at harvest (66.30 cm and 72.0 cm), respectively and average no. of branches per plant (8.20) minimum no. of days to 50% flowering (47.5). It was also recorded significantly the highest average no. of pods per plant (107.0) ultimately secured higher seed yield and harvest index (2847 Kg ha⁻¹ and 42.1%), respectively.

For securing higher seed yield, gross and net realization from Chickpea crop cv. “GG-1” raised on loamy sand soils of middle Gujarat conditions, it is advisable to apply four irrigations, including common irrigation applied after sowing for uniform plant stand and the rest of irrigations, given each of 50 mm depth to be scheduled either based on three critical growth stage, first irrigation at branching stage at 34 DAS, second at flowering at 46 DAS and third at pod formation 62 DAS with an application of growth regulator NAA @ 25 ppm at 40 DAS or irrigation each of 50 mm soil depth to be scheduled at IW:CPE ratio of 0.6 (3 irrigations) at an interval of 23 to 26 days with an application of growth regulator either Ascorbic acid @ 20 ppm at 40 DAS or NAA @25 ppm at 40 DAS.

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CERTIFICATE

This is certify that the thesis entitled **“INFLUENCE OF IRRIGATION SCHEDULES BASED ON CRITICAL GROWTH STAGES AND GROWTH REGULATORS ON GROWTH, YIELD ATTRIBUTES AND SEED YIELD OF CHICKPEA (*Cicer arietinum* L.) UNDER MIDDLE GUJARAT CONDITIONS.”** submitted by **SABNIS NIKHIL UTTAMRA Reg. No. 04-1051-2009** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY** of the Anand Agricultural University is a record of bonafide research work carried out by him under my personal guidance and supervision. The thesis has not previously formed the basis for award of any degree, diploma or other similar title.

Place : Anand

(J.J. PATEL)

Date : / /2011

Major Guide

DECLARATION

This is to declare that the whole of research work reported herein the thesis for partial fulfillment of the requirement for the degree of **Master of Science (Agri.) in Agronomy** by the undersigned is a result of investigation done by me under direct guidance and supervision of Dr. J. J. Patel, Professor of Agronomy, Dept. of Agronomy, B. A. College of Agriculture, A.A.U., Anand - 388110 and no part of work has been submitted for any other degree so far.

Place: **Anand**
Date: / /2011

(Sabnis N. U.)

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Place : Anand

Date : / /2011

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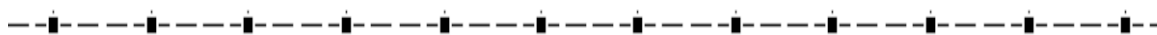


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LIST OF ABBREVIATION



AND SYMBOLS



AA	Ascorbic acid
AAU	Anand Agricultural University, Anand ,Gujarat
AAU	Assam Agricultural University, Jorhat, Assam
A. P.	Andhra Pradesh
Anon.	Anonymous
B. D.	Bulk density
C. D.	Critical difference
C. V.	Coefficient of variation
cm.	Centimeter
CPE	Cumulative pan evaporation
CUW	Consumptive use of water
cv.	Cultivar
DAP	Diammonium phosphate
DAS	Days after sowing
E	East
EC	Electrical conductivity
<i>et al</i>	et alii :and other
etc.	Etcetera
F. C.	Field capacity
Fig.	Figure

g.	Gram
g/cc	Gram per cubic centimeter
GAU	Gujarat Agricultural University
GA	Gibberellic acid
H. P.	Himachal Pradesh
ha.	Hectare
HPKVV	Himachal Pradesh Krishi Vishwa Vidyalaya
hr.	Hour
I	Irrigation
IBA	Indol Butaric Acid
i.e.	That is
IARI	Indian Agricultural Research Institute
IW	Irrigation water
K	Potash
Kg.	Kilogram
Kg ha ⁻¹	Kilogram per hectare
Kg ha ⁻¹ -mm	Kilogram per hectare millimeter
M	Man
m	Meter
M. P.	Madhya Pradesh
Max.	Maximum
MH	Maleic Hydrazide
Min.	Minimum

mm.	Millimeter
MPKV	Mahatma Phule Krishi Vidyapith
N	Nitrogen
N	North
NAA	Naphthalene acetic acid
No.	Number
NS	Non-significant
°C	Degree Celsius
P	Phosphorus
PB	Pair of bullock
PE	Pan Evaporation
PGRs	Plant growth regulators
pH	Potential of hydrogen ion
ppm	Parts per million
PWP	Permanent wilting point
q	Quintal
Rs.	Rupees
S. Em.	Standard error of mean
S. K. Nagar	Sardar Krushinagar
spp.	Species
SPD	Split Plot Design
Sr.	Serial number
T	Tonne

T. N.	Tamil Nadu
U. P.	Utter Pradesh
USWB	United State Weather Bureau
var.	Variety
viz.	Namely
W. B.	West Bengal
WUE	Water use efficiency
WEE	Water expense efficiency
%	Per cent
@	At the rate of
2, 4- D	2, 4- Dichlorophenoxy acetic acid

INTRODUCTION

Pulses form an integral part of the vegetarian diet and the cheapest source of protein for the resource poor farmers of the Indian sub-continent. Pulses also have an inherent capacity to fix atmospheric nitrogen in the soil and adaptability to a wide range of agro-ecological cropping systems and variable management. India is the world's the largest producer of pulses occupying an area of 23.89 million hectares under different agro-ecological regions with production of 15.12 million tonnes and average productivity of 638 kg ha⁻¹ (Anon., 2009), which is comparatively low to the average pulse yield (857 kg ha⁻¹) of world.

Among the grain legumes, chickpea (*Cicer arietinum* L.) commonly in english known as bengal gram and locally *chana* is an important and unique food legume because the variety of food products like snack foods, sweets, condiments and vegetables are prepared from it worldwide. Gram is a good source of protein (18-22%), carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorous, iron) and vitamins. It is an excellent animal feed and straw has good forage value. India is a premier chickpea growing country in the world, accounting 76% of total area and production of the world. In India it occupies about 7.58 million ha area with production of 6.91 million tonnes and average productivity 780 kg ha⁻¹ (Anon., 2009).

In Gujarat, chickpea is grown in an area of 0.25 million hectares producing 0.21 million tonnes with a average productivity of 870 kg ha⁻¹ (Anon., 2009). It occupies about 8.12 per cent of the total pulse cultivation in the Gujarat which is very low as compared to other states.

Augmenting the production of pulse crops is not only essential for providing protein rich food grains at reasonable cost to human and farm cattle but also for overall productivity of chickpea per unit time and area can be increased by adopting appropriate agronomic practices such as selecting suitable high yielding variety. Irrigation and moisture conservation practices and prudent nutrient management.

In spite of importance of this crop in our daily diet and agricultural production, productivity of this crop is low in India as well as in Gujarat the low productivity is mainly due to inadequate competition, lack of winter precipitation, improper time of sowing, seed rate, lack of pest and diseases management, irrigation schedules and growth regulators are not used in this crop.

Water is the basic input for increasing crop production. Agricultural Productivity cannot be maintained without assured supply of moisture to the plant, which is accomplished by irrigation. Even though chickpea thrives well under scarcity moisture conditions it responds well to irrigation (Saxena, 1984) each crop has certain critical growth stages, at which adequate moisture required for proper growth. Hence, efficient

water management is the key factor for boosting the crop production. Knowledge about critical growth stages of the crop is essential for the judicious application, the importance of critical stages of crop growth for irrigation needs of the crop, particularly under middle Gujarat conditions does not seem to have received due importance so far.

Climatological approach based on the ratio between irrigation water and cumulative pan evaporation was found to be the most appropriative approach, as it integrates all the weather parameters giving them their natural weightage in given soil water plant continuum. Scheduling of irrigation based on the data of the pan evaporation is likely to increase agricultural production at least to the tunes of 15-20 percent (Dastane, 1972).

Chickpea in India is usually grown on conserved soil moisture, though the crop responds to supplemental irrigation. In chickpea pod development stage is the most critical in respect of soil moisture but irrigation at early vegetative growth (branching) also benefit the crop in light soil. Thus a irrigation schedules have to be modified to suit to the requirement of gram.

Among the various strategies employed to increase crop yield, use of plant growth regulators have great promise due to modified crop growth by changing the rate or pattern of growth (Nickel, 1982).

Plant growth regulators are known to influence the growth and development of plants and ultimately the yield attributing characters

and yield. Senescence in plant is complex phenomenon, which is influenced by environmental conditions and endogenous plant hormones. Senescence can also be regulated by exogenous hormone application in India. Attempts are being made to improve quantitative status of chickpea employing different agronomical management but less emphasis was given towards its qualitative improvement among the possible ways of promoting chickpea seed quality, application of cost effective plant growth regulator have been used (Karim *et al.* 2006). Growth regulator acts at gene level of plant by influencing the translational and transcriptional mechanisms (key, 1969).

The use of plant growth regulators can improve the physiological efficiencies of plant and offer a sufficient role in increasing the crop yields, their use in many crops has been reported to delay senescence of leaves and to retard the abscission of reproductive organ (Fletcher and Adedipe, 1970). Further, they are also known to increase flowering, fruiting and grain filling (Ries *et al.*, 1978).

Application of NAA (Naphthalene acetic acid) is effective in weed control and used to induce the rooting of cutting of woody plants, improve fruit-setting and increase flowering.

Among the multi-nutrient deficiencies, phosphorus and sulphur deficiencies posing a serious problem particularly in pulse crops. Recently plant growth regulators have been found to increase crop yields

up to 56 per cent. Those encouraging results from certain growth regulators with particular formulations in field crop in the country.

Information regarding this aspect is scarce; hence, this experiment was conducted at college Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *rabi* season of the year 2009.

Objectives

1. To Study the effect of irrigation scheduling based on critical growth stages on growth, yield attributes and yield of chickpea.
2. To Study the effect of various plant growth regulators on growth and yield attributes and yield of chickpea.
3. To study interaction effect between irrigation scheduling and plant growth regulator.

REVIEW OF LITERATURE

Chickpea is one of the most important pulse crop commonly used in various food forms. It plays a vital role in providing reasonably balanced protein component in the diet of primarily cereal eating people of India. Irrigation scheduling and different plant growth regulators are the important factors, which regulates the yield of many crops. Irrigation water is a very precious commodity and its judicious use is essential for maximizing crop yield. For efficient utilization of irrigation water, it is necessary to find out proper approach for scheduling irrigation. Whatever works has been done so far for determining the water requirement of this crop was confined mostly to soil moisture deficit and crop critical growth stages approach in which climate parameters are not considered. Therefore, irrigation schedule based on critical crop growth stages to find out the water requirement and scheduling of irrigation for this crop based on critical growth stages.

Plant growth regulators have been reported to increase yield by reducing flowers drop and fruit shedding and by making the plant photosynthetically most effective.

Very limited information is available on scheduling of irrigation and plant growth regulators for Chickpea crop for middle Gujarat region. An attempt has therefore, been made in this chapter to

review the research work carried out on these aspects in India and abroad and grouped them under appropriate heads:-

2.1 Irrigation schedules

2.1.1 Effect of Irrigation schedules on yield attributes and yield

2.1.2 Effect of Irrigation schedules on consumptive use and water use efficiency.

2.1.3 Effect of Irrigation schedules

2.1.4 Economics of Irrigation schedules

2.2 Growth regulators

2.2.1 Effect of growth regulators on growth and growth attributes

2.2.2 Effect of growth regulators on yield attributes and yield

2.2.3 Effect of growth regulators on quality.

2.3 Interaction effect

2.1 Irrigation schedules

Bhale and Katare (1984) was conducted field experiment during the years 1980-83 on chickpea (*Cicer arietinum* L.) at Agricultural research station, Badnapur, Marathwada Agriculture University, (Maharashtra). The results revealed that scheduling irrigation at critical growth stages saved 23 mm water as compared with the package of improved management practices and also produced the highest yield (0.96) t ha⁻¹ as compared with a yield (0.74) t ha⁻¹ with farmers practices of an un scheduled irrigation.

Poonia (1984) at Bonswara reported that irrigation significantly increased the seed yield of gram over no irrigation under clay loam soil. Two irrigation, one at flowering and another at pod formation stages gave maximum seed yield followed by one irrigation at flowering stage (10.5 q ha⁻¹). While in another study at same location, Singh (1984) observed maximum seed yield under one irrigation at pre-flowering stage (45 DAS) which was found at par with two irrigations given at pre-flowering and pod filling stages during the year of study.

A field experiment was conducted at water management scheme, Regional research station, U. A. S Dharwad (Karnataka) in 1978 on deep black soil to study the effect of soil moisture stress on gram. From the results of this trial Palled *et al.* (1985) reported that irrigating the gram crop at 0.8 IW/CPE ratio through out the crop growth period which required six irrigations significantly increased number of pods plant⁻¹ test weight and seed yield over control.

Roy *et al.* (1988) at Bhagalpur (Bihar) concluded that single irrigation applied during the period from 45- 50 DAS or at pod initiation was beneficial to yield and yield attributes of late sown chickpea.

The results of an experiment conducted on clay loam soil at JNKVV, Jabalpur (M.P) by Sharma (1994) in *rabi* season, results indicated that one irrigation either at branching or flowering growth stage as well as two irrigations at both these stages in addition to pre-sowing

irrigation gave significantly higher seed and straw yield than only pre-sowing irrigation in chickpea.

Tiwari and Tripathi (1995) at Department of Agronomy, Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (M.P) studied the effect of planting date, irrigation and phosphorus on chickpea (*Cicer arietinum* L.) grown on clay-loam soil during winter season of the year 1988-89 and 1989-90, they reported that two irrigations applied at branching and pod formation stages at (35 and 75 DAS) gave significantly higher seed yield than no irrigation at either of stages.

While working at Department Of Agronomy, Punjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) on clay loam soil, Ghatol *et al.* (1998) conducted an experiment during *rabi* season of the year 1996-97 to study the effect of safflower-chickpea (*Cicer arietinum* L.) intercropping on yield attributing characters and yield of both the crops under varied soil moisture regimes observed that the highest yields of chickpea was recorded under two irrigations at branching and seed development crop growth stages and at par with three irrigations at rosette, branching and seed development stages.

From the above reviews, it is indicated that irrigation schedule at critical growth stages as two irrigations at branching and pod development stage gave significant effect on chickpea.

2.1.1 Effect of Irrigation schedules on seed yield attributes and yield

Dobariya (1985) while working at working at pulse research station G.A.U. Junagadh, (Gujarat) on clayey soil reported that number of pods plant⁻¹, test weight and seed yield did not differ significantly due to different IW/CPE ratios (0.3, 0.4 and 0.5).

Khushawaha *et al.* (1985) from college of Agriculture, Rajmata Vijaya Raje Scindhia Krishi Vishwa Vidyalaya, Indore (M.P) in winter season. They observed that irrigation applied at 45 DAS gave significantly higher yield of chickpea than that applied at 75 DAS and no irrigation.

The result of an experiment conducted at G.B. Pant University of Agri & Tech., Pantnagar (U.K.) by Naresh *et al.* (1985) during *rabi* season of the year 1980-81, results indicated that one irrigation applied at 90 DAS significantly increased seed pod⁻¹, test weight and seed yield over no irrigation. Where as significantly the highest straw yield was recorded when two irrigation were applied at 90 and 120 DAS.

Shinde *et al.* (1985) at College of Agriculture, MPKV, Rahuri (Maharashtra) in *rabi* season recorded maximum seed yield of chickpea with three irrigations at pre-sowing, second first at branching and third irrigations at pod development stages.

A field experiment was conducted on clay loam soil of College of Agriculture, MPKV, Rahuri (Maharashtra) during the year

1982-83, 1983-84 and 1984-85. From studies Ramshe *et al.* (1987) found that maximum seed yield of chickpea under three irrigations applied at branching, flowering and pod filling stage.

Research work carried out at Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur (W. B) by Parihar (1990) during *rabi* season of the year 1982-83 and 1983-84 for two years on sandy clay loam soil to find out the effect of irrigation schedule and phosphorus on chickpea (*Cicer arietinum* L.) results indicated that irrigations applied at 0.4 IW/CPE ratio (three irrigation) resulted significantly in to higher pods plant⁻¹ and seed yield over control.

Reddy and Ahlawat (1998) conducted an experiment at Division of Agronomy, IARI, (New Delhi) to study the response of chickpea (*Cicer arietinum* L.) genotypes to irrigation and fertilizer under late sown conditions during *rabi* season of the year 1988-90. An observing the growth attributes in chickpea influenced by irrigation at critical growth stages of the crop. They found that the availability of moisture along with nutrients at the two critical growth stages of moisture stress in chickpea obviously contributed to increase growth attributes, the better plant growth and development of higher pods plant⁻¹, finally led to higher seed and straw yields.

Nijme (1991) conducted an experiment during winter season at Bhopal (M.P) to study the effect of irrigation on chickpea in deep

vertisol. He found that seed and straw yields of chickpea (*Cicer arietinum* L.) significantly improved up to 3 irrigations.

Prabhakar and saraf (1991) studied the influence of irrigation and phosphorus on growth, yield and water – use efficiency of chickpea (*Cicer arietinum* L.), at Division of Agronomy, IARI at (New Delhi) during *rabi* season of the year 1984-85 and 1985-86, they observed that maximum plant height, branches plant⁻¹ and yield under two irrigations applied at 0.4 IW/CPE ratio.

While working at Raipur (M.P) Shrivastav *et al.* (1991) found that three irrigations applied at 45, 74 and 90 DAS gave significantly higher values of yield and yield attributes over one irrigation applied at 45 DAS when scheduling of irrigation based on calendar dates. While in case of IW/CPE ratio, two irrigations given at 0.6 IW/CPE ratio at (54 and 84 DAS) gave significantly higher values of yield, yield attributes over one irrigation at 0.4 IW/ CPE ratio at (69 DAS), but it was remained at par with three irrigations at 0.8 IW/CPE ratio at (49,72 and 92 DAS).

Field experiments were conducted during the winter season of the year 1992-93 and 1993-94 on sandy loam soil at, Research station Ujhani, Baduan G.B. Pant University of Agriculture And Teshnology (U.P) by Kaushik and Chaubey (1999). The results showed that application of one irrigation at branching at (45 DAS) produced

significantly higher yield of gram (*Cicer arietinum* L.) as compared to no irrigation and one irrigation at pre-flowering at (75 DAS) or at pod filling stage at (105 DAS).

From an experiment conducted on clay loam soil at Narmada irrigation project, G.A.U, Anand campus Khanda (Gujarat) Maliwal *et al.* (1999) reported that two irrigations applied at post sowing (80mm) and flowering (70 mm) stages gave significantly higher yield than one branching or pod forming stage, but it was remained at par with two irrigations either applied at flowering and at pod formation or at branching and at pod formation growth stages and with three irrigations applied at branching, at flowering and at pod formation stages.

Field experiment carried out by Singh *et al.* (2004) to study the effect of irrigation, sulphur and seed inoculation on growth, yield and sulphur uptake of chickpea (*Cicer arietinum* L.) under late sown conditions at Department of Agronomy, college of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hissar (Haryana) during *rabi* seasons of the year 2000-2001. They noted that number of pods plant⁻¹, test weight, seed yield /plant, and seed and straw yields increased significantly up to 2 irrigations. Two irrigations increase yield to the tune of 16.4% and 7.4% more seed yield over no irrigation and one irrigation respectively.

Ahlawat *et al.* (2005) conducted an experiment during the *rabi* seasons of the year 2000-2001 and 2001-2002 at Division of Agronomy, IARI (New Delhi), results revealed that increase in seed yield with irrigation at 0.2 IW:CPE ratio over no irrigation being increased at extent of 23% in first and 41.7% in second year, respectively. This increase in seed yield was largely attributed to increased pods plant⁻¹.

Mustafa *et al.* (2008) was conducted an experiment during *rabi* season of the year 2004 at S.V. Agricultural College Farm, Tirupati (A.P) to study the growth and yield of chickpea as influenced by irrigation and nutrient management. They found that application of four irrigation at sowing, at branching, at flowering and at pod filling stages significantly improved the number of pods plant⁻¹, number of seeds pod⁻¹, test weight, seed yield.

A field experiment was conducted during *rabi* season at Regional Agriculture Research Station, Nandyal ANGRAU, (A.P) of the year 2004 and 2005 to study the influence of dates of sowing and irrigation on chickpea by Munirathnam and Sangita (2009), they observed that maximum number of pods, test weight was found under two irrigation. Mean data of two years indicated that maximum seed yield was recorded with application of two irrigations at 35 and at 55 DAS. The magnitude of increase with two irrigations was increase to tune of 28.8 and 3.9% over no irrigation and one irrigation, respectively

An experiment carried out by Thomas *et al* (2010) during the *rabi* season of the year 2005-06 and 2006-07 at Department of Agronomy, Amar singh College, lakkhoti (U.P) to study the impact of levels of irrigation and fertility gradients on yield of chickpea. They noted that significantly the highest yield in both year was found under two irrigation levels at pre-flowering and pod formation growth stages of chickpea.

From the different reviews it can be concluded that the irrigation based on critical growth stage approach at branching, flowering, pod formation, stages recorded maximum seed yield of chickpea.

2.1.3 Effect of Irrigation schedules on water use efficiency and on consumptive use.

A field experiment was conducted at Department of Irrigation Water Managent, College of Agriculture, MPKV, Rahuri (Maharashtra) during winter season of the year 1989-90 by Pawar *et al.* (1992) to study the effect of irrigation schedule based on critical growth stages on yield, quality and water use of chickpea on vertisol. They observed that significantly higher seed yield was obtained irrigation schedule at branching, at flowering and at pod development and Consumptive use of water increases with increase no. of irrigation and also decrease in water use efficiency with increase in no. of irrigation.

Pramanik (2009), a field experiment was conducted at Indian Institute of Pulse Research, Kanpur (U.P) during *rabi* seasons of the year 2005-06 and 2006-07 to elucidate the effect of raised bed planting on growth, yield, water use efficiency and economics of chickpea (*Cicer arietinum* L.) Under various irrigation depths. Chickpea recorded maximum seed yield (average 2.24 t ha⁻¹), water use efficiency (11.69 kg ha⁻¹mm) and net returns (Rs 20,810 ha⁻¹).

Experiments carried out at different places indicated that in chickpea decrease in water use efficiency with increase in number of irrigation and also increase in consumptive use water by increasing number of irrigation.

2.1.4 Economics of Irrigation schedules

Rajput *et al.* (1999) conducted an experiment at Department Agronomy, Indira Gandhi Agricultural University, Raipur (MP). They found that maximum net return and benefit: cost ratio was obtained with one irrigation, followed by two irrigations and no irrigation. There was no change in plant population due to irrigation schedules.

Perusal of above indicated that irrigation water is becoming limiting factor in increasing the chickpea yield. Irrigation scheduled at different crop growth stages of chickpea is more effective for getting higher yield. Application of 2-3 irrigations at branching and at pod development stages or at branching, at flowering and at pod development stages was found most beneficial in obtaining higher yield.

2.2 growth regulators

2.2.1 Effect of growth regulators on growth and growth attributes

Iqbal *et al.* (2001) conducted experiment during *rabi* season of the year 1996-97 at Department of Botany, University of Agriculture, Faisalabad, Pakistan to find out response of plant growth regulator on initiation of flowering @ of 10 ppm to 20 ppm. Results revealed that foliar spray of Gibberelic acid at flowering initiation stage produced more positive effect as compared to their spray at vegetative growth stage.

Karim and Quazi, (2007) conducted an experiment to study growth analysis of chickpea affected by foliar spray of plant growth regulator during *rabi* season of the year 2001-2002 at sher-e-bangla University, Dhaka (Bangladesh) reported that Chick pea, application of 1500 ppm KNap recorded the highest stem dry weight at 95 and 113 (4.12 g plant⁻¹ and 5.63 g plant⁻¹), respectively and also treatment (1500 ppm KNap) recorded the highest pod dry weight at 95, 113 DAS (2.80 g plant⁻¹ and 5.84 g plant⁻¹), respectively which was remained at par with treatment (1500 ppm Knap + 10 ppm NAA).

GA₃ and KNap plays an important role in the development of vegetative growth and dry weight of plant and pod pointed out in the above literature.

2.2.2 Effect of growth regulators on yield attributes and seed yield

A field experiment was carried out by Kalita *et al.* (1995) during rabi and summer season of the year 1993-1994 to study the influence of foliar application of phosphorus and NAA on N, dry matter accumulation and yield of green gram at department of crop physiology, Assam Agricultural University, Joharat (Assam), results indicated that seed yield, number of pods plant⁻¹, number of seeds pod⁻¹ was found significantly higher under treatment (0.3% P₂O₅ + 100 ppm NAA), 22.24 no. of pods plant⁻¹, 13.69 no. of seeds pod⁻¹ and 7.85 q ha⁻¹ seed yield, respectively.

A field experiment was conducted to study the effect of foliar application of nutrients and plant growth hormones either alone or in combination on yield of soyabean by Kalpana and Krishnarajan (2003) at Department of Agronomy, TNAU, Coimbatore (T.N) during *rabi* season of the year reported that seed yield was found significantly the highest under treatment (T₄ + NAA 40 ppm, 1525 kg ha⁻¹). Increase in yield to the tune of 22.30% over control in soyabean, respectively.

Upadhyay (2003) conducted an experiment at Berth in Palampur, Himachal Pradesh krishi vishvavidyalya (H.P) to find out the response of plant Growth regulator on flower drop fruit setting biochemical constitution and yield of chickpea under middle hill conditions, results indicated that plant growth regulators application had significant effect on its component and finally the seed yield. It was

found that foliar application of NAA, GA₃ and kinetin improved the yield and recorded significantly higher seed yield.

Hasanuzzaman *et al.* (2007) conducted an experiment at Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka (Bangladesh) to observe the plant character yield attributes and yield of chickpeas as influenced by growth regulator, the concentration of knap (1500ppm) recorded significantly higher number of pods per plant.

Saxena *et al.* (2007) conducted an experiment to find out the effect of ethrel on reproductive efficiency in chickpea at Division of plant physiology, IARI (New Delhi), results revealed that the result on pre flowering vegetative growth stage (S₁), mid flowering stage (S₂), and post flowering, pod development stage (S₃) recorded significantly higher total dry weight under the treatment (low 250 ppm) with different days.

Chaurasia and Chaurasia (2008) conducted field experiment during winter seasons of the year 2004-05 and 2005-06 to study the effect of fertility levels and plant growth regulators on growth and yield of chickpea at Department of Botany, Government Girls P.G. College, Rewa (M.P.) They reported that significantly higher seed yield was found under the application of tricontanol (Miraculan) plant growth regulator on pooled basis data of two years.

From the above literature that it be can assumed that plant growth regulators application had significant effect on its component and

finally the seed yield and also NAA plays an important role in increasing the flowers.

2.2.3 Effect of plant growth regulators on quality

Kumar *et al.* (2003) conducted an experiments during *rabi* season of the year 1998-99 at S.K.N.college of Agriculture, Jobner (Rajasthan) to study effect of sulphur and plant growth regulator on yield and quality parameters of chickpea, they reported that protein content of seed increased over control due to NAA, Cycocel and MH to the tune of 19.98,17.91 and 20.65 per cent respectively.

Karim *et al.* (2006) at Department of Agronomy, Sher –e – Bangla Agricultural University, Dhaka (Bangladesh) during *rabi* season of the year 2001-2002 to study the changes in bio components of chickpea sprayed with NAA and KNap stated that crude protein was significantly higher under the treatment of (500 KNap + 20 NAA) 20.95 %, which was closely followed by that in treatment (1500 KNap + 10 NAA).

A field experiment was conducted during winter seasons of the year 2004-05 and 2005-06 at Department of Botany, Government Girls P.G. College, Rewa (M.P.) to study the effect of fertility levels and plant growth regulators on nutrient contents and uptake of chickpea by Chaurasia and Chaurasia (2008). They observed that nutrient contents (N, P and S) in seed was found significantly higher under the application of

tricontanol (Vipul) plant growth regulator and also total nutrients uptake (N, P,K and S) per hectare by seed and straw was noted significantly higher under the application of tricontanol (Vipul) growth regulator.

The experiment was conducted at Department of Botany Chaudhary Charan Singh University, Meerut (U.P) by Jain *et al.* (2008) on chickpea during *rabi* season of the year 2004 season to study the effect of plant growth regulators on leghaemoglobin biosynthesis in chickpea root nodules, the results noted that in stage 1, (15 Days after nodule initiation) the highest leghaemoglobin (mg/g),protein (mg/g) and Lb% was found under treatment IAA at 10 ppm (16.79 mg/g, 51.38mg/g 32.67% respectively) and also in stage 2, (30 Days after nodule initiation) the highest leghaemoglobin (mg/g), protein (mg/g) and Lb% was observed under the treatment GA₃ @25 ppm.

From above stated reviews on pulses on different plant Growth regulators applications are very effective on synthesis of protein content by increasing root nodulation, biocomponents and also increases the uptake of different nutrients and ultimately yield.

2.3 Interaction effect

Field experiment was conducted by Meisheri (1988) during *rabi* season of the year (1982-83) at the National Agricultural Research project, Arnej, Bhal, G.A.U.,(Gujarat) to study the effect of irrigation,

gypsum and plant growth regulators. Pod length was found significant under treatment combination of irrigation and growth regulator (irrigation at pre-flowering along with application of NAA @ 10 ppm) produced significantly higher pod length (1.30 cm).

MATERIAL AND METHODS

The details of the material use, experimental method followed and technique adopted during the course of investigation on “Influence of irrigation schedules based on critical growth stages and growth regulators on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions.” are given below.

3.1 Experimental site

The present experiment was conducted in plot no. 27 at College Agronomy Farm, B A College of Agriculture, Anand Agricultural University, Anand, (Gujarat) during winter season of the year 2009 (Plate 1).

3.2 Climate and weather condition

Geographically, Anand is situated at 22° - 35' N latitude, 72° - 55' E longitude at an altitude of about 45.1 meters above the mean sea level. Anand is about 70 km away from the Arabian Sea coast and hence this region enjoys a typical sub-tropical climate with dry and hot summer, fairly cold and dry winter and moderately humid monsoon. The rainy season commences by the middle of June and retreats by the middle of September with an average annual rainfall of 864.5 mm. The total rainfall recorded during 2009 was 961 mm. July and August are the months of heavy rainfall. Practically there is no rainfall in winter and summer season almost all part of Gujarat state expect sporadic showers in *rabi* season.

The overall climate was fairly cool and dry with normal daily sunshine of 8-9 hours during investigation period of November to March. The maximum and minimum temperature ranged from 26.4°C-37.8°C and 10.3-20.8°C, respectively. The mean values of weekly weather parameters as recorded at meteorological observatory are presented in Table 3.1 and graphically depicted in Fig. 3.1.

Table 3.1: Mean weekly weather parameters recorded during the crop season (2009-2010)

Month & Year	Met. Std. week	Dates	Temperature °C			Mean R.H. (%)	Bright Sun-shine hrs.	Evapo ration (mm)
			Max.	Min.	Mean			
Novemb er 2009	45	5-11	34.7	16.7	25.7	51	9.4	5.0
	46	12-18	32.8	15.9	24.4	52	7.9	4.4
	47	19-25	30.9	16.2	23.5	53	7.4	4.8
	48	26-2	29.5	16.5	23.0	48	5.6	4.6
Decemb er, 2009	49	3-9	33.8	17.1	25.4	52	9.5	4.2
	50	10-16	30.5	16.9	23.7	65	7.0	3.0
	51	17-23	30.3	16.9	23.6	61	4.9	2.9
	52	24-31	29.5	10.3	19.9	62	9.2	3.1
January, 2010	1	1-7	27.9	11.3	19.6	61	8.3	2.9
	2	8-14	26.4	14.6	20.5	68	7.0	3.1
	3	15-21	30.7	17.3	24.0	69	5.6	2.9
	4	22-28	28.3	12.8	20.6	60	6.9	3.2
	5	29-4	30.6	10.9	20.8	58	9.7	3.9
February , 2010	6	5-11	30.4	12.2	21.3	58	9.9	4.3
	7	12-18	30.3	13.3	21.8	56	9.9	4.8
	8	19-25	34.0	16.3	25.2	48	9.0	5.2
	9	26-4	36.6	17.6	27.1	51	9.8	5.8
March, 2010	10	5-11	35.1	16.2	25.6	46	9.6	6.2
	11	12-18	37.7	18.9	28.3	41	8.9	6.6
	12	19-25	37.2	20.6	28.9	42	9.3	7.1
	13	26-1	37.8	20.8	29.3	39	9.6	8.4

Dates	November 2009		December 2009		January2010		February2010	
	PE	CPE	PE	CPE	PE	CPE	PE	CPE
01	-	-	3.7	53.1	3.0	152.5	3.7	262.8
02	-	-	3.9	57	3.6	156.1	3.5	266.3
03	-	-	3.9	60.9	2.9	159	3.8	270.1
04	-	-	3.4	64.3	3.1	162.1	5.1	275.2
05	-	-	2.5	66.8	3.4	165.5	5.2	279.4
06	-	-	2.6	69.4	3.7	169.2	3.4	282.8
07	-	-	4.4	73.8	4.0	173.2	3.1	285.9
08	-	-	2.8	76.6	3.5	176.7	3.8	289.7
09	-	-	3.8	80.4	2.7	179.4	4.2	293.9
10	-	-	2.8	83.2	3.4	182.8	5.0	298.9
11	-	-	2.9	86.1	3.5	186.3	4.8	303.7
12	-	-	3.0	89.1	2.8	189.1	5.0	308.7
13	-	-	3.6	92.7	4.4	193.5	5.5	314.2
14	-	-	3.4	96.1	4.3	197.8	5.8	320
15	-	-	2.7	98.8	4.5	202.3	5.1	325.1
16	-	-	3.1	101.9	3.7	205.4	5.4	330.5
17	-	-	2.6	104.5	3.0	208.4	5.4	335.9
18	3.1	3.1	2.5	107	3.9	219.1	5.4	341.3
19	3.8	6.9	3.5	110.5	3.5	222.6	5.5	346.8
20	5.3	12.2	3.4	113.9	3.3	225.9	5.5	352.3
21	4.5	16.7	2.9	116.8	3.5	222.6	5.2	357.5
22	3.8	20.5	2.9	119.7	3.3	225.9	5.0	362.5
23	2.8	23.3	3.1	122.8	3.7	229.6	5.4	367.9
24	2.3	26.5	3.0	125.8	3.7	233.3	5.3	373.2
25	3.4	29.9	2.8	128.6	4.1	237.4	4.7	377.9
26	4.1	34	3.8	132.4	3.8	241.2	4.8	382.7
27	4.4	38.4	3.2	135.4	4.0	245.2	5.9	388.6
28	3.7	42.1	4.5	140.1	3.7	248.9	5.9	394.5
29	3.1	45.2	3.3	143.4	2.6	251.1	-	-
30	4.2	49.4	3.3	146.7	3.8	255.2	-	-
31	-	-	2.8	149.5	4.0	259.1	-	-

Tabel 3.2 Daily pan evaporation (mm) measured under the course of investigation.**3.3 Physico-chemical characteristics of soil**

The experimental field had an even topography with a gentle slope having good drainage. The soil is representative of the region and is locally known as *Goradu* soil. The texture of the soil is loamy sand. The soil is very deep and fairly moisture retentive. The soil responds well to manures and fertilizers. It is suitable for all the crops of tropical and sub tropical regions.

Table 3.3: Physico-chemical properties of experimental field

Particular	Soil depth		Method employed
	0-15 cm	15-30 cm	
Physical properties			
Coarse sand (%)	0.63	0.62	International pipette method (Piper, 1980)
Fine sand (%)	84.10	85.40	-do-
Silt (%)	10.21	8.70	-do-
Clay (%)	5.0	5.24	-do-
Textural class	Loamy sand		
Chemical properties			
Organic carbon (%)	0.23	0.20	Walkly and Black method (Jackson, 1973)
Total nitrogen (%)	0.019	0.017	Kjeldahl's method (Jackson, 1973)
Available P ₂ O ₅ (kg ha ⁻¹)	24.20	23.30	Olsen's method (Olsen, 1976)
Available K ₂ O (kg ha ⁻¹)	358.86	350.10	Flame photometric method (Jackson, 1973)
Soil pH (1:2:5 soil : water ratio)	7.5	7.6	pH meter (Jackson, 1973)
Electrical conductivity dS m ⁻¹ at 25 ^o c	0.14	0.16	Conductivity meter (Jackson, 1973)

The physico-chemical properties of experimental plot were determined by drawing soil sample randomly from a depth of 0-15 cm and 15-30 cm and a composite sample was prepared and analyzed for physical and chemical properties of the soil. The values of soil analysis along with method are furnished in Table 3.3.

3.4 Cropping history of the experimental site

The cropping history of the experimental plot for preceding three year are presented in Table 3.4

Table 3.4: The crop taken during last three year in the experimental plot

Year	Season	Crop	Fertilizer (kg ha ⁻¹)		
			N	P ₂ O ₅	K ₂ O
2007-08	Kharif	Sunhemp (GM)	18	46	0
	Rabi	Lucerne	20	80	40
	Summer	Fallow	-	-	-
2008-09	Kharif	Maize Seed production	100	50	0
	Rabi	Bajara	100	50	0
	Summer	Fallow	-	-	-
2009-10	Kharif	Maize Seed production	100	50	0
	Rabi	Present Experiment	25	50	0
	Summer	-	-	-	-

3.5 Crop and variety

Chickpea (Gujarat Gram-1) was selected for the present investigation. This variety is evolved and released from Pulse Research Station, GAU, Junagadh, Gujarat for cultivation in Gujarat.

Tabel 3.5 The details of this variety are Gujarat Gram-I as below:

Sr. No.	Character	Description
1	Plant height (cm)	38
2	Maturity (days)	108
3	Branches plant ⁻¹	4.4
4	Pods plant ⁻¹	37
5	Weight of 100 seeds (g)	18.15
6	Seed size	Medium
7	Seed colour	Reddish brown
8	Protein content (%)	21.5
9	Grain yield, kg ha ⁻¹	1622

Table 3.6 Calendar of cultural operations carried out during the experiment

Sr. No.	Operation	Date
1	Tractor cultivation and planking	17/11/2009
2	Removal of stubbles of previous crop	17/11/2009
3	Field layout of experiment	17/11/2009
4	Preparation of beds and opening of furrow apart by 'kudali'	17/11/2009
5	Fertilizer application	17/11/2009
6	Sowing	18/11/2009
7	Common irrigation	19/11/2009
8	hand weeding	18/12/2009
9	Spraying of plant growth regulator	26/12/2009
10	spraying for plant protection	04/01/2010
11	Interculturing (wheel hoe)	08/01/2010
12	Harvesting	06/03/2010

3.7 Irrigation scheduling

The irrigation treatment was imposed after establishment of crop and common light irrigation of 25 mm soil depth was given immediately after sowing. The detail regarding dates of the irrigation for

treatments along with number of irrigation and total quantity of water applied are given in Table 3.5

Table No. 3.7: Date of irrigation, number of irrigation and total quantity of irrigation applied

Treatments / number of irrigation	I ₁ At branching	I ₂ At branching + flowering	I ₃ At branching + flowering + pod formation	I ₄ IW: CPE ratio (0.6)
Common	19/11/2009	19/11/2009	19/11/2009	19/11/2009
1	23/12/2009	23/12/2009	23/12/2009	10/12/2009
2		4/01/2010	4/01/2010	6/01/2010
3			20/01/2010	29/01/2010
NO. of irrigation applied	(1+1)=2	(2+1)=3	(3+1)=4	(3+1)=4
Total quantity of water (mm)	100	150	200	200

The cumulative pan evaporation values were calculated from daily pan evaporation measured with the help of USWB class ‘A’ open pan evaporimeter installed at meteorological observatory, which was in the proximity of the experimental plot. The quantity of irrigation water applied in surface flooding was measured by 9.0 cm head parshall flume. A fixed depth of 50 mm irrigation water was applied to each treatment at irrigation based on critical growth stages and IW: CPE ratio of 0.6.

3.8 Preparation of solution and procedure for foliar spray of growth

regulator

For each of the concentration of NAA (25 ppm), IBA (25 ppm) and AA (20ppm) the required quantity of GRs were dissolved in small quantity of 95% alcohol. The dissolved material was poured into small quantity of distilled water. The total volume of the solution required to be sprayed was decided by spraying water on a representative Chickpea crop, foliar spray of NAA @ 25 ppm, IBA @ 25 ppm and AA @ 20 ppm were given at 40 DAS in the morning hours in 12 liters of water in respected plots with ‘Ganesh’ hand sprayer. Teepol solution was added @ 0.5 % as wetting agent. Spraying was done before noon on the upper surface of the leaf area.

3.8.1 Treatment details

(A) Main plot treatment: Irrigation scheduling (I): 4 level

(I₁)- At branching

(I₂)- At branching + flowering

(I₃)-At branching + flowering + pod formation

(I₄)- IW: CPE ratio (0.6)

(B) Subplot treatment: Growth regulator (GR): 4 level

GR₀- Water spray at 40 DAS (Control)

GR₁- NAA @25 ppm at 40 DAS

GR₂- IBA @25 ppm at 40 DAS

GR₃- Ascorbic Acid @20 ppm at 40 DAS

Treatment combination

Sr. No.	Treatment combination	Sr. No.	Treatment combination
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1.	I ₁ GR ₀	9.	I ₃ GR ₀
2.	I ₁ GR ₁	10.	I ₃ GR ₁
3.	I ₁ GR ₂	11.	I ₃ GR ₂
4.	I ₁ GR ₃	12.	I ₃ GR ₃
5.	I ₂ GR ₀	13.	I ₄ GR ₀
6.	I ₂ GR ₁	14.	I ₄ GR ₁
7.	I ₂ GR ₂	15.	I ₄ GR ₂
8.	I ₂ GR ₃	16.	I ₄ GR ₃

3.8.2 Experimental design and lay out

Experimental Design	: Split Plot
Plot Size	: (a) Gross plot: 3.00 m x 5.00 m (b) Net plot : 1.80 m x 4.00 m
Spacing	: 30 cm × 10 cm.
Seed Rate	: 60kg ha ⁻¹
Fertilizer application	: Common application of N+P=25kg N ha ⁻¹ +50kg P ₂ O ₅ ha ⁻¹ as basal
No. of Replication	: 4
Total No. of plots	: 64
Crop & variety	: Var. GG-1

3.9 Cultural operation

The experimental field was thoroughly prepared by tractor cultivator followed by harrowing and at last planking for leveling the soil.

The sequence of operations carried out in the field during the course of investigation is outlined in Table 3.6.

3.9.1 Application of fertilizer

The crop was fertilized with 25 kg N and 50 kg P₂O₅ per hectare from DAP and Urea i.e. before sowing in opened furrow as common application.

3.9.2 Sowing of the experiment

Dry sowing was done at 30 cm row to row and 10 cm plant to plant distance. As sowing was performed under dry condition and the seeds were covered with the soil by manually.

3.10 Post sowing operation

One common light irrigation of 25 mm soil depth was given immediately after dry sowing the seeds. Thinning, weeding and plant protection measures were taken as and when required.

3.10.2 Weeding

To remove the weed from the experimental plot one hand weedings manually were performed at 30 DAS and one Interculturing with Wheel hoe at 50 DAS.

3.10.3 Plant protection

To save the crop from sucking pest like aphids, jassides, pod

borer etc. One spraying of Monocrotophos 35 EC was performed at flowering stage at 45 DAS.

3.11 Soil physical constant

Soil physical constant viz. field capacity, permanent wilting point and bulk density were determined for experiment at site up to 60 cm soil depth. The values are presented in the Table 3.8 along with procedure followed.

Table 3.8: Physical constant of the soil experimental plot

Depth (cm)	Physical properties of soil		
	F. C. %	P.W.P. %	B. D. g/cc
0-15	17.5	4.65	1.45
15-30	17.0	4.65	1.47
30-45	16.5	4.95	1.50
45-60	16.2	5.16	1.50
Procedure Followed	Actual field method (Dastane, 1972)	Pressure plat apparatus method (Richard, 1948)	Actual field method (Dastane, 1972)

3.12 Soil moisture studies

The soil moisture studies were started right from sowing of crop and continued up to its maturity. The soil moisture constant of all the treatments in one replication was determined on same day just before irrigation and 48 hours after irrigation at 0-15, 15-30, 30-45 and 45-60 cm soil depth were recorded.

3.12.1 Sampling technique

Soil samples were taken with the help of screw auger from four different soil depths. The soil samples were taken around fixed spot selected at random in net plot area of each treatment from one replication. The samples were transferred immediately to aluminum boxes and covered with gunny bag to avoid moisture losses from the samples. The samples were shifted immediately for oven dry.

3.12.2 Weighting and drying of sample

The soil samples were weighed (W_1) by physical balance immediately and then transferred to electrically heated oven with thermostat control. The samples were dried at temperature of 105° C for 8 to 12 hrs. till constant weight (W_2) was obtained. The loss in soil moisture was expressed in percentage on oven dry weight basis with following formula.

$$\text{Moisture percentage} = \frac{W_1 - W_2}{W_2}$$

Where, W_1 = wet soil sample
 W_2 = dry soil sample

The values were used to compute the seasonal consumptive use of water and moisture use rate.

3.12.3 Consumptive use of water

The consumptive use of water under different treatments was computed by using the following formula as described by Mishra and Ahmad (1987).

CU of water (mm) = $(E_0 \times 0.6) + \text{Profile soil moisture} + \text{Effective rainfall} + \text{Ground water contribution}$.

The depth of water table was more than three meters below the surface throughout the period of experimentation. Hence, the ground water contribution was considered as zero. The profile soil moisture (depletion) was worked out as under which is described by Patel (1993),

$$d = \frac{\sum M_{1i} - M_{2i}}{100} \times A_{si} \times D_i$$

Where, d = Moisture deficit in the root zone,

$\sum$ = Summation of 'n' number of the root zone,

M_{1i} = Soil moisture in the i^{th} layer of profile after irrigation,

M_{2i} = Soil moisture in the i^{th} layer of profile on the day before next,

A_{si} = Apparent specific gravity of the layer (Bulk density of i^{th} layer),

D_i = Depth of i^{th} layer,

E_0 = PE mm/day (from saturation to FC)

3.12.5 Water use efficiency ($\text{kg ha}^{-1}\text{-mm}$)

The response of seed yield per unit of irrigation water used at varying level of irrigation was worked out by dividing per hectare seed yield of chickpea crop obtained under various treatment with the total consumptive use of water (mm) of the respective treatment and it was recorded as water use efficiency ($\text{kg ha}^{-1} \text{ mm}$) which was worked out by the following formula which is described by Patel (1993).

$$\text{WUE (Kg ha}^{-1}\text{-mm)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Total consumptive use of water (mm)}}$$

3.13 Harvesting and Threshing

The crop was harvested manually on 06 March, 2010, when the crop matured. Randomly selected plants (Previously tagged) from each net plot were first harvested for recording necessary biometric observations and produce was added to respective net plot later on. The border lines were harvested first and were separated out of the experimental plots. Then the net plot area was harvested separately and produce left for sun drying in respected plots for about three to four days. After complete drying, the harvested produce was weighed just before threshing to record biological yield. The threshing and cleaning operations of individual plot were done manually with stick. Seed per plot thus collected were winnowed, cleaned and weighed. Data were converted into kg ha⁻¹ for statistical analysis.

3.14 Biometric observation

The details of the various growth and yield attributes as well as quality parameters studied during the course of investigation are given in Table 3.9 along with size of samples and time of observation.

The details of treatment followed for recording above stated biometric observations are given as under.

3.14.1 Growth attributes

The details of technique employed for recording observation on growth characters are described below.

3.14.1.1 Plant population

Plant population at 30 DAS and at harvest was recorded by counting number of plants in each net plot.

3.14.1.2 Plant height

The plant height of previously selected and tagged five plants were measured at 30, 60 DAS and at harvest. Average value for each treatment at each stage was calculated and recorded.

3.14.1.3 Days to 50 % flowering

The numbers of days required for the crop to attain 50 percent flowering was recorded from randomly each net plot. The mean value for each experimental plot was worked out and recorded.

3.14.1.4 Days to maturity:

Number of days required by the crop to attain maturity was recorded for individual net plot. The mean value (in days) as worked out and recorded.

3.14.1.5 Average no. of branches per plant:

All the effective branches from selective five plants in each plot and average value for each plot were worked out.

3.14.2 Yield and Yield attributing characters

Five randomly selected and tagged plants from each plot were used for recording observation on yield attributes.

3.14.2.1 Average no. of Pods Plant⁻¹

The total number of developed pods from previously five tagged plants at the time of harvest was counted and their average value per plant was worked out and recorded for each treatment.

3.14.2.2 No. of seeds per pod

No. seeds per of developed 5 pods counted and their average value was worked out and recorded for each treatment.

3.14.2.3 Seed Yield (kg ha⁻¹)

The produce of each net plot area was threshed separately, cleaned and the seed yield was recorded per net plot and then computed on hectare basis as per treatment.

Table 3.9: Parameters studied during course of investigation

(A) Growth attributes			
1	Plant population	Net plot	At 30 and at harvest DAS
2	Plant height (cm)	Counted by randomly selected and tagged five plant in each net plot and in each replication	At 30,60 DAS and at harvest
3	Days to 50 % flowering	Five selected and tagged plants	At flowering
4	Maturity days	Measured from sowing to maturity	At maturity of plant

5	Average no. of branches per Plant	Counted by randomly selected and tagged five plant in each net plot and in each replication	At harvest
(B) Yield attributes			
1	Average no. of pods per plant	Five selected and tagged plants	At harvest
2	Average no. of seed per pod	Five selected and tagged plants	At harvest
3	Seed yield kg/net plot and kg ha ⁻¹	As prescribed in procedure	At harvest
4	Dry gotar yield kg/net plot and kg ha ⁻¹	As prescribed in procedure	At harvest
5	Harvest index (HI)	As prescribed in procedure	At harvest
6	Test weight (g)	One composite sample from each net plot	At harvest
7	Disease index	As per procedure mentioned	At harvest
(C) Quality parameter			
1	% Protein	Worked out by multiplying the N content of seed with a factor 6.25	After harvest

3.14.2.4 Dry gotar yield (kg ha⁻¹)

Yield was obtained by subtracting the yield of each net plot from their respective total dry matter (above ground) or biological yield and computed in terms of kilograms per net plot and then it on hectare basis.

3.14.2.5 Harvest Index (%)

The harvest index is the ratio of economic yield to the biological yield per plot. The harvest index for each treatment was worked out by using the formula (Donald and Hamblin, 1976).

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.14.2.6 Test weight (g)

A representative grain sample was drawn randomly from the bulk the produce of each net plot and one hundred grains were counted from the sample and their weight in gramme was recorded as test weight for each treatment.

3.14.2.7 Disease index

Observation on diseases index of non systemic infection was recorded at 105 days after sowing on fifty randomly selected plants from each net plot. The plants were rated on 0-5 scale as described here: 0 = plants completely free from diseases symptoms; 1 = 1-20 % plants affected by wilt; 2 = 21-40 % plants affected by wilt; 3 = 41-60 % plants affected by wilt; 4 = 61-80 % plants affected by wilt and 5 = more than 80 % plants affected by wilt. The diseases index was calculated by using the following formula (Yadav *et al* 2005).

$$\text{PDI} = \frac{\sum \text{all rating} \times 100}{\text{No. of plants assessed} \times \text{Maximum rating}}$$

3.14.3 Quality parameter

3.14.3.1 Protein content (%) _____

The protein content in seeds was calculated by multiplying nitrogen content (%) of seeds with the conversion factor of 6.25 as reported by Gupta *et al.* (1972).

3.16 Economics

Cost of cultivation of the crop for individual treatment was worked out considering the cost of all the cultivation operations starting from preparatory tillage to harvesting including the cost of all inputs. The gross and net realization in terms of Rs ha⁻¹ was worked out taking the present market value of seed yield and dry gotar yield obtained for each treatment. The net realization was worked out by subtracting the total cost of production from gross realization of treatment and recorded accordingly.

Net realization (Rs ha⁻¹) = Gross realization - Total cost of production

3.17 Statistical analysis

The data generated on yield, quality and various characterized were subjected to statistical analysis using “Analysis of variance technique”. The value of table ‘F’ at 5 % level of significance, where the treatment differences were found significant the value of CD was worked out to compare the treatment mean (Snedecor and Cochran, 1967).

EXPERIMENTAL RESULTS

The chapter embodies the results of the present investigation entitled “Influence of irrigation schedules based on critical growth stages and growth regulators on growth, yield attributes and seed yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions”. Conducted during *rabi* season of the year 2009-2010 at College Agronomy Farm, B. A. College of Agriculture Anand Agricultural, University, Anand, Gujarat. The results pertaining to various growth, yield attributes, seed yield, quality parameters and economics as influenced by different irrigation schedules based on critical growth stages and plant growth regulators along with statistical inferences are presented in tables and also illustrated graphically wherever found necessary in this chapter.

4.1. Plant population

The data regarding plant population as influenced by different irrigation schedules based on critical growth stages and plant growth regulators was furnished in Table 4.1.

4.1.1.(a) Effect of irrigation schedules on plant population at 30 DAS

An appraisal of data presented in table 4.1 indicated that the difference in plant population at 30 DAS due to different irrigation schedules based on critical growth stage was non - significant.

Table 4.1 Plant population at 30 DAS and at harvest influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatment	Plant population at 30 DAS	Plant population at harvest
Main plot treatment [Irrigation (I)] 4 level		
I₁ at branching	42.70	41.87
I₂ at branching + at flowering	43.36	41.70
I₃ at branching + at flowering + at pod formation	44.02	44.02
I₄ 0.6 IW: CPE ratio	45.48	43.49
S.Em. ±	0.60	0.59
C.D. at 5%	NS	NS
C. V %	5.55	5.58
Sub plot treatment [Growth Regulator] (GR) 4 level		
GR₀ (water spray)	43.73	42.06
GR₁ (NAA @ 25 ppm) at 40 DAS	43.80	43.16
GR₂ (IBA @ 25 ppm) at 40 DAS	43.83	42.59
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	44.19	43.27
S.Em.±	0.49	0.48
C.D.5%	NS	NS
Interaction (IxGR)	NS	NS
C.V. %	4.49	4.53

4.1.2.(b) Effect of plant growth regulators on plant population at 30

DAS

The effect of different plant growth regulator was also non significant.

4.1.3.(c) Interaction effect

Plant population at 30 DAS was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.2.1 (a) Effect of irrigation schedules based on critical growth stage on plant population at harvest

An appraisal of data presented in Table 4.1 indicated that difference in the plant population at harvest due to different irrigation schedules based on critical growth stage was non-significant.

4.2.2. (b) Effect of plant growth regulators on plant population at harvest

The effect of different plant growth regulator was non-significant.

4.2.3.(c) Interaction effect

Plant population at harvest was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.3. Plant height (cm)

The mean data pertaining to plant height recorded periodically at 30 and 60 DAS and at harvest as influenced due to different irrigation schedules based on critical growth stage and plant growth regulators along with statistical inferences are presented in respective Table 4.2.

4.3.1.1(a) Effect of irrigation schedules based on critical growth stage on plant height at 30 DAS

Perusal of data presented in Table 4.2 indicated that differences in the plant height due to different irrigation schedules based on critical growth stage was non- significant.

4.3.1.2.(b) Effect of plant growth regulators on plant height at 30 DAS

Effect of different plant growth regulator treatments was found non- significant.

4.3.1.3.(c) Interaction effect

Plant height at 30 DAS was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.3.2.1.(a) Effect of irrigation schedule based on critical growth stage on plant height at 60 DAS

Data presented in Table 4.2, there was significant effect on plant height due to irrigation schedules based on critical growth stage at 60 DAS. Among different irrigation schedules, treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly taller plants (54.86cm), being at par with treatment I₂ irrigation at branching and at flowering, (52.37 cm). Treatment I₁ irrigation at branching recorded significantly lower plant height (48.69 cm), which was remained at par with treatment I₂ irrigation at branching and at flowering, (52.37 cm) and I₄ irrigation at 0.6 IW: CPE ratio, (49.34 cm).

4.3.2.2.(b) Effect of growth regulators on plant height at 60 DAS

The data further indicated that plant height at 60 DAS was significantly influenced due to application of plant growth regulators. Among different plant growth regulators, treatment GR₁ (NAA @ 25 ppm) at 40 DAS recorded higher plant height (54.25 cm), which were remained at par with treatments GR₃ (Ascorbic Acid @ 25ppm) at 40 DAS (51.39 cm). Treatment GR₀ (Control- water spray) recorded significantly lower plant height (49.33 cm) which was remained at par with treatment GR₃ (Ascorbic Acid @20 ppm) at 40 DAS (51.39cm).

Table 4.2 Plant height (cm) at 30 DAS and 60 DAS and at harvest influenced by irrigation scheduling based on critical growth stages and growth regulators.

Treatment	plant height at 30 DAS	Plant height at 60 DAS.	plant height at harvest
Main plot treatment [Irrigation (I)] 4 level			
I₁ at branching	19.73	48.69	51.49
I₂ at branching + at flowering	30.76	52.37	53.26
I₃ at branching + at flowering + at pod formation	30.23	54.86	58.63
I₄ 0.6 IW: CPE ratio	30.49	49.34	53.39
S.Em.±	0.35	1.39	1.28
C.D. at 5%	NS	4.44	4.11
C. V %	7.00	10.84	9.50
Sub plot treatment [Growth Regulator (GR)] 4 level			
GR₀ (water spray)	30.06	49.33	51.28
GR₁ (NAA @ 25 ppm) at 40 DAS	30.56	54.25	57.01
GR₂ (IBA @ 25 ppm) at 40 DAS	30.49	50.29	53.71
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	30.10	51.39	54.14
S.Em.±	0.295	1.135	0.804
C.D.5%	NS	3.25	2.83
Interaction (I_xGR)	NS	Sig	Sig
C.V. %	5.81	8.85	7.29

4.3.2.3. (c) Interaction effect

The interaction effect between irrigation schedules based on critical growth stage and plant growth regulators on plant height at 60 DAS was recorded significantly the highest (66.30 cm) with the application of treatment I₃ irrigation at branching, at flowering and at pod formation and growth regulator GR₁ (NAA @ 25 ppm) at 40 DAS in Table 4.3. Significantly higher plant height found under the treatment combination.

I₂GR₁ (I₂ irrigation at branching, at flowering and GR₁ (NAA @ 25 ppm) at 40 DAS) which was remained at par with treatment combination I₂GR₂ (I₂ irrigation at branching, at flowering and GR₂ (IBA @ 25 ppm) at 40 DAS at 40 DAS), I₁GR₃ (I₁ irrigation at branching and GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS), I₄GR₃ (I₄ 0.6 IW: CPE ratio and GR₃ (Ascorbic Acid @ 20 ppm at 40 DAS) and I₃GR₀ (I₃ irrigation at branching, at flowering and at pod formation and GR₀ water spray).

Significantly lower plant height found under the treatment combination I₁GR₀ (I₁ irrigation at branching, and GR₀ (water spray) (46.2 cm) which was remained at par with the treatment combination I₁GR₁ (I₁ irrigation at branching, and GR₁ (NAA @ 25 ppm) at 40 DAS), I₄GR₂ (I₄ 0.6 IW: CPE ratio and GR₂ (IBA @ 25 ppm) at 40 DAS), I₁GR₂ (I₁ irrigation at branching, and GR₂ (IBA @ 25 ppm) at 40 DAS), I₂GR₃ (I₂ irrigation at branching, at flowering and GR₃ (Ascorbic Acid @ 20

ppm) at 40 DAS) , I₃GR₀ (I₃ irrigation at branching, at flowering and at pod formation and GR₀ water spray), I₄GR₀ (I₄ 0.6 IW: CPE ratio and GR₀ water spray), I₄GR₁ (I₄ 0.6 IW: CPE ratio and GR₁ (NAA @ 25 ppm) at 40

Interaction effect	Plant height at 60 DAS			
Irrigation schedules (I) 4 level	Growth Regulator (GR) 4 level			
	GR ₀ (water spray)	GR ₁ (NAA @ 25ppm) at 40 DAS	GR ₂ (IBA @ 25ppm) at 40 DAS	GR ₃ (Ascorbic Acid @20 ppm)at 40DAS
I ₁ at branching	46.2	47.9	46.4	54.3
I ₂ at branching + at flowering	49.9	55.7	55.4	48.6
I ₃ at branching + at flowering + at pod formation	51.3	66.3	53.1	48.8
I ₄ 0.6 IW: CPE ratio	48.3	48.7	46.5	53.9
S.Em±	2.0			
C. D. at 5 %	6.51			
C. V. %	8.85			

DAS), I₂GR₀ (I₂ irrigation at branching, at flowering and GR₀ water spray),

Table 4.3 Interaction effect of irrigation schedules based on critical growth stages and growth regulators on height at 60 DAS.

4.3.3.1.(a) Effect of irrigation schedules based on critical growth stages on plant height at harvest

An appraisal of data presented in Table 4.2 indicated that difference in plant height at harvest due to different irrigation schedules based on critical growth stage were significant. Among different irrigation schedules, treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly the tallest plants (58.63cm), treatment I₁ irrigation at branching recorded significantly lower plant height (51.49 cm), which was remained at par with treatment I₂ at branching and at flowering, (53.26 cm) and treatment I₄ irrigation at 0.6 IW: CPE ratio, (53.39 cm).

4.3.3.2.(b) Effect of growth regulators on plant height at harvest

Different plant growth regulators exerted their significant effect on plant height at harvest. Among different plant growth regulators, treatment GR₁ (NAA @ 25 ppm) at 40 DAS recorded significantly the highest plant height (57.01 cm), Treatment GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS,(54.14), (87.31 cm) being at par with treatment GR₂ (IBA @ 25 ppm) at 40 DAS, (53.71cm). Treatment GR₀ (Control-Water spray) recorded lower plant height (51.28 cm) which was remained at par with treatment GR₂ (IBA @ 25 ppm) at 40DAS, (53.71 cm).

Table 4.4 Interaction effect of irrigation schedules based on critical growth stages and plant growth regulators on height at harvest.

Interaction effect	Plant height at harvest			
Irrigation schedules (I) (4 level)	Growth Regulator (4 level)			
	GR ₀ (water spray)	GR ₁ (NAA @25ppm) at 40 DAS	GR ₂ (IBA @ 25ppm) at 40 DAS	GR ₃ (Ascorbi c Acid @20 ppm) at 40DAS
I₁ at branching	48.2	53.0	53.0	51.9
I₂ at branching + at flowering	52.8	52.4	54.1	53.9
I₃ at branching + at flowering + at pod formation	52.4	72.0	54.3	55.9
I₄ 0.6 IW: CPE ratio	51.9	53.2	53.6	55.0
S.Em ±	2.3			
C. D. at 5 %	5.67			
C. V. %	7.29			

4.3.3.3. (c) Interaction effect

Plant height at harvest was significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators in table 4.4. Application of I₃ irrigation at branching, at flowering and at pod formation with application of treatment GR₁ (NAA @ 25 ppm) at 40 DAS recorded the significantly the highest plant height (72.0 cm) at harvest. Treatment combinations

I₃GR₃(I₃ irrigation at branching, at flowering and at pod formation and application of treatment GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS), I₄GR₃(I₄ 0.6 IW: CPE ratio and GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS), I₃GR₂(I₃ irrigation at branching, at flowering and at pod formation and GR₂ (IBA @ 25 ppm) at 40 DAS), I₂GR₂(I₂ at branching and at flowering and GR₂ (IBA @ 25 ppm) at 40 DAS), I₂GR₃ (I₂ at branching and at flowering and GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS), I₄GR₂(I₄ 0.6 IW: CPE ratio and GR₂ (IBA @ 25 ppm) at 40 DAS), I₄GR₁(I₄ 0.6 IW: CPE ratio and GR₁ (NAA @ 25 ppm), I₁GR₂(I₁ at branching and GR₂ (IBA @ 25 ppm) at 40 DAS), I₂GR₁(I₂ at branching and at flowering and GR₁ (NAA @ 25 ppm) at 40 DAS), I₃GR₀(I₃ irrigation at branching, at flowering and at pod formation and GR₀ (water spray) were remained at par with each other. Treatment combination I₁GR₀ recorded significantly lower plant height. Which was remained at par with each other treatment combinations I₁GR₃ (I₁ irrigation at branching and GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS), I₂GR₀ (I₂ Irrigation at branching and at flowering and GR₀ (water spray), I₃GR₀ (I₃ irrigation at branching, at flowering and at pod formation and GR₀ water spray). Application of irrigation at all 3 critical growth stages with application of plant growth regulator NAA @ 25 ppm at 40 DAS significantly increased the plant height, it was found that application of only irrigation with water spray gave lower plant height it was identical

the response of plant growth regulator only with higher no. of irrigation application at all the three critical growth stage.

4.4. Number of days to 50 per cent flowering

The data regarding days to 50 % flowering as influenced by different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.5.

4.4.1. Effect of irrigation schedules based on critical growth stage on no. of days to 50 per cent flowering

Perusal of data presented in Table 4.5 indicated that a difference in days to 50 per cent flowering due to irrigation schedules based on critical growth stage was non- significant.

Table 4.5 No. of days to 50 per cent flowering influenced by irrigation schedules based on critical growth stages and plat growth regulators.

Treatments	No. of days to 50 per cent flowering
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	52.00
I₂ at branching + at flowering	50.50
I₃ at branching + at flowering + at pod formation	52.25
I₄ 0.6 IW:CPE ratio	54.56
S.Em. ±	0.92
C.D. at 5%	NS
C. V %	7.09
Sub plot treatment [Plant Growth Regulator (GR)] 4 level	
GR₀ (water spray)	52.81
GR₁ (NAA @ 25 ppm)at 40 DAS	49.63
GR₂ (IBA @ 25 ppm) at 40 DAS	53.50
GR₃ (Ascorbic Acid @ 20 ppm)at 40 DAS	53.38
S.Em. ±	0.39
C.D. at 5%	1.12
Interaction (IxGR)	Sig
C.V. %	3.00

4.4.2. Effect of growth regulators on days to 50 per cent flowering

Perusal of data presented in Table 4.5 indicated that differences in days to 50 per cent flowering due to different plant growth regulators was significant, treatment GR₂ (IBA @ 25 ppm) at 40 DAS being at par with treatments GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS and treatment GR₀ (Control-Water spray), The lowest no. of days to 50 per cent flowering was found significantly under treatment (GR₁ NAA @ 25 ppm) at 40 DAS.

Table 4.6 Interaction effect of irrigation schedules based on critical growth stages and growth regulators on no. of days to 50 per cent flowering.

	No. of days to 50 per cent flowering			
Irrigation schedules(I) 4 level	Growth Regulator 4 level			
	GR₀ (water spray)	GR₁ (NAA @ 25ppm) at 40 DAS	GR₂ (IBA @ 25ppm) at 40 DAS	GR₃ (Ascorbic Acid @20 ppm) at 40DAS
I₁ at branching	51.8	51.8	52.3	52.3
I₂ at branching + at flowering	52.0	45.0	53.0	52.0
I₃ at branching + at flowering + at pod formation	53.5	47.5	54.0	54.0
I₄ 0.6 IW:CPE ratio	54.0	54.3	54.8	55.3
S.Em±	0.8			
C. D. at 5 %	2.25			
C. V. %	3.00			

4.4.3. Interaction effect

Days to 50 % flowering was significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators in table 4.6.

Application of treatment combination I₂GR₁ (I₂ irrigation at branching at flowering and GR₁ (NAA @ 25 ppm) at 40 DAS) gave the significantly lowest No. of days to 50 per cent flowering (45.0) at harvest. While treatment combination I₄GR₃ recorded significantly higher no. of days to 50 % flowering (55.3), being at par with treatment combination I₄GR₂ (I₄ irrigation at 0.6 IW:CPE ratio and GR₂ (IBA @25 ppm) at 40 DAS), I₄GR₁(I₄ irrigation at 0.6 IW:CPE ratio and GR₁ (NAA @ 25 ppm) at 40 DAS), I₃GR₂ (I₃ irrigation at branching at flowering and at pod formation and GR₂ (IBA @25 ppm) at 40 DAS), I₃GR₃ (I₃ irrigation at branching at flowering and at pod formation and GR₃ (Ascorbic Acid @ 20 ppm)at 40 DAS), I₄GR₀ (I₄ irrigation at 0.6 IW:CPE ratio and GR₀ water spray), I₃GR₀(I₃ irrigation at branching at flowering and at pod formation and GR₀ water spray). Treatment combination I₂GR₂ (I₂ irrigation at branching at flowering and GR₂ (IBA @25 ppm) at 40 DAS), I₁GR₂ (I₁ irrigation at branching and GR₂ (IBA @25 ppm) at 40 DAS), I₁GR₃ (I₁ irrigation at branching and Ascorbic Acid @ 20 ppm) at 40 DAS), I₂GR₀(I₂ irrigation at branching at flowering and GR₀ water spray), I₂GR₃ (I₂ irrigation at branching at flowering and Ascorbic Acid @ 20 ppm) at 40 DAS, I₁GR₁ (I₁ irrigation at branching and GR₁ (NAA @ 25

ppm) at 40 DAS) and I_1GR_0 (I_1 irrigation at branching and GR_0 water spray) being at par with each other.

4.5 Days to maturity

The data pertaining to days to maturity as influenced due to different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.7.

4.5.1. Effect of irrigation schedules on days to maturity

Perusal of data presented in Table 4.7 indicated that a difference in days to maturity due to different irrigation schedules based on critical growth stage was significant. Among different irrigation schedules, treatment I_1 irrigation at branching required significantly the lowest days to maturity (94.81), treatment I_3 irrigation at branching, at flowering and at pod formation recorded significantly the maximum days to maturity (103.75).

4.5.2. Effect of growth regulators on days to maturity

Perusal of data presented in Table 4.7 indicated that differences in days to maturity due to different plant growth regulators was non-significant.

Table 4.7. Days to maturity by irrigation scheduling based on critical growth stages and growth regulators.

Treatments	Days to maturity
Main plot treatment [Irrigation (I)] 4 level	
I1 at branching	94.81
I2 at branching + at flowering	96.63
I3 at branching + at flowering + at pod formation	103.75
I4 0.6 IW:CPE ratio	100.75
S.Em. ±	1.93
C.D. at 5%	6.18
C. V %	7.81
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR0 water spray	99.88
GR1 (NAA @ 25 ppm)at 40 DAS	99.00
GR2(IBA @ 25 ppm) at 40 DAS	98.50
GR3 (Ascorbic Acid @ 20 ppm)at 40 DAS	98.56
S.Em. ±	0.85
C.D. at 5%	NS
Interaction (IxGR)	NS
C.V. %	3.44

4.5.3. Interaction effect

Days to maturity was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.6. Average no. of branches per plant

The data pertaining to average no. branches as influenced due to different irrigation schedules and plant growth regulators are presented in table 4.8.

4.6.1. Effect of irrigation schedules based on critical growth stages on average number of branches per plant

The average number of branches per plant was significantly influenced due to different irrigation schedules based on critical growth stage in Table 4.8. Among the irrigation treatments, treatment I₃ irrigation at branching, at flowering and at pod formation gave significantly higher average no. of branches per plant (7.68) which was remained at par with treatment I₄ 0.6 IW: CPE ratio (7.30). Significantly lower average no. branches was found under the treatment I₁ (6.49) irrigation at branching, being at par with treatment I₂ irrigation at branching and flowering (6.64).

Table 4.8 Average no. of branches per plant influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Average no. of branches per plant
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	6.49
I₂ at branching + at flowering	6.64
I₃ at branching + at flowering + at pod formation	7.68
I₄ 0.6 IW:CPE ratio	7.30
S.Em. ±	0.16
C.D. at 5%	0.53
C. V %	9.53
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ water spray	6.86
GR₁ (NAA @ 25 ppm) at 40 DAS	7.06
GR₂ (IBA @ 25 ppm) at 40 DAS	7.01
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	7.16
S.Em. ±	0.07
C.D. at 5%	0.20
Interaction (IxGR)	Sig
C.V. %	4.11

4.6.2. Effect of growth regulators on average number of branches per plant

The results presented in table 4.8 revealed that average number of branches per plant was significantly influenced due to application of the plant growth regulators. Among different plant growth regulator, treatment GR₃ (Ascorbic Acid @20 ppm) at 40 DAS recorded significantly higher average no. of branches (7.16), which being at par with treatment GR₁ (NAA @25 ppm) at 40 DAS (7.06) and GR₂ (IBA @25 ppm) at 40 DAS (7.01), respectively. The significantly lower average no. of branches per plant was observed under treatment GR₀ (control-Water spray) (6.86), which being at par with treatments GR₂ (IBA @25 ppm) at 40 DAS (7.01) and GR₁ (NAA @25 ppm) at 40 DAS (7.06). respectively.

Table 4.9 Interaction effect of irrigation schedules based on critical growth stages and growth regulators on average no. of branches.

Interaction effect	Average no. of branches per plant			
Irrigation schedules (I) 4 level	Growth Regulator (GR) 4 level			
	GR ₀ (water spray)	GR ₁ (NAA @ 25ppm) at 40 DAS	GR ₂ (IBA @ 25ppm) at 40 DAS	GR ₃ (Ascorbi c Acid @20 ppm) at 40DAS
I ₁ at branching	6.2	6.6	6.4	6.6
I ₂ at branching + at flowering	6.3	6.5	6.8	7.3
I ₃ at branching + at flowering + at pod formation	7.5	8.2	7.6	7.6
I ₄ 0.6 IW:CPE ratio	7.3	7.4	7.4	7.3
S.Em±	0.1			
C. D. at 5 %	0.41			
C. V. %	4.11			

4.6.3. Interaction effect

The interaction effect between treatment I₃ irrigation at branching, at flowering and at pod formation irrigation schedules based on critical growth stages and growth regulators, application of GR₁ (NAA @25ppm) at 40 DAS on average no. of branches observed significantly highest (8.20) in table 4.9. Significantly lower average no. of branches recorded under treatment I₁ irrigation at branching and GR₀ (water spray)

(6.2), which was remained at par with treatment combinations I₂GR₀ (I₂ irrigation at branching at flowering, GR₀ control-Water spray), I₁GR₂ (I₁ irrigation at branching and GR₂, IBA @25 ppm) and I₂GR₂ (I₂ irrigation at branching and at flowering and GR₂, IBA @25 ppm), I₁GR₁ (I₁ irrigation at branching and GR₁ (NAA @25ppm) at 40 DAS), I₁GR₃(I₁ irrigation at branching and GR₃ (Ascorbic Acid @20 ppm) at 40DAS.

4.7. Average number of pods per plant

The data regarding to average number of pods per plant as influenced by different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.10.

4.7.1. Effect of irrigation schedules based on critical growth stage on average number of pods per plant

The results given in table 4.10 revealed that the average number of pods per plant was significantly influenced due to different irrigation schedules based on critical growth stage. Among different irrigation schedules, treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly the highest average number pods per plant (89.75), treatments I₂ irrigation at branching and at flowering gave (81.28), I₄ (0.6 IW: CPE ratio), (76.23) being at par with each others. Treatment I₁ produced significantly lower number of pods per plant (74.71) which was remained at par with treatment I₄ (0.6IW: CPE ratio) (76.23).

Table 4.10 Average no. of pods per plant influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	average no. of pods per plant
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	74.71
I₂ at branching + at flowering	81.28
I₃ at branching + at flowering + at pod formation	89.75
I₄ 0.6 IW:CPE ratio	76.23
S.Em. ±	1.96
C.D. at 5%	6.27
C. V %	9.74
Sub plot treatment [Plant Growth Regulator (GR)] 4 level	
GR₀ water spray	79.04
GR₁ (NAA @ 25 ppm) at 40 DAS	85.15
GR₂ (IBA @ 25 ppm) at 40 DAS	79.23
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	78.55
S.Em. ±	0.72
C.D. at 5%	2.07
Interaction (IxGR)	Sig
C.V. %	3.60

4.7.2. Effect of growth regulators on average number of pods per plant.

The results given in table 4.10 indicated that average number of pods per plant was significantly influenced due to application of the plant growth regulators. Among different plant growth regulators, treatment GR₁ (NAA @ 20 ppm) at 40 DAS recorded the highest average number of pods per plant (85.15). The lowest average number of pods per plant (79.04) was observed under the treatment GR₀ (Control- water spray), which was remained at par with the treatments GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS (78.55), GR₂ (IBA @ 25 ppm) at 40 DAS, (79.23), respectively.

Table 4.11 Interaction effect of irrigation schedules based on critical growth stages and growth regulators on average no. of pods.

Interaction effect	Average no. of pods per plant			
	Growth Regulator (GR) 4 level			
Irrigation schedules (I) 4 level	GR ₀ (water spray)	GR ₁ (NAA @ 25ppm) at 40 DAS	GR ₂ (IBA @ 25ppm) at 40 DAS	GR ₃ (Ascorbi c Acid @20 ppm) at 40DAS
I₁ at branching	73.2	75.6	75.0	75.1
I₂ at branching + at flowering	82.0	83.2	80.3	79.7
I₃ at branching + at flowering + at pod formation	86.3	107.0	82.3	83.5
I₄ 0.6 IW:CPE ratio	74.7	74.8	79.4	76.0
S.Em±	1.4			
C. D. at 5 %	4.16			
C. V. %	3.60			

4.7.3. Interaction effect

The interaction effect presented in table 4.11 indicated that treatment combination I_3GR_1 irrigation at branching, at flowering and at pod formation irrigation schedules based on critical growth stage and plant growth regulator GR_1 (NAA @ 20 ppm) at 40 DAS recorded significantly the highest (107.0) average no. pods per plant. Treatment combinations I_3GR_0 (I_3 irrigation at branching, at flowering and at pod formation, GR_0 control-Water spray), I_3GR_3 (I_3 irrigation at branching, at flowering and at pod formation, GR_3 (Ascorbic Acid @ 20 ppm) at 40 DAS), I_2GR_1 (I_2 irrigation at branching, at flowering, GR_1 (NAA @ 20 ppm) at 40 DAS) and I_3GR_2 (I_3 irrigation at branching, at flowering and at pod formation and GR_2 (IBA @ 25 ppm) at 40 DAS). Significantly lower average no. of pods per plant observed under treatment combination I_1GR_0 (I_1 irrigation at branching, and GR_0 control-Water spray) (73.2) which was remained at par with treatment combination I_4GR_0 (I_4 0.6 IW:CPE ratio and GR_0 control-Water spray), I_4GR_1 (I_4 0.6 IW:CPE ratio and GR_1 (NAA @ 20 ppm) at 40 DAS), I_1GR_1 (I_1 irrigation at branching and GR_1 (NAA @ 20 ppm) at 40 DAS), I_1GR_3 (I_1 irrigation at branching and GR_3 (Ascorbic Acid @20 ppm) at 40DAS), I_1GR_2 (I_1 irrigation at branching and GR_2 (IBA @ 25 ppm) at 40 DAS) here average no. pods reduces with moisture stress. Also the treatment combination I_3GR_2 (I_3 irrigation at branching, at flowering and at pod formation and GR_2 (IBA

@ 25 ppm) at 40 DAS), I₂GR₀ (I₂ irrigation at branching, at flowering and GR₀ control-Water spray, I₂GR₃ (I₂ irrigation at branching, at flowering and GR₃ (Ascorbic Acid @20 ppm) at 40DAS) and I₄GR₂ (I₄ 0.6 IW:CPE ratio and at pod formation and GR₂ (IBA @ 25 ppm) at 40 DAS) remained at par with each other. From above table we can conclude that irrigation at critical growth stage with application of growth regulator increases the average no. of pods per plant.

4.8. Average number of seeds per pod

The data regarding to the number of seeds per pod as influenced by different irrigation schedules based on critical growth stage and plant growth regulators are presented in table 4.12.

4.8.1. Effect of irrigation schedules based on critical growth stage on average no. of seeds per pod.

An appraisal of data presented in table 4.12 indicated that average no. of seeds per pod due to different irrigation schedules based on critical growth stage was found non-significant.

4.8.2 Effect of growth regulators on average no. of seeds per pod

The effect of different plant growth regulator treatments was also non-significant.

Table 4.12 Average no of seeds per pod influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Average no. of seed per pod
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	1.25
I₂ at branching + at flowering	1.28
I₃ at branching + at flowering + at pod formation	1.25
I₄ 0.6 IW:CPE ratio	1.24
S.Em. ±	0.042
C.D. at 5%	NS
C. V %	13.32
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	1.18
GR₁ (NAA @ 25 ppm) at 40 DAS	1.30
GR₂ (IBA @ 25 ppm) at 40 DAS	1.28
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	1.26
S.Em. ±	0.035
C.D. at 5%	NS
Interaction (IxGR)	NS
C.V. %	11.23

4.8.3. Interaction effect

Average no. of seeds per pod was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.9. Seed yield (kg ha^{-1})

The data pertaining to seed yield as influenced due to different irrigation schedules based on critical growth stage and plant growth regulators are presented in table 4.13.

4.9.1. Effect of different irrigation schedules based on critical growth stages on seed yield

An appraisal of data presented in table 4.13 indicated that difference in seed yield as influenced due to different irrigation schedules based on critical growth stage was significant. Among different treatments, treatment I_3 irrigation at branching, at flowering and at pod formation recorded significantly higher seed yield (2570 kg ha^{-1}), which was remained at par with treatment I_4 (2444 kg ha^{-1}). Treatment I_4 0.6 IW: CPE ratio was also remained at par with treatment I_2 irrigation at branching and at flowering, (2308 kg ha^{-1}). Significantly lowest seed yield was observed under treatment I_1 irrigation at branching, (1956 kg ha^{-1}). There is increase in yield of I_3 irrigation at branching, at flowering and at pod formation in the tune of 23% over I_1 irrigation at branching and increase in yield over control by 5% and also over I_2 irrigation at branching, at flowering by 10.19%.

Table 4.13 Seed yield kg ha^{-1} as influenced by irrigation schedules based on critical growth stage and growth regulators.

Treatments	Seed yield kg ha ⁻¹
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	1956
I₂ at branching + at flowering	2308
I₃ at branching + at flowering + at pod formation	2570
I₄ 0.6 IW:CPE ratio	2442
S.Em. ±	72.82
C.D. at 5%	232.98
C. V %	12.56
Sub plot treatment [Growth Regulator] (GR) 4 level	
GR₀ (water spray)	2195
GR₁ (NAA @ 25 ppm) at 40 DAS	2404
GR₂ (IBA @ 25 ppm) at 40 DAS	2278
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	2400
S.Em. ±	59.14
C.D. at 5%	169.64
Interaction (IxGR)	Sig
C.V. %	10.20

4.9.2. Effect of growth regulators on seed yield (Kg ha⁻¹)

An appraisal of data presented in table 4.13 indicated that different plant growth regulators exerted their significant effect on seed yield. Among different growth regulators, treatment GR₁ (NAA @ 25ppm) at 40 DAS recorded significantly higher seed yield (2404 kg ha⁻¹), which was remained at par with treatments GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS (2400 kg ha⁻¹) and GR₂ (IBA @ 25 ppm) at 40 DAS. Significantly lower seed yield was found under treatment GR₀ (water spray), which was remained at par with treatment GR₂ (IBA @ 25 ppm) at 40 DAS. Seed yield increasing at the extent of 8.6% over control GR₀ (water spray) by GR₁ (NAA @ 25ppm) at 40 DAS. Seed yield increasing in the tune of 5.24% over GR₂ (IBA @ 25 ppm) at 40 DAS and over GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS by 16%.

4.9.3. Interaction effect

An appraisal of data presented in table 4.14 indicated that Seed yield was significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators. The interaction effect between treatment I₃ at branching, at flowering and at pod formation irrigation schedules and plant growth regulator GR₁ (NAA @ 20 ppm) at 40 DAS on seed yield kg ha⁻¹ was found significantly higher which was remained at par with treatment combination I₄GR₃ (I₄ 0.6 IW: CPE ratio and GR₃ (Ascorbic Acid @20 ppm) at 40DAS), I₄GR₁ (I₄ 0.6 IW: CPE ratio and GR₁ (NAA @ 20 ppm)

at 40 DAS) and also treatment combination I_4GR_3 (I_4 0.6 IW: CPE ratio and GR_3 (Ascorbic Acid @20 ppm) at 40DAS) recorded significant seed yield (2692kg/ha) which was remained at par with I_3GR_0 (I_3 at branching, at flowering and at pod formation irrigation schedules and GR_0 water spray), I_4GR_0 (I_4 0.6 IW: CPE ratio and GR_0 water spray), I_3GR_2 (I_3 at branching, at flowering and at pod formation irrigation schedules and GR_2 (IBA @ 25ppm) at 40 DAS), I_3GR_3 (I_3 at branching, at flowering and at pod formation irrigation schedules and GR_3 (Ascorbic Acid @20 ppm) at 40DAS), I_2GR_3 (I_2 at branching, at flowering and GR_1 (NAA @ 20 ppm) at 40 DAS), I_2GR_2 (I_2 at branching, at flowering and GR_2 (IBA @ 25ppm) at 40 DAS).

Also significantly lower seed yield was found under treatment combination I_1GR_0 (I_1 at branching and GR_0 water spray) (1683 Kg ha⁻¹), which was remained at par with treatment combination I_1GR_2 (I_1 at branching and GR_2 (IBA @ 25ppm) at 40 DAS), I_4GR_2 (I_4 0.6 IW: CPE ratio and GR_2 (IBA @ 25ppm) at 40 DAS) and also I_4GR_2 (I_4 0.6 IW: CPE ratio and GR_2 (IBA @ 25ppm) at 40 DAS) recorded significant yield (1910kg ha⁻¹) which was remained at par with I_1GR_2 (I_1 at branching and GR_2 (IBA @ 25ppm) at 40 DAS), I_2GR_0 (I_2 at branching, at flowering and GR_0 water spray), I_1GR_3 (I_1 at branching and GR_3 (Ascorbic Acid @20 ppm), I_2GR_3 (I_2 at branching, at flowering and GR_3 (Ascorbic Acid @20 ppm)).

Table 4.14 Interaction effect of irrigation schedules based on critical growth stages and growth regulators on Seed yield (kg ha^{-1}).

Interaction effect	Seed yield			
	Growth Regulator (GR) 4 level			
Irrigation schedules (I) 4 level	GR ₀ (water spray)	GR ₁ (NAA @ 25ppm) at 40 DAS	GR ₂ (IBA @25ppm)a t 40 DAS	GR ₃ (Ascorbic Acid @20 ppm) at 40DAS
I ₁ at branching	1683	1823	2097	2222
I ₂ at branching + at flowering	2220	2448	2326	2240
I ₃ at branching + at flowering + at pod formation	2535	2847	2448	2448
I ₄ 0.6 IW:CPE ratio	2535	2639	1910	2692
S.Em $\pm$	118.3			
C. D. at 5 %	339.29			
C. V. %	10.20			

4.10. Dry gotar yield (kg ha^{-1})

The data pertaining to dry gotar yield Kg ha^{-1} as influenced due to different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.15.

4.10.1. Effect of irrigation schedules based on critical growth stage on

Dry gotar yield.

An appraisal of data presented in Table 4.15 indicated that difference in dry gotar yield influenced due to different irrigation schedules based on critical growth stage was significant. Among different treatments, treatment I₃ irrigation at branching, at flowering and at pod formation recorded the significantly the higher dry gotar yield ($4633.26 \text{ kg ha}^{-1}$), which was remained at par with treatment I₄ 0.6 IW: CPE ratio ($4340.28 \text{ kg ha}^{-1}$).

Table 4.15 Dry gotar yield (kg ha⁻¹) influenced by irrigation schedules based on critical growth stages and plant growth regulators.

Treatments	Dry gotar yield
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	3542
I₂ at branching + at flowering	3819
I₃ at branching + at flowering + at pod formation	4633
I₄ 0.6 IW:CPE ratio	4340
S.Em. ±	153.04
C.D. at 5%	489.60
C. V %	14.99
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	4247
GR₁ (NAA @ 25 ppm) at 40 DAS	3884
GR₂ (IBA @ 25 ppm) at 40 DAS	4040
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	4162
S.Em. ±	142.07
C.D. at 5%	NS
Interaction (I×GR)	NS
C.V. %	13.92

4.10.2. Effect of growth regulators on dry gotar yield (Kg ha⁻¹)

Different plant growth regulators exerted their significant effect on dry gotar yield was non- significant.

4.10.3. Interaction effect

An appraisal of data presented in Table 4.15 indicated that dry gotar yield was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.11. Harvest Index (%)

The data pertaining to harvest index as influenced due to different irrigation schedules based on critical growth stages and plant growth regulators are presented in table 4.16.

4.11.1 Effect of irrigation schedules based on critical growth stages on Harvest Index

An appraisal of data presented in Table 4.16 indicated that difference in harvest index due to different irrigation schedules was non - significant.

Table 4.16 Harvest Index (%) influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Harvest Index
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	35.63
I₂ at branching + at flowering	37.87
I₃ at branching + at flowering + at pod formation	35.86
I₄ 0.6 IW:CPE ratio	36.22
S.Em. ±	1.40
C.D. at 5%	NS
C. V %	15.41
Sub plot treatment [Plant Growth Regulator (GR)] 4 level	
GR₀ (water spray)	34.31
GR₁ (NAA @ 25 ppm) at 40 DAS	38.00
GR₂ (IBA @ 25 ppm) at 40 DAS	36.29
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	36.98
S.Em. ±	1.02
C.D. at 5%	NS
Interaction (IxGR)	Sig
C.V. %	11.24

4.11.2 Effect of growth regulators on harvest index

The effect of different plant growth regulator treatments was non-significant.

Table 4. 17 Interaction effect of irrigation schedules based on critical growth stages and plant growth regulators on Harvest Index (%).

Interaction effect	Harvest Index			
	Growth Regulator (GR) 4 level			
Irrigation schedules (I) 4 level	GR ₀ (water spray)	GR ₁ (NAA @ 25ppm) at 40 DAS	GR ₂ (IBA @ 25ppm) at 40 DAS	GR ₃ (Ascorbi c Acid @ 20 ppm) at 40DAS
I₁ at branching	35.3	31.9	34.5	40.8
I₂ at branching + at flowering	37.3	39.5	40.0	34.7
I₃ at branching + at flowering + at pod formation	34.8	42.1	31.5	35.0
I₄ 0.6 IW:CPE ratio	37.8	38.5	31.2	37.4
S.Em±	2.0			
C. D. at 5 %	5.87			
C. V. %	11.24			

4. 11.3. Interaction effect

Harvest index was significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators in Table 4.17. The significantly higher harvest index (42.1%) was observed under treatment combination I₃GR₁ application of treatment (I₃ irrigation at branching, at flowering and pod formation and

application of GR₂ (IBA @ 25 ppm) at 40 DAS) which was remained at par with treatment combinations I₁GR₃ (I₁irrigation at branching and GR₃ Ascorbic Acid @ 20 ppm at 40 DAS), I₂GR₂ (irrigation at branching, at flowering and GR₂ IBA @ 25 ppm at 40 DAS), I₂GR₁(I₂ irrigation at branching, at flowering and GR₂ IBA @ 25 ppm at 40 DAS), I₄GR₀ (0.6 IW:CPE ratio and GR₀ water spray), I₄GR₃ (I₄ 0.6 IW:CPE ratio and Ascorbic Acid @ 20 ppm at 40 DAS), I₂GR₀ (I₂ irrigation at branching, at flowering and GR₀ water spray).

4.12. Test weight of 100 seed (g)

The data regarding test weight as influenced by different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.18.

Table 4.18 Test weight of 100 seed (g) influenced by irrigation schedules based on critical growth stage and growth regulator.

Treatments	Test weight
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Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	18.00
I₂ at branching + at flowering	18.71
I₃ at branching + at flowering + at pod formation	19.94
I₄ 0.6 IW:CPE ratio	18.16
S.Em. ±	0.43
C.D. at 5%	1.38
C. V %	9.23
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	18.56
GR₁ (NAA @ 25 ppm) at 40 DAS	19.18
GR₂ (IBA @ 25 ppm) at 40 DAS	18.38
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	18.69
S.Em. ±	0.34
C.D. at 5%	NS
Interaction (IxGR)	NS
C.V. %	7.46

4.12.1. Effect of irrigation schedules based on critical growth stage on test weight of 100 seed (g).

Perusal of data presented in Table 4.18 indicated that a difference on test weight due to different irrigation schedules based on critical growth stage was significant. Among different irrigation

schedules based on critical growth stage, treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly higher 100 seed weight (19.94g) which was remained at par with the treatment I₂ irrigation at branching, at flowering (18.71g). The significantly lowest seed weight was found under treatment I₁ irrigation at branching (18.00g).

4.12.2 Effect of growth regulators on Test weight of 100 seed.

The effect of different plant growth regulator treatments was non-significant.

4.12.3. Interaction effect

Test weight was non-significantly affected due to interaction effect between different irrigation schedules based on critical growth stage and plant growth regulators.

4.12 Protein (%)

The data pertaining to protein per cent as influenced due to different irrigation schedules based on critical growth stage and plant growth regulators are presented in Table 4.19.

Table 4.19 Protein (%) influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Protein
Main plot treatment [Irrigation (I)] 4 level	

I₁ at branching	19.90
I₂ at branching + at flowering	20.32
I₃ at branching + at flowering + at pod formation	21.84
I₄ 0.6 IW:CPE ratio	20.30
S.Em. ±	0.372
C.D. at 5%	1.19
C. V %	7.23
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	20.13
GR₁ (NAA @ 25 ppm) at 40 DAS	20.55
GR₂ (IBA @ 25 ppm) at 40 DAS	20.88
GR₃ (Ascorbic Acid) @ 20 ppm at 40 DAS	20.80
S.Em. ±	0.35
C.D. at 5%	NS
Interaction (IxGR)	NS
C.V. %	6.95

4.13.1 Effect of irrigation schedules based on critical growth stage on protein(%)

An appraisal of data presented in Table 4.19 indicated that the difference on protein % due to different irrigation schedules based on critical growth stage was significant. Significantly the highest protein content (21.84%) was observed under treatment I₃ irrigation at

branching, at flowering and at pod formation. Treatment I₁ (19.90%) gave significantly lower protein % which was remained at par with treatments I₄ (0.6 IW: CPE ratio) (20.30%) and I₂ irrigation at branching and at flowering (20.32%).

4.13.2. Effect of t growth regulators on protein %

Different plant growth regulators exerted their non significant effect on protein %.

4.13.3. Interaction effect

Protein % was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and plant growth regulators.

4.14. Consumptive use of water (mm)

The mean values of consumptive use of water as influenced by different irrigation scheduling based on critical growth stage and growth regulators are illustrated in Table 4.20.

Table 4.20 Consumptive use of water (mm) influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Mean Consumptive use of water
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	95.58

I₂ at branching + at flowering	149.77
I₃ at branching + at flowering + at pod formation	199.68
I₄ 0.6 IW:CPE ratio	191.23
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	149.72
GR₁ (NAA @ 25 ppm) at 40 DAS	159.84
GR₂ (IBA @ 25 ppm) at 40 DAS	153.50
GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS	152.18

4.14.1. Effect of irrigation schedules based on critical growth stages on consumptive use of water (mm)

The data revealed that the mean consumptive use of water was influence due to different irrigation schedules based on critical growth stage. The highest consumptive use of water (199.68 mm) recorded under treatment I₃ irrigation at branching, at flowering and at pod formation, followed by treatment I₄ 0.6 IW: CPE ratio, (191.23 mm) I₂ irrigation at branching and at flowering (149.77), and I₁ irrigation at

branching, (95.58 mm). While, the lowest consumptive use of water increased with the increased in the quantity of irrigation water.

4.14.2 Effect of plant growth regulators on consumptive use of water (mm)

The results further indicated (Table 4.20) that mean consumptive use of water was also influenced due to application of different plant growth regulators. The highest consumptive use of water (159.84mm) was recorded under treatment GR₁ (NAA @ 25 ppm) at 40 DAS, followed by treatment (153.50mm) was noticed under treatment GR₂ (IBA @ 25 ppm) at 40 DAS and treatment GR₃ (Ascorbic Acid @ 20 ppm at 40 DAS, 152.18mm). The lower consumptive use of water GR₀ (control- water spray, 149.72 mm).

4.15. Water use efficiency (kg ha⁻¹-mm).

The mean values of water use efficiency as influenced by different irrigation scheduling based on critical growth stage and growth regulators are illustrated in Table 4.21.

Table 4.21 Water use efficiency (kg ha⁻¹-mm) influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Mean Water use efficiency
Main plot treatment [Irrigation (I)] 4 level	

I₁ at branching	19.84
I₂ at branching + at flowering	15.41
I₃ at branching + at flowering + at pod formation	12.87
I₄ 0.6 IW:CPE ratio	12.78
Sub plot treatment [Growth Regulator (GR)] 4 level	
GR₀ (water spray)	14.66
GR₁ (NAA @ 25 ppm) at 40 DAS	15.04
GR₂ (IBA @ 25 ppm) at 40 DAS	14.84
GR₃ (Ascorbic Acid) @ 20 ppm at 40 DAS	15.77

4.15.1. Effect of irrigation schedules based on critical growth stages on water use efficiency (kg ha⁻¹-mm).

From the data Table 4.21, the results revealed that the mean water use efficiency was influenced due to different irrigation schedules based on critical growth stage. The highest water use efficiency (19.84 kg ha⁻¹-mm) was recorded I₁ irrigation at branching followed by treatments I₂ irrigation at branching and at flowering. While the lowest water use efficiency (12.78 kg ha⁻¹-mm) recorded under treatment I₄ 0.6 IW:CPE ratio.

4.15.2. Effect of growth regulators on water use efficiency kg ha⁻¹-mm.

The data presented in Table 4.21 indicated that water use efficiency was influenced due to different treatments of plant growth regulator. The highest water use efficiency (15.77 kg ha⁻¹-mm) was observed under treatment GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS, followed by treatment GR₁ (NAA @ 25 ppm) at 40 DAS and GR₂ IBA @ 25 ppm at 40 DAS. The lowest water use efficiency (14.66 kg ha⁻¹-mm) was recorded under GR₀ (water spray).

4.16. Disease index (%)

The mean values of disease index as influenced by different irrigation scheduling based on critical growth stage and growth regulators are illustrated in Table 4.22.

Table 4.22 Disease index (%) influenced by irrigation schedules based on critical growth stages and growth regulators.

Treatments	Disease index
Main plot treatment [Irrigation (I)] 4 level	
I₁ at branching	0.52
I₂ at branching + at flowering	0.50
I₃ at branching + at flowering + at pod formation	0.52
I₄ 0.6 IW:CPE ratio	0.53
S.Em. ±	0.019
C.D. at 5%	NS
C. V %	14.39

Sub plot treatment [Growth Regulator (GR)] 4 level	
GR ₀ (water spray)	0.50
GR ₁ (NAA @ 25 ppm) at 40 DAS	0.54
GR ₂ (IBA @ 25 ppm) at 40 DAS	0.51
GR ₃ (Ascorbic Acid) @ 20 ppm at 40 DAS	0.51
S.Em. $\pm$	0.014
C.D. at 5%	NS
Interaction (IxGR)	NS
C.V. %	10.59

4.16. 1Effect of irrigation schedules based on critical growth stages on Disease index (%).

An appraisal of data presented in Table 4.22 indicated that difference disease index due to different irrigation schedules based on critical growth stage was non-significant.

4.16.2. Effect of growth regulators on Disease index (%).

The effect of different plant growth regulator was non-significant.

4.16.3. Interaction effect

Disease index was non-significantly affected due to interaction effect between irrigation schedules based on critical growth stage and growth regulators.

DISCUSSION

A brief discussion of the results obtained from the present investigation entitled “Influence of irrigation schedules based on critical growth stages and growth regulators on growth, yield attributes and seed yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions”. has been presented in this chapter. It has been attempted to establish “effect and cause” relationship in the light of available evidences and literature. For the sake of convenience, the entire chapter has been divided into following heads.

5.1 EFFECT OF WEATHER ON CHICKPEA CROP IN WINTER SEASON

5.2 EFFECT OF IRRIGATION SCHEDULES

5.3 EFFECT OF PLANT GROWTH REGULATORS

5.4 INTERACTION EFFECT

5.5 ECONOMICS

5.1 EFFECT OF WEATHER PARAMETERS AND SOIL

Among the various factors responsible for affecting the yield and performance of crop, the weather conditions play a key role. The various weather parameters pertaining during 2009-10 crop season are presented in table (3.1) and graphically depicted in Fig. (3.1). It is evident from the data that all the meteorological parameters were congenial for normal crop growth and development. The maximum and minimum temperature was also normal. There was no off season rain during the experimental period. As a result, the

crop growth was normal and hence the entire effects of the crop were assigned to the treatment effect only.

The overall soil conditions at the time of sowing of chickpea were favourable for good crop germination as revealed from the better plant stand. None of the treatment had significant influence on germination of seeds. This indicated that whatever difference observed in growth and yield attributes were mainly due to the treatment effects.

5.2 EFFECT OF IRRIGATION SCHEDULES BASED ON CRITICAL GROWTH STAGE

5.2.1 Plant population

To obtain maximum possible yield, it is essential for crop to utilize equitably and efficiently all available factors viz., water, nutrients, light and CO₂. This could be achieved by uniform plant population. Plant stand during initial stage was maintained uniformly by thinning and gap-filling. However, plant stand recorded at 30 DAS and at harvest was non-significant by different irrigation treatments. This indicated that whatever differences were observed in growth and yield attributes were mainly due to treatment effects in table 4.1.

5.2.2 Growth attributes

Different irrigation schedules treatments exhibited non-significant influence on plant height recorded at 30 DAS. Plant height at 60 DAS and at harvest table 4.2 of chickpea was significantly influenced

due to different irrigation schedules. Among different irrigation schedules, treatments I_4 (0.6 IW: CPE ratio) and I_3 irrigation at branching, at flowering and at pod formation recorded significantly the maximum plant height 54.86 cm and 58.63 cm at 60 DAS and at harvest, respectively. Adequate and timely supply of irrigation water must be ensured for normal growth and development of chickpea.

It was also envisaged to determine the effect of soil moisture stress for the adequacy at different physiological growth stages upon the performance of high yielding chickpea cultivar GG-1. This aspect of water management is specially important when the water supply is either limited or plenty. Moreover, water being a costly input, there is a need to improve its efficiency or its utilization in order that for unit quantity of water a comparative high rate of production would be achieved. Similar effect of irrigation on plant height was observed by Prabhakar and saraf (1991)

Perusal of data presented in Table (4.5) revealed that a difference in days to 50 % flowering due to irrigation schedules based on critical growth stage was non- significant. Among different irrigation schedules, treatment I_1 irrigation at branching required significantly the minimum days to maturity (94.81) presented in table (4.7), treatment I_3 irrigation at branching, at flowering and at pod formation required significantly the maximum days to maturity (103.75). Due to moisture

stress there is earlier flowering was found in only one irrigation I_1 -irrigation at branching.

In dicot plants, number of branches is one of the basic yield components. The results presented in Table (4.8). indicated that irrigation scheduling irrigation I_3 at all critical growth stage i.e irrigation at branching, at flowering and at pod formation exerted notable impact in the improvement of number of branches per plant. It produced significantly higher average no. of branches per plant(7.68).

The growth of branches depends on progressive initiation of tissue and expansion of cell under these treatments due to increased water supply which might have helped nutrient mobilization and thereby making the plant physiologically more active. The results are in agreement with the finding of Reddy and Ahlawat (1998).

5.2.3 Effect on yield attributes and yield

The yield attributes viz., average no. of pods per plant, as well as seed yield, dry gotar yield and test weight were significantly influenced due to irrigation treatment Average no. of pods per plant was significantly influenced due to increase in the irrigation frequencies under the treatment I_3 irrigation at branching, at flowering and at pod formation recorded significantly the highest average number pods per plant (89.75), the reduction in average no. of pods per plant in treatments receiving less no. of irrigation i.e treatment I_1 (irrigation at branching) could be due to

increased moisture stress in plant which might have affected the flowering proliferation and untimely produced small and less no. of pods, resulting in lower yield under treatment I₁ irrigation at branching as compared to those of higher frequency under irrigation treatment I₂ irrigation at branching. Different irrigation schedules produced significant influence on seed yield table (4.15). Treatment I₃ irrigation at branching, at flowering and at pod formation recorded maximum the seed yield (2570 kg ha⁻¹) but it was remained at par with the treatment irrigation at I₄ 0.6 IW: CPE ratio. These results are in the consonance with those reported by Naresh *et al.* (1985), Khushawaha *et al.* (1985), Dobariya (1985), Shinde *et al.* (1985), Ramshe *et al.* (1987), Parihar (1990).

This was evidently due to the cumulative effect of improvement in the growth and yield attributes such as plant height, average no. of branches per plant table 4.8, number of pods per plant, and test weight Table(4.18). These results are also in consonance with those reported by Ghatol *et al.* (1998) Abraham *et al* (2010). Remarkably lower seed yield was registered under the irrigation treatment I₁ irrigation at branching. This might be due to reduce rate of water supply leads to keep the stomata closed, thus indirectly impairing the actual process of photosynthesis. Efficiency of conversion of dry matter to seed yield. Hence, moisture stress at flowering and pod development stages caused progressively adverse effect on growth and yield attributes which have reflected on seed yield.

Reduction in yield under one irrigation than two or three irrigations was also observed by Srivastav *et al.* (1991). Khushawaha *et al.* (1985)

Dry gotar was also higher under higher number of irrigation. results clearly indicated that the differences in straw yield was significant treatment I₃ irrigation at branching, at Flowering and at pod formation produced significantly the highest dry gotar yield (4633 Kg/ha) over treatment I₁ irrigation at branching and I₂ irrigation at branching, at flowering. The increase in dry gotar yield was (23.54%) and (18.75%) per cent over treatment I₁ irrigation at branching and I₂ irrigation at branching, at flowering, respectively. Higher dry gotar yield with more number of irrigation in chickpea was also reported by Naresh *et al.* (1985), Nimje (1991) and Srivastav *et al.* (1991).

Harvest index (Table 4.8) was non significantly affected due to schedule of irrigation table no (4.16). Treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly higher test weight (19.94 g) which was remained at par with the treatment I₂ irrigation at branching, at flowering (18.71 g).

5.2.4Effect on Quality

Reference to the results of protein content in seed (Table 4.9), it was revealed that protein content was significantly influenced by irrigation schedules. Treatment I₃ irrigation at branching, at flowering and at pod formation recorded significantly the highest protein content (21.84%),

Treatment I₁ irrigation at branching (19.90%) gave significantly lower protein %. The increase in protein content under higher frequency of irrigation might be due to more availability of nitrogen, which might have caused higher nitrogen content in seed (Table 4.19) results into higher protein content in seed.

5.2.5 Effect on water use

The total quantity of water applied were different irrigation treatments, like I₁ irrigation at branching, I₂ irrigation at branching, at flowering and I₃ irrigation at branching, at flowering and at pod formation and treatment I₄ (0.6 IW: CPE ratio), with the depth of water was 50 mm under different irrigation schedules. The mean consumptive use of water was 95.58, 149.77, 199.68 and 191.23mm under respective treatments presented in table (4.20). Thus, the consumptive use of water was increased with increase in irrigation water quantity. This might be due to higher number of irrigations with high quantity of water increased the consumption of water, due to better growth of crop and simultaneously the loss of water through evapotranspiration. Inadequate moisture supply to the crop under treatment I₁ irrigation at branching treatment resulted in lower consumptive use of water. These findings are analogous to those reported by Pawar *et al.* (1992), Pramanik (2009),

Water use efficiency refers largely to the production of economics produce of crop per unit of water used by it throughout the life

of a crop. Unlike consumptive use of water, the water use efficiency decreased with each successive increase in the irrigations table (4.21). The highest water use efficiency (19.84Kg/ha-mm) was observed under irrigation scheduling under treatment I₁ irrigation at branching. The WUE under treatment I₃ irrigation at branching, at flowering and at pod formation (12.87Kg/ha-mm) might be due to frequent irrigation and more losses through evapotranspiration. The second reason might be due to high WUE under treatment. I₁ irrigation at branching would be less evapotranspiration ultimately less consumptive use of water and high WUE. Reduction in water use efficiency when more quantity of water was applied because, in higher moisture regimes more moisture is used for evaporation rather than for production, thereby reducing the water use efficiency. It might be also proportional to quantity of water used. frequent irrigation applied under these treatments increased moisture loss due to evapotranspiration in winter season. Higher WUE with treatment I₁ irrigation at branching was stemmed from less water loss due to evapotranspiration under limited water supply. The reason for low WUE under treatment I₃ irrigation at branching, at flowering and at pod formation and I₄ (0.6 IW: CPE ratio) might be due to an increase in the frequency of irrigation resulted in to higher soil moisture content and greater evapotranspiration. Pawar *et al.* (1992), Pramanik (2009),

Difference in days to Disease index due to growth regulator based on critical growth stage was non- significant.

5.3 EFFECT OF GROWTH REGULATORS

5.3.1 Effect on growth attributes

Growth regulator treatments exhibited non-significant influence on plant population recorded at 30 DAS and at harvest.

Different growth regulators showed a remarkable influence on growth attributes. Significant differences was observed in average plant height at 60 DAS and at harvest. Among different growth regulators, treatments GR₁ (NAA @ 25 ppm at 40 DAS) recorded significantly the maximum plant height of 54.25 and 57.01 cm at 60 DAS and at harvest, respectively, it might be due to growth regulators known to increase the vegetative growth and increase the assimilate production that favoured the reproductive phase. While the lowest plant height (49.33 cm) and (51.28 cm) was observed under treatment GR₀ (control-water spray) at 60 DAS and at harvest, respectively, that was supported by Iqbal *et al.* (2001)

The minimum no. of days (49.63) to 50% flowering was recorded significantly higher under treatment (GR₁ NAA @ 25 ppm) at 40 DAS. Differences in days to maturity due to different growth regulators was remained non- significant._

Average no. branches per plant was found significantly higher under treatment GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS (7.16), being at par with treatments GR₁ (NAA @25 ppm) at 40 DAS (7.06) and GR₂ (IBA @25 ppm) at 40 DAS (7.01), respectively. Significantly lower average no. of branches per plant was observed under treatment GR₀ (control-Water spray) (6.86).

5.3.3 Effect on yield attributing attributing characters and seed yield

Treatment GR₁ (NAA @ 20 ppm) at 40 DAS recorded the significantly the highest average no. of pods per plant (85.15) given in table 4.10. Lower average no. of pods per plant (79.04) was observed under the treatment GR₀ (Control- water spray), increase average number of pods per plant might be due to that use of growth regulators is one of the patent forces in the improving crop growth, flower and fruit setting and thats why increase in average number of pods per plant. The results are confirmed with those of. Kalita *et al.* (1995), Upadhayay (2003), Hasanuzzaman *et al.* (2007)

The effect of different growth regulator treatments on no. of seeds per pod was also non-significant.

Growth regulator NAA enhanced the early flowering and pod setting. It has definitely positive effect on the seed yield of chickpea.

The data regarding the seed yield presented in table 4.13 indicated that, they were significantly influenced due to different growth regulator treatments. Among them, treatment GR₁ (NAA @ 25 ppm) at 40 DAS recorded significantly higher seed yield (2404 kg ha⁻¹) which was remained at par with treatments GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS (2400 kg ha⁻¹) and GR₂ (IBA @ 25ppm) at 40 DAS (2278 Kg ha⁻¹). Seed yield increasing to tune of 5.24% over treatment GR₂ (IBA @ 25ppm) at 40 DAS. Seed yield increasing at the extent of 8.6% over control GR₀ (water spray) by GR₁ (NAA @ 25ppm) at 40 DAS. Maximum seed yield found due to maximum no. of pods/plant. Similar trend was observed by Kumar *et al.* (2003), Kalpana and Krishnarajan (2003).

The maximum seed yield was recorded under treatment GR₁ (NAA @ 25 ppm) at 40 DAS due to making the plants photosynthetically more effective and also preventing flower shading, improving pod setting and consequently increasing the seed yield. Another reason is maximum seed yield might be due to its pivotal role in regulating the metabolic and enzymatic processes including photosynthesis, respiration which reflected in increased the yield reported by Singh *et al.* (2004).

The increase in average number of pods per plant might be due to large number of new pods leading to greater activity of carboxylating enzymes and rate of protein synthesis. This resulted in higher photosynthetic rate, translocation and accumulation of metabolites in the pods and by reducing flower drop and ultimately increase average number of pods per plant. Other reason for increase average number of pods per plant might be due to that use of growth regulators is one of the patent forces in the improving the growth, flower and fruit setting and that is why increase in average number of pods per plant. Fourth reason is another reason might be the growth regulators may function in sucrose assimilation and loading. Growth regulators may act directly on the loading of the assimilates from the leaf into transport or alternatively loading may be indirectly influenced by rate of unloading at the pods.

Different plant growth regulators exerted non-significant effect on dry gotar yield.

The effect of different growth regulator treatments was non-significant on harvest index (%).

The effect of different growth regulator treatments on test weight was also non-significant.

5.3.3 Effect on Quality

Different growth regulators exerted their non-significant effect on protein (%).

5.2.4 Effect on water use

Results presented revealed in table no 4.20 maximum mean consumptive use of water was observed that under the treatment GR₁ (NAA @ 25ppm) at 40 DAS (159.84mm) and the lowest consumptive use of water recorded under treatments GR₀ water spray (149.72mm) and also maximum water use efficiency was found under the treatment GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS (15.77 Kg ha⁻¹-mm), low water use efficiency was found under the treatment GR₀ (water spray) (14.84 Kg ha⁻¹-mm).

Difference in days to Disease index due to growth regulator based on critical growth stage was non- significant.

5.4 INTERACTION EFFECT

5.4.1 Effect on plant height at 60 and at harvest

The combined effect of treatment I₃ irrigation at branching, at flowering and at pod formation and growth regulator GR₁ (NAA @ 25 ppm) at 40 DAS presented in Table 4.3 recorded significantly the highest (66.30 cm) plant height at 60 DAS and also application of treatment I₃ irrigation at branching, at flowering and at pod formation with application of treatment GR₁ (NAA @ 25 ppm) at 40 DAS recorded significantly the

highest plant height (72.0 cm) at harvest. Treatment combination I_1GR_0 I_1 irrigation at branching with treatment GR_0 (water spray) recorded significantly lower plant height at harvest, table 4.4

5.4.2 Effect on average no. of branches/plant

The interaction effect between irrigation and growth regulator i.e treatment combination I_3 irrigation at branching, at flowering and at pod formation irrigation schedules based on critical growth stage and growth regulator, application of GR_1 (NAA @25ppm) at 40 DAS on average no. of branches observed significantly the highest (8.20). table no. 4.9 Significantly lower average no. of branches/plant recorded under treatment I_1 irrigation at branching and GR_0 (water spray) (6.2).

5.4.3 Effect on days to 50 % flowering

Treatment combination I_2GR_1 (I_2 irrigation at branching at flowering and GR_1 (NAA @ 25 ppm) at 40 DAS) required significantly the minimum no. of days to 50 % flowering (45). While treatment combination I_4GR_3 (I_4 0.6 IW: CPE ratio and GR_3 (Ascorbic Acid @ 20 ppm) at 40 DAS) recorded significantly maximum no. of days to 50 % flowering (55.3).

5.4.5 Effect on average no. of pod per plant

Treatment combination I_3GR_1 (I_3 irrigation at branching, at flowering and at pod formation irrigation schedules based on critical

growth stage and growth regulator GR₁ (NAA @ 20 ppm) at 40 DAS) recorded significantly the highest average no. pods per plant (107.0) presented in table 4.11. Significantly lower average no. of pods per plant observed under treatment combination I₁GR₀ (I₁ irrigation at branching, and GR₀ control-Water spray) (73.2).

5.4.6 Effect on seed yield

Treatment combination I₃GR₁ (I₃ at branching, at flowering and at pod formation irrigation schedules and plant growth regulator GR₁ (NAA @ 20 ppm) at 40 DAS) recorded significantly higher seed yield (2847 kg ha⁻¹) being at par with treatment combination I₄GR₃ (I₄ 0.6 IW: CPE ratio and GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS. Also significantly lower seed yield was found under treatment combination I₁GR₀ (I₁ at branching and GR₀ water spray) (1683 Kg ha⁻¹) presented in (1683 Kg ha⁻¹) table 4.14.

5.4.7 Effect on harvest index (%)

The significantly higher harvest index (42.1%) was observed under treatment combination I₃GR₁ (application of treatment I₃ irrigation at branching, at flowering and pod formation and with application of GR₂ (IBA @ 25 ppm) at 40 DAS) given table 4.17.

5.5 ECONOMICS

5.5.1 Effect of irrigation schedules base on critical growth satge

The data presented in Table 4.22, indicated that the highest gross (Rs, 79417 ha⁻¹) and net realization (Rs., 69837 ha⁻¹) was secured under treatment I₃ irrigation at branching, at flowering and pod formation, followed by treatment I₄ 0.6 IW: CPE ratio with (Rs. 75430 ha⁻¹ and Rs. 65857 ha⁻¹) gross and net realization, respectively. The lowest gross (Rs. 60451 ha⁻¹) and net realization (Rs. 51871 ha⁻¹) was observed under treatment I₁ irrigation at branching.

5.5.2 Effect of growth regulators

The data pertaining to economics (Table 4.22), results revealed that the highest gross (Rs. 74062 ha⁻¹) and net realization (Rs. 66128 ha⁻¹) was observed under treatment GR₁ (NAA @ 25 ppm) at 40 DAS and also on par with having gross GR₃ (Ascorbic Acid @ 20 ppm) at 40 DAS and also on par with having gross (Rs. 74081 ha⁻¹) and net realization (Rs. 66085 ha⁻¹), application of GR₀ (water spray) recorded the lowest (67974 Rs. ha⁻¹ and Rs. 60394 ha⁻¹) gross and net realization, respectively.

5.5.3 Interaction effect

The results regarding economics Table 4.21 revealed that the highest gross realization (Rs. 88610 ha⁻¹) and net realization (Rs. 78676 ha⁻¹) was recorded under treatment combination I₃GR₁

(I₃ irrigation at branching, at flowering and pod formation, along with application of NAA @ 25ppm at 40 DAS), the lowest gross and net realization was observed under treatment combination I₁GR₀ (Rs.52281 ha⁻¹) (Irrigation at branching along with application of water spray (control)). The lowest net realization (Rs 43701 ha⁻¹) was recorded under treatment combination I₁GR₀ (I₁ irrigation at branching along with application GR₀(water spray)).

SUMMARY AND CONCLUSION

A field experiment was conducted during *rabi* season of the year 2009-2010 at College Agronomy Farm, B. A. college of Agriculture, Anand Agricultural University, Anand, Gujarat to study the “Influence of irrigation schedules based on critical growth stages and growth regulators on growth, yield attributes and seed yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions.” Sixteen treatment combinations consisting of four levels of irrigation schedules based on critical growth stage viz., treatment I₁ – irrigation at branching, treatment I₂ – irrigation at branching + at flowering, treatment I₃ – irrigation at branching + at flowering + at pod formation, treatment I₄ – 0.6 IW: CPE ratio as a main plot treatments and four plant growth regulators viz., treatment GR₀ – Control- water spray, treatment GR₁ – NAA @ 25 ppm at 40 DAS, treatment GR₂ – IBA @ 25 ppm at 40 DAS, and treatment GR₃ – Ascorbic Acid @ 20 ppm at 40 DAS were relegated in sub plot as sub plot treatment tested under split plot design with four replications.

Each experimental unit had 3.00 m X 5.00 m gross plot and 1.80 m X 4.00 m net plot. The soils of the experimental plot was loamy sand in texture having good drainage, low in available nitrogen, medium in available phosphorus and high in available potash with 7.7 soil pH.

The weather conditions were favourable for normal crop growth of chickpea during the crop season. The different irrigation treatments based on critical growth stage were imposed after establishment of the crop with the help of 7.5 parshall flume. The application of different plant growth regulators were sprayed as per treatment. The periodical observations on different growth parameters and yield attributes were recorded. The protein content in seed was determined.

The experimental results presented and discussed in the former chapters are briefly summarized and concluded here.

6.1 Effect of irrigation schedules based on critical growth stage

The growth attributes such as plant population at 30 DAS and at harvest was non- significant, periodical plant height was non – significant at 30 DAS. It was significant at 60 DAS and at harvest (54.86cm and 54.86 cm, respectively) and were significantly higher at 60 DAS and significantly the highest at harvest when irrigation was applied at branching, at flowering and at pod formation (I₃).

The yield attributes viz., days to 50 % flowering was non-significant under irrigation treatment. Significantly the minimum days to maturity (94.81) due to treatment I₁ irrigation at branching, significantly the maximum days to maturity (103.75) due to treatment I₃ irrigation at branching, at flowering and at pod formation. Significantly higher average no. branches per plant (7.68) and significantly the highest

average number pods per plant (89.75) found under treatment I_3 irrigation at branching, at flowering and at pod formation. average no. of seeds per pod due to different irrigation schedules based on critical growth stage was found non-significant.

Significantly higher seed yield (2570 kg ha^{-1}) and higher dry gotar yield ($4633.26\text{ kg ha}^{-1}$) were observed under irrigation treatment I_3 irrigation at branching, at flowering and at pod formation. The protein content was non-significantly influenced due to different irrigation treatment Difference in harvest index was also non-significant. significantly higher test seed weight (19.94g), Significantly the highest protein content (21.84%) were observed under the treatment of irrigation at branching, at flowering and at pod formation (I_3).

The maximum mean consumptive use of water (199.68 mm) was noticed under treatment of irrigation at branching, at flowering and at pod formation (I_3). The maximum mean water use efficiency was recorded with less no. of irrigation i.e. I_1 irrigation at branching ($19.84\text{ Kg ha}^{-1}\text{-mm}$).

Disease index was non-significantly influenced due to different irrigation treatment

The highest gross (Rs. 79417 ha^{-1}) and net realization (Rs, 69837 ha^{-1}) was secured under treatment I_3 irrigation at branching, at flowering and at pod formation, the lowest gross realization

(Rs. 60451ha⁻¹) and net realization (Rs, 51871ha⁻¹) was observed under treatment I₁ irrigation at branching.

6.2 Effect of plant growth regulators

Plant population at 30 DAS and at harvest was non-significantly influenced due to application of different growth regulators. The periodically plant height at 30 was found non - significant, at 60 DAS was significantly higher and at harvest was significantly the highest under application of NAA @ 25 ppm at 40 DAS (GR₁).

Growth regulators had significant influenced on the yield attributes. Days to 50 % flowering was non- significantly influenced due to application of different growth regulators. Differences in days to maturity due to different plant growth regulators was also non- significant._

Treatment GR₃ (Ascorbic Acid @20 ppm) at 40 DAS recorded significantly higher average no. of branches (7.16), being at par with treatment GR₁ (NAA @25 ppm) at 40 DAS (7.06). Significantly the highest average no. of pods per plant (85.15) was secured under treatment GR₁. The effect of different growth regulator treatments was also non-significant on average no. of seeds per pod.

Treatment GR₁ (NAA @ 25ppm) at 40 DAS recorded significantly higher seed yield (2404 kg ha⁻¹). The lowest seed yield (2195 Kg ha⁻¹) were observed under treatment GR₀ (control-water spray). The seed yield were increased under treatment GR₁ (NAA @ 25 ppm at 40

DAS) to the tune of 8.6 % over treatment GR₀ (control-water spray), over GR₂ and GR₃ (5.24 and 16%). Dry gotar yield was non- significantly influenced due to application of different growth regulators. The effect of different growth regulator treatments was non-significant on harvest index, test weight, protein% and the effect of different growth regulator treatments was non-significant on disease index.

Maximum consumptive use of water (159.84mm) was recorded under treatment GR₁ (NAA @ 25 ppm at 40 DAS). lowest water use efficiency was found under treatment GR₀ (control-water spray) (14.66 Kg ha⁻¹).

The gross (Rs.74062 ha⁻¹) and net realization (Rs, 66128 ha⁻¹) was observed under treatment GR₁ (NAA @ 25 ppm at 40 DAS).The highest gross treatment GR₃ Ascorbic Acid @ 20 ppm at 40 DAS with gross realization (Rs.74081 ha⁻¹) and net realization (Rs. 66085 ha⁻¹).

6.3 Interaction effect

Plant height at 60 DAS and at harvest were recorded significantly the highest (66.30 cm and 72.0 cm), respectively with the treatment combination I₃ irrigation at branching, at flowering and at pod formation and growth regulator GR₁ (NAA @ 25 ppm) at 40 DAS.

Treatment combination I_2GR_1 (I_2 irrigation at branching at flowering and GR_1 (NAA @ 25 ppm) at 40 DAS) gave the significantly the lowest no. of days to 50% flowering (45.0).

Treatment combination I_3GR_1 (I_3 irrigation at branching, at flowering and at pod formation irrigation schedules based on critical growth stage and growth regulator, application of GR_1 (NAA @25ppm) at 40 DAS) on average no. of branches observed/plant significantly the highest (8.20).

I_3GR_1 irrigation at branching, at flowering and at pod formation irrigation schedules based on critical growth stage and plant growth regulator GR_1 (NAA @ 20 ppm) at 40 DAS recorded significantly the highest average no. pods plant⁻¹(107.0).

Treatment combination I_3GR_1 (I_3 at branching, at flowering and at pod formation irrigation schedules and growth regulator GR_1 (NAA @ 20 ppm) at 40 DAS) recorded seed yield 2847 kg ha⁻¹ and it was significantly higher.

The significantly higher harvest index (42.1%) was observed under treatment combination I_3GR_1 (I_3 irrigation at branching, at flowering and pod formation and application of GR_2 (IBA @ 25 ppm) at 40 DAS.

CONCLUSION

For securing higher seed yield, gross and net realization from Chickpea crop cv. “GG-1” raised on loamy sand soils of middle Gujarat conditions, it is advisable to apply four irrigations, including common irrigation applied after sowing for uniform plant stand and the rest of irrigations, given each of 50 mm depth to be scheduled either based on three critical growth stage first irrigation at branching stage at 34DAS, second at flowering at 46 DAS and third at pod formation 62 DAS with an application of growth regulator NAA @ 25 ppm at 40 DAS or irrigation each of 50 mm soil depth to be scheduled at IW:CPE ratio of 0.6 (3 irrigations) at an interval of 23 to 26 days with an application of growth regulator either Ascorbic acid @ 20 ppm at 40 DAS or NAA @25 ppm at 40 DAS.

FUTURE LINE OF WORK

On the basis of present investigation, the following suggestions are made for future line of work.

1. It will be of great interest to ascertain the scheduling of irrigation under limited of irrigation water supply.
2. The present experiment should be repeated for two or three years to know the consistency of treatment effects.
3. Irrigation at critical growth stage should be tested to know further response of chickpea to high frequency of irrigation.
4. The response of NAA may be tested through wide range of application and concentration at different crop growth stages.

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APPENDICES

Appendix-I

COST OF CULTIVATION OF CHICKPEA

Sr. No.	Operational cost	Cost (Rs./ha)
A. Land preparation		
1.	Tractor cultivation (3hrs. @ Rs. 200/hr)	600
B. Sowing		
1.	Field layout and opening of furrows (4 M + 2 W)	600
2.	Cost of Seed (6 kg @ Rs. 30 kg ⁻¹)	180
3.	Seed treatment and sowing (4 W)	420
4.	Application of Fertilizer Urea (Rs5.56 kg/ha) @ Rs 278 bag ⁻¹ DAP (Rs 10.42 kg/ha) @ Rs 521.0 bag ⁻¹	984
C. After care		
1.	Gap filling and thinning (5 W)	500
2.	Weeding (One weeding, 5 W+2M)	700
3.	Interculturing (1 Wheel hoe, 2 M)	200
4.	Plant protection measures Monocrotophos 35 EC (300 ml ha ⁻¹ @ Rs. 570 lt ⁻¹ + 2M) Endosulphan (320 ml ha ⁻¹ @ Rs. 270 lt ⁻¹ + 3M)	4 71 278
D	Harvesting (10 W)	1000
E	Threshing and winnowing (10 W)	1000
F	Land revenue charge	75
G	Interest on working capital @ 4 % for 4 month (Rs./ha)	280
H	Supervision charges @ 3.5% for 4 month (Rs./ha)	292
I	Total cost common(Rs/ha)	7580

Note:

PB : Pair of bullock @ Rs. 250 /day M : Man @ Rs. 100.00 / Day

W : Woman @ Rs. 100.00 / Day Urea : Rs. 278 bag⁻¹

DAP : Rs 521.0 bag⁻¹

Appendix -II

Details of cost of irrigation and growth regulators

Treatments	Quantity required per ha	Cost (Rs ha ⁻¹)
------------	--------------------------	--------------------------------

(I ₁) = At branching (I ₂) = At branching + flowering (I ₃) = At branching + flowering + pod formation (I ₄) = IW: CPE ratio (0.6)	Two irrigations (1+1) Three irrigations (1+2) Four irrigations (1+3) Four irrigations (1+3)	1000 1500 2000 2000
GR ₀ -Water spray 40 DAS (Control) GR ₁ - NAA @25 ppm at 40 DAS GR ₂ - IBA @25 ppm at 40 DAS GR ₃ - Ascorbic Acid @20 ppm at 40 DAS	--- 34.725g (One spray) 34.725g (One spray) 27.780g (One spray)	- 354 2049 416

Note: 1. The cost of one irrigation Rs. 500 ha⁻¹ with application charge

2. NAA @ 440.00 Rs. / 100 g

3. IBA @ Rs.5283 / 100 g

4. AA (Ascorbic acid) @ 770.00 Rs. / 100 g

5. Teepol @ 30.00 Rs. / 100 m

Appendix -IV

Analysis of variance

Mean sum of square

SOURCE	DF	No. of days to 50 % flowering	Days to maturity	Av. no. of branches	No. of pods per plant	No. of seeds per pod	Seed yield Kg/ha	Dry gotar yield Kg/ha	Harvest index (%)	Test weight (g)	Protein %	Harvest index (%)	Disease index
REP	3	8	27	0.4	53	0.10	620560	445604	150	1	5	150	0.0059
I	3	45	260	5.0	736	0.00	1120459	3903177	16	12	14	16	0.0021

ERR(a)	9	14	60	0.4	62	0.03	84856	374743	31	3	2	31	0.0055
GR	3	53	6	0.3	156	0.05	164489	398778	39	2	4	39	0.0056
I X GR	9	14	8	0.4	140	0.03	263695	597929	55	2	8	55	0.0050
ERR (b)	36	8	12	0.1	8	0.02	55976	322966	17	2	2	17	0.0030

IV

Appendix -III

Analysis of variance

Mean sum of square

SOURCE	DF	Plant population		Plant height		
		At 30 DAS	At harvest	30 DAS	60 DAS	At harvest
REP	3	0.1	0.1	6.6	70	15
I	3	22.6	22.6	3.7	130	152
ERR(a)	9	5.9	5.9	2.2	31	27

GR	3	0.7	0.7	0.8	73	110
I X GR	9	7.5	7.5	3.3	108	82
ERR (b)	36	3.9	3.9	1.2	21	16

III

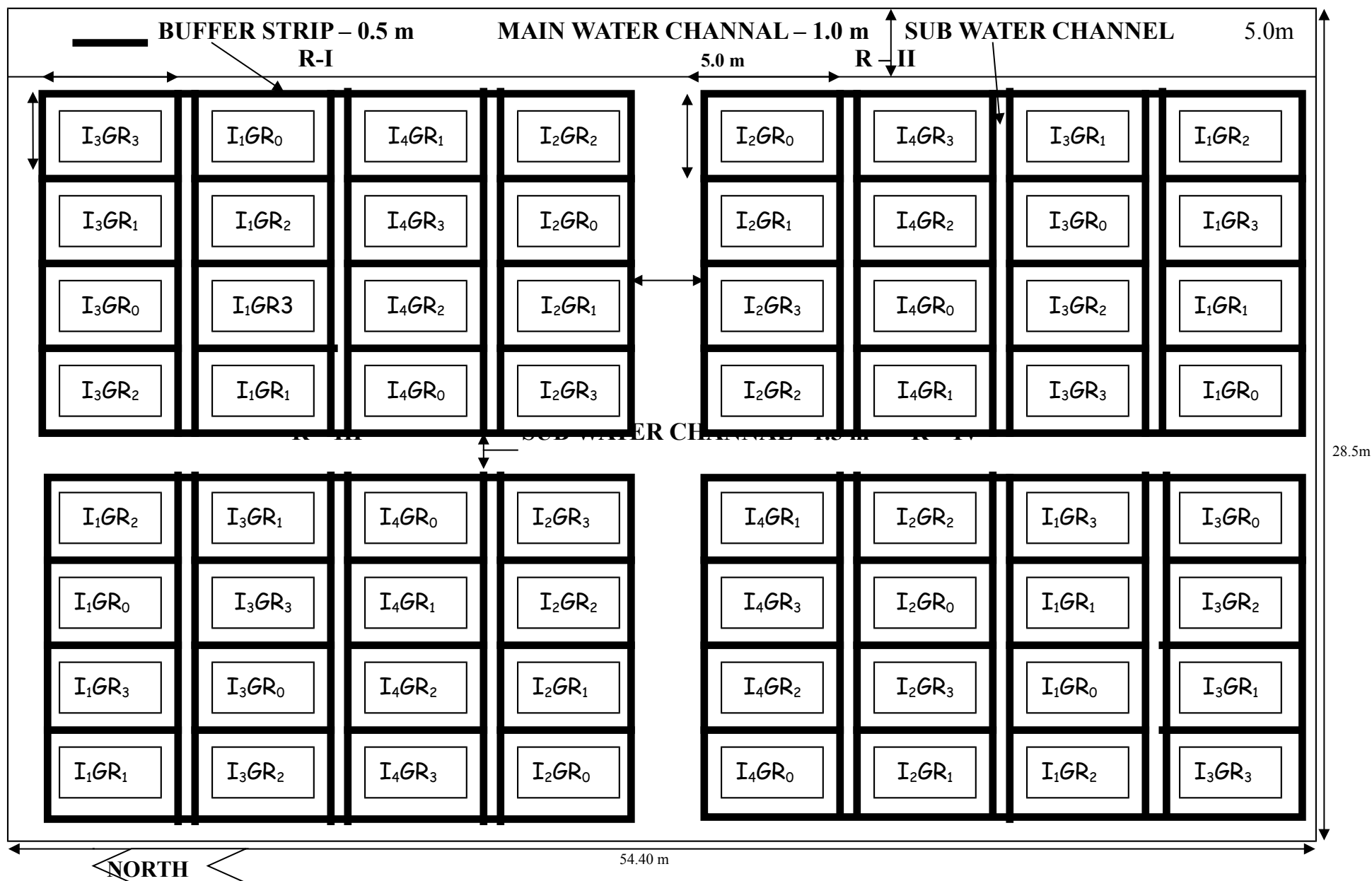
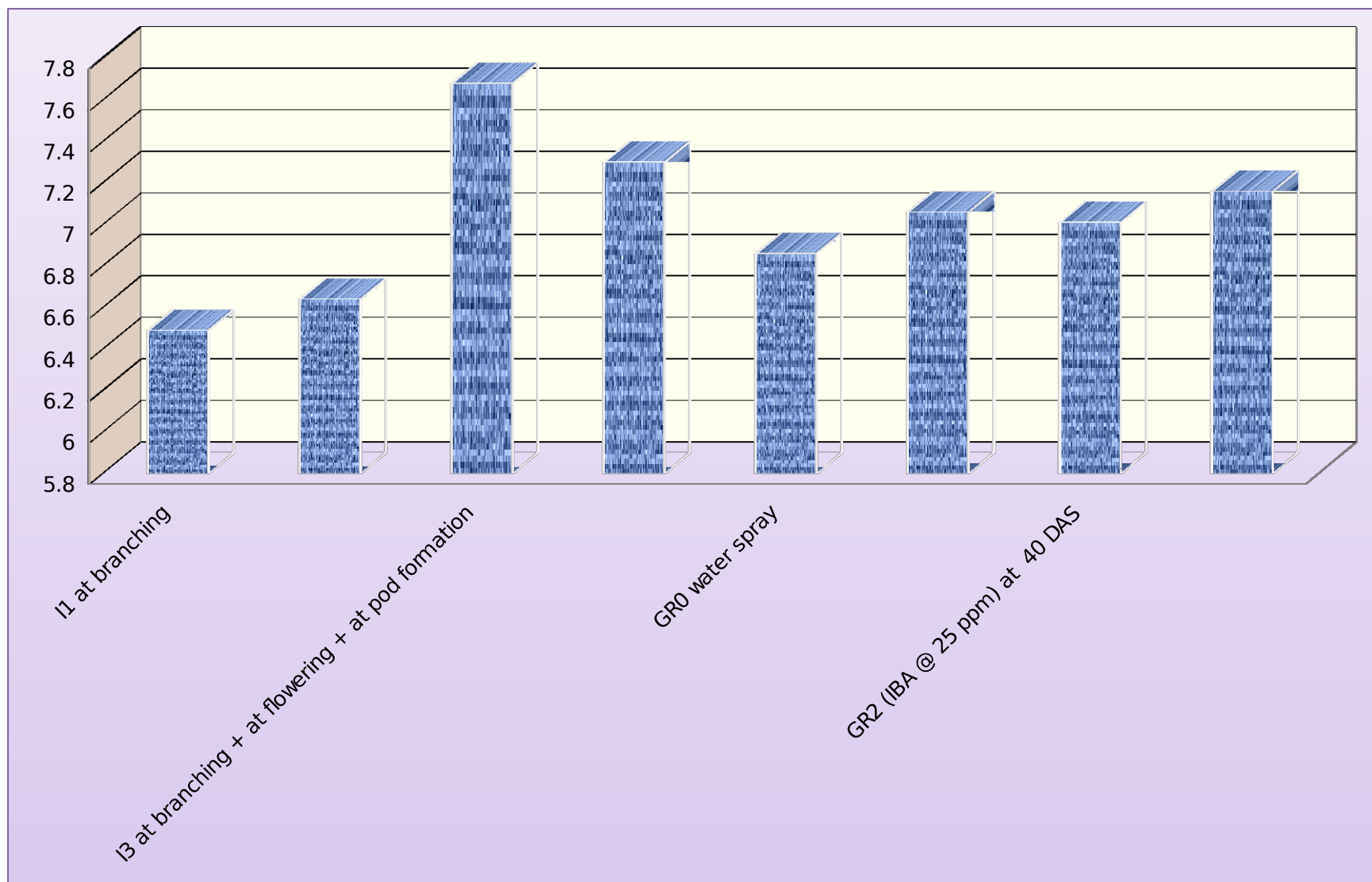
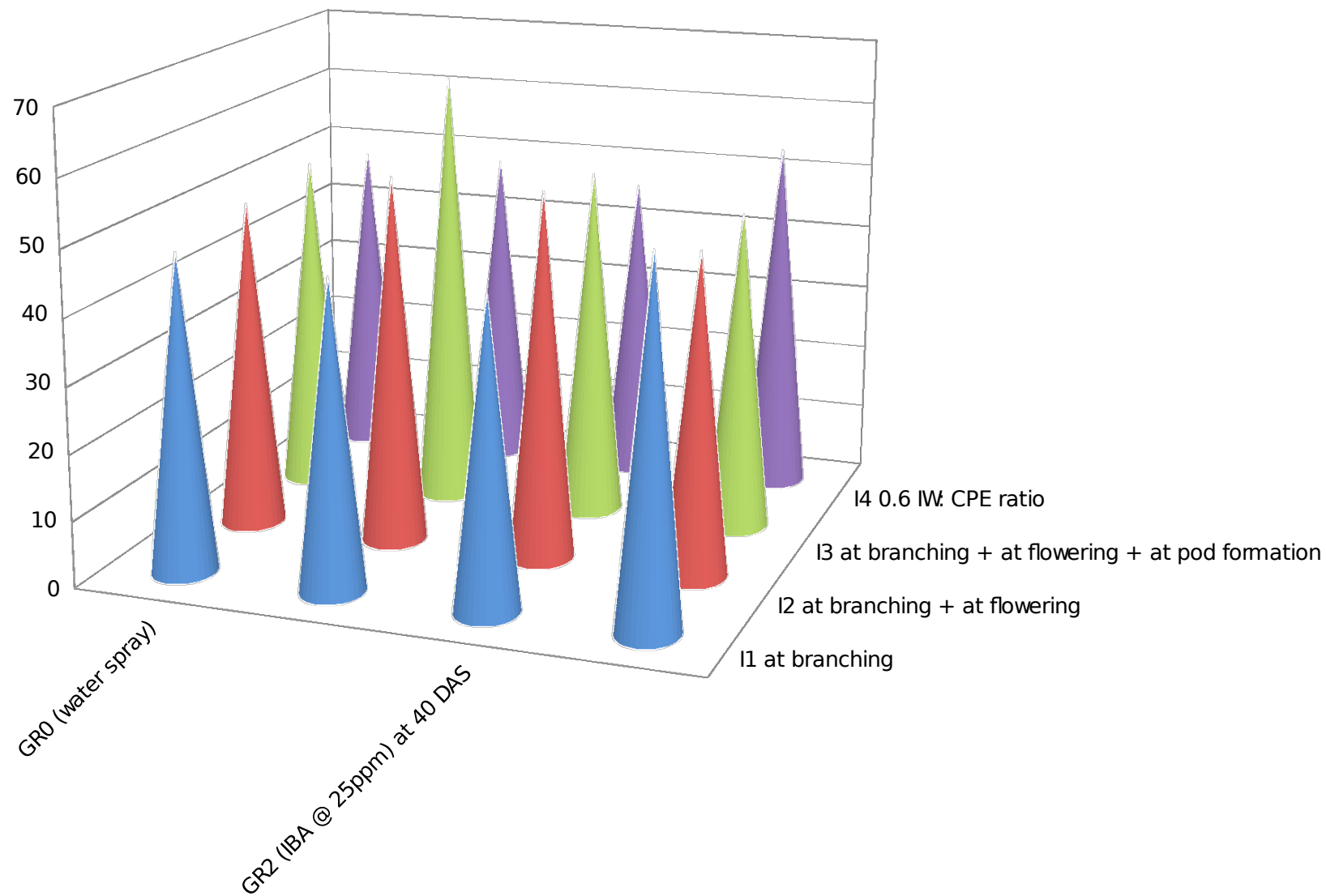


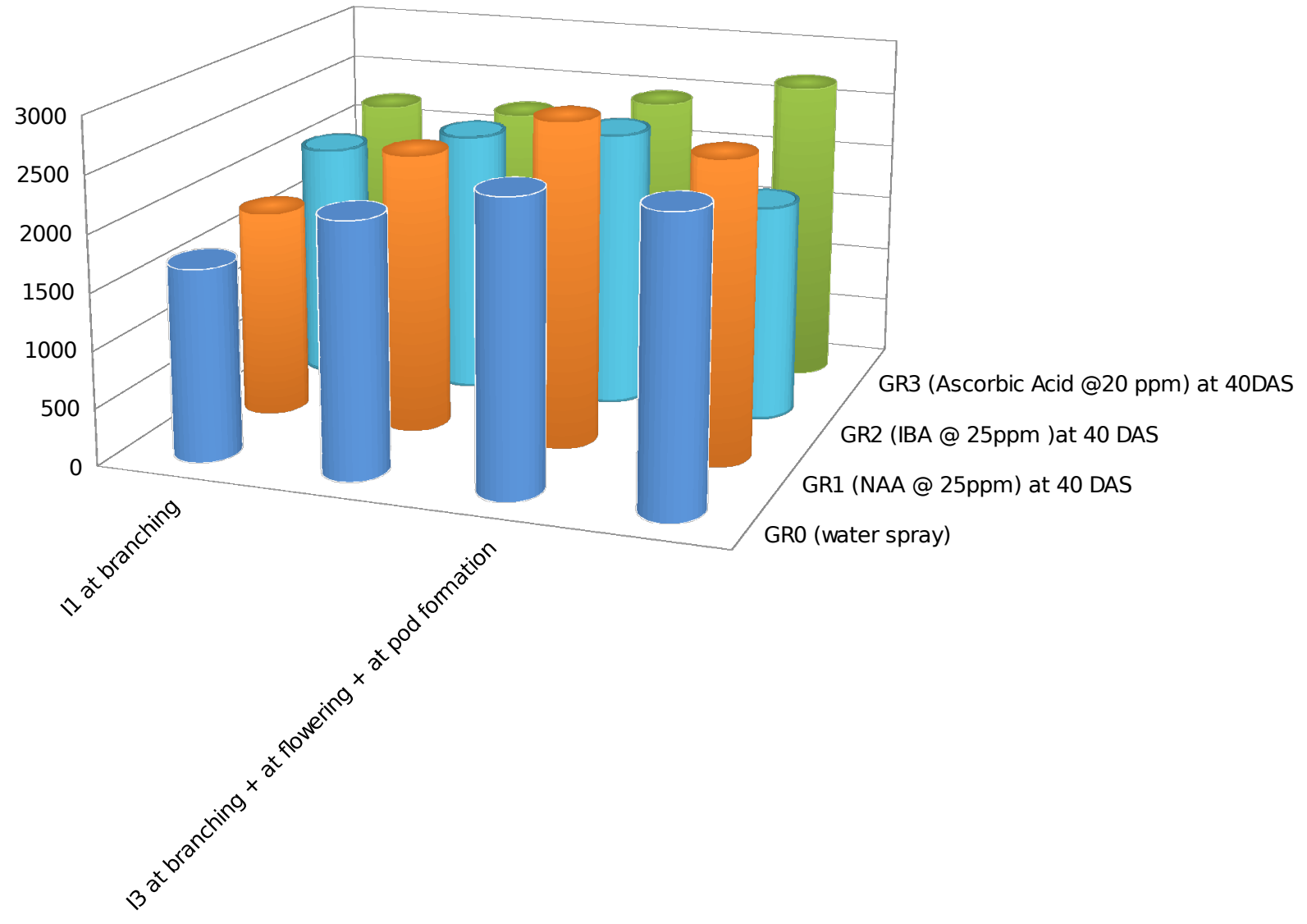
Fig. 3.2 Lay out plan of experimental site

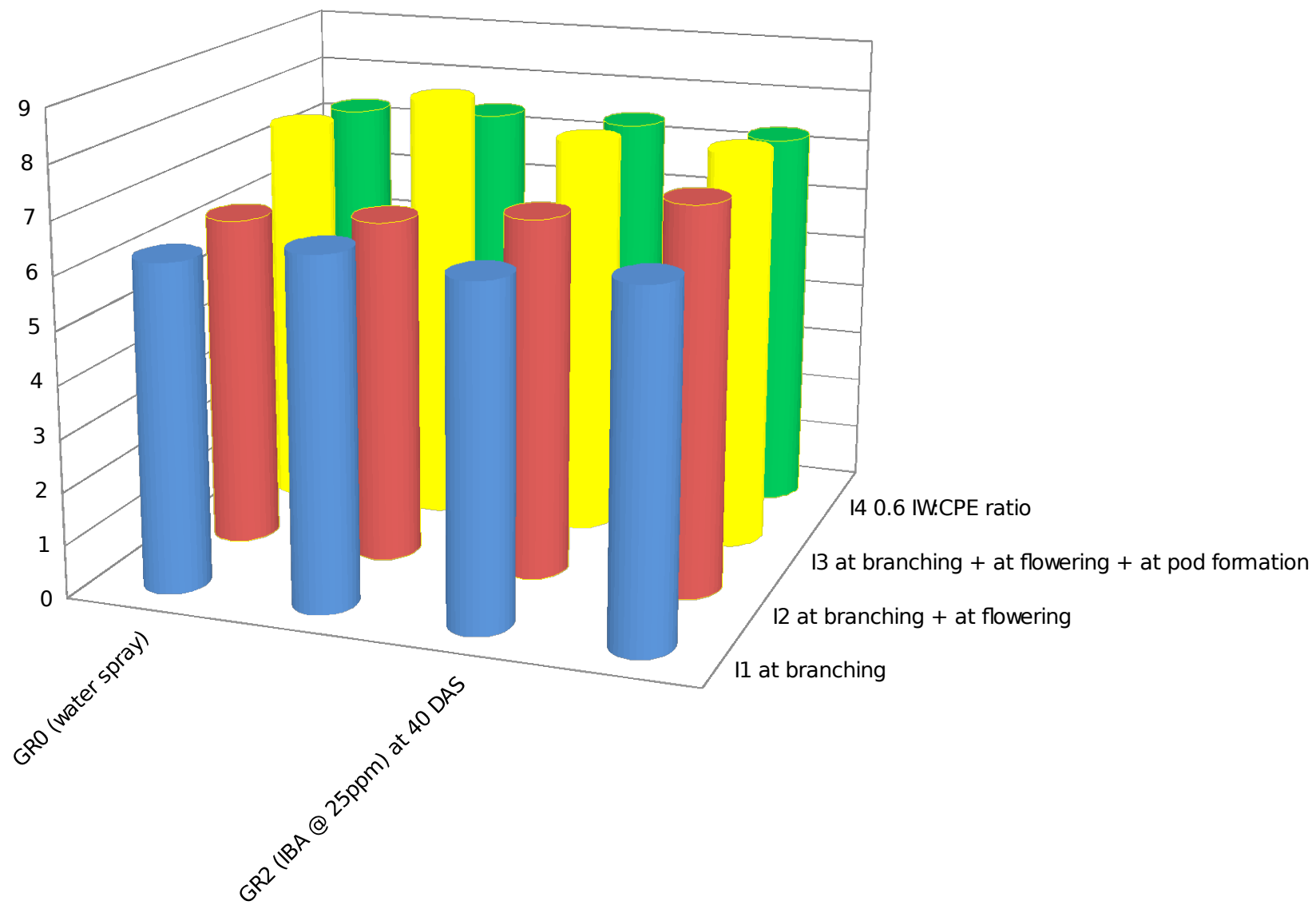
Design: Split plot design
Replication: Four

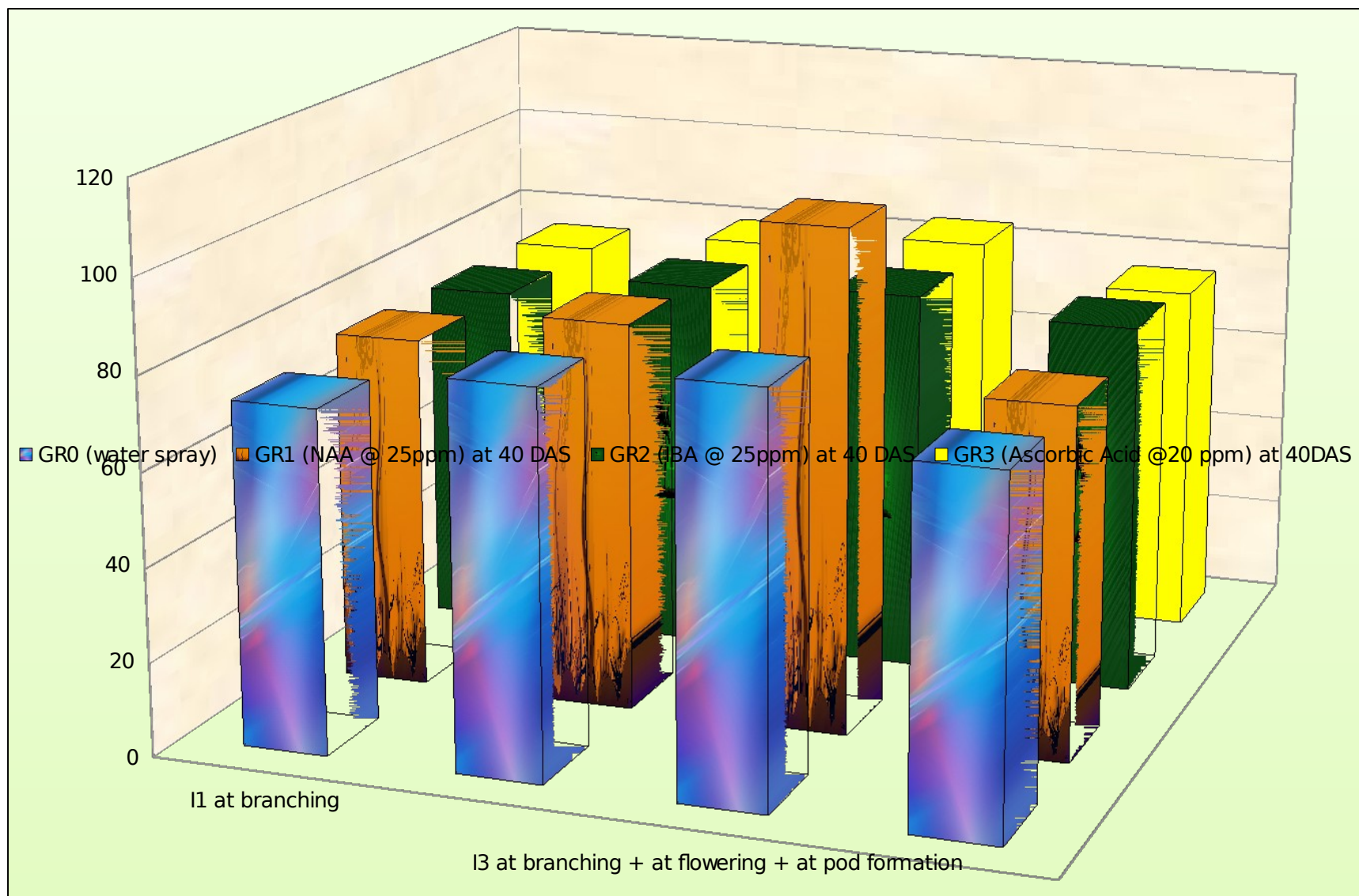
Gross plot size: 3.00 m x 5.00 m
net plot size : 1.80 m x 4.00 m

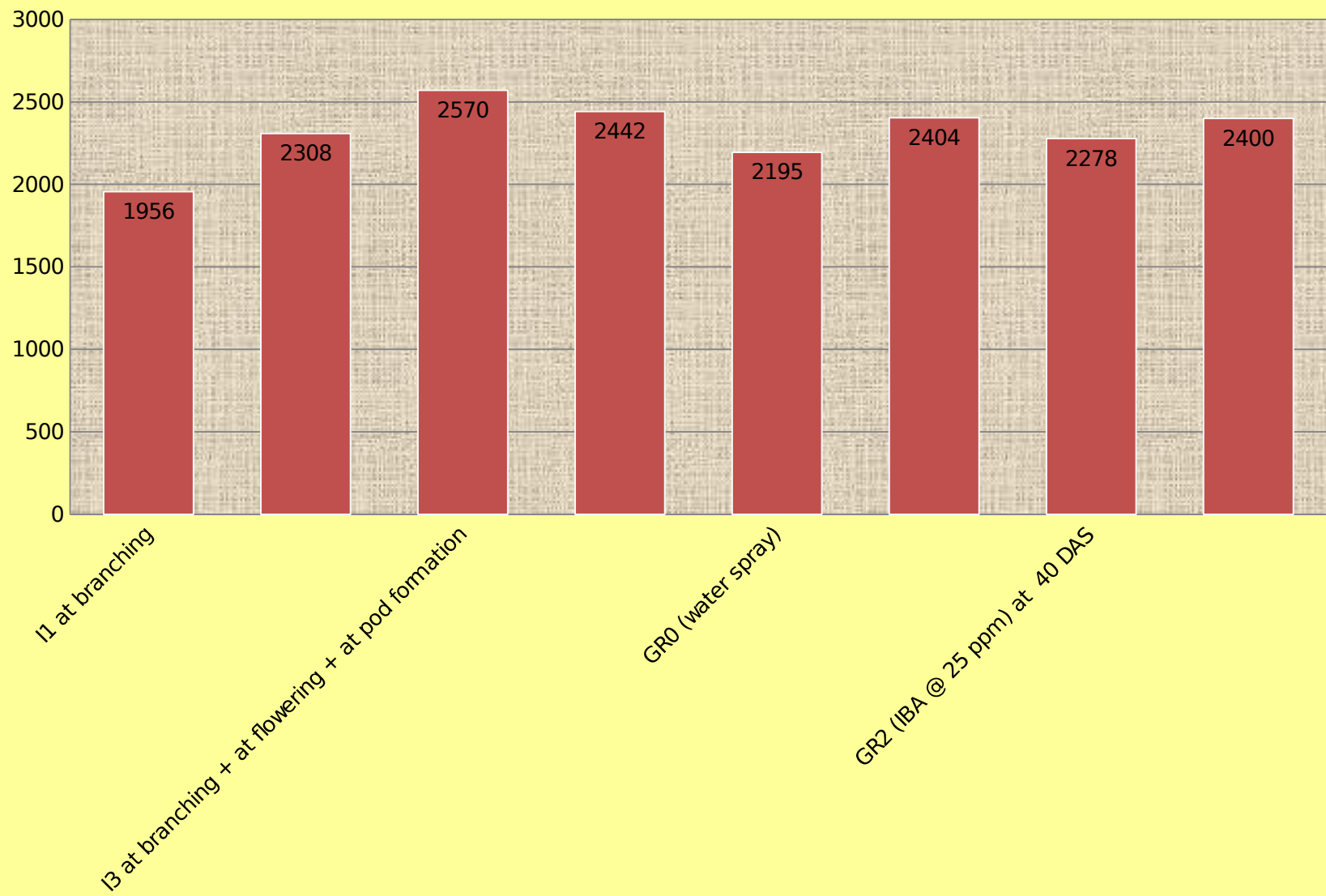














plant height (cm) at harvest

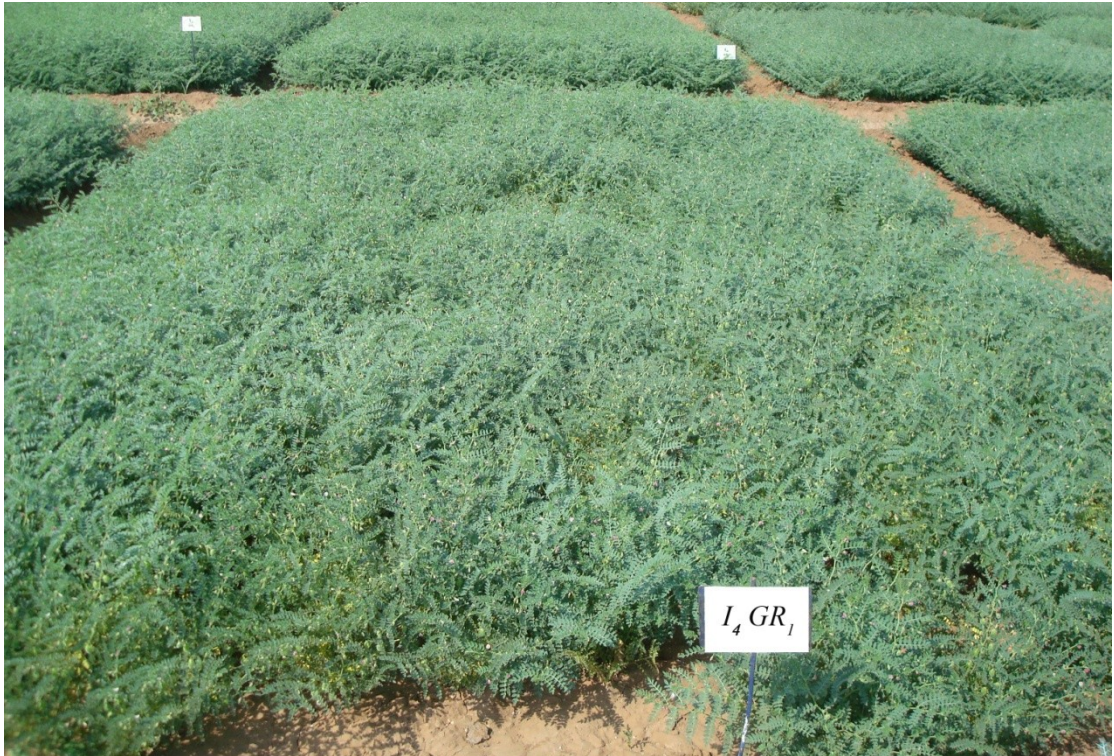


**Plate 5.5 : Crop growth treatment combination I_4GR_1 .
(I_4)- IW: CPE ratio (0.6) GR_1 - NAA @25 ppm at 40 DAS**



**Plate 5.6 : Crop growth under treatment combination I_4GR_3 .
(I_4)- IW: CPE ratio (0.6) GR_3 - Ascorbic Acid @20 ppm at 40 DAS**



Plate 5.2 : Comparison of irrigation treatments



Plate 5.2 : Comparison of irrigation treatments

(I₁)- At branching

(I₂)- At branching + flowering

(I₃)-At branching + flowering + pod formation

(I₄)- IW: CPE ratio (0.6)



Plate 5.3 : Comparison of growth regulator treatments
GR₁- NAA @25 ppm at 40 DAS GR₀- Water spray at 40 DAS (Control)

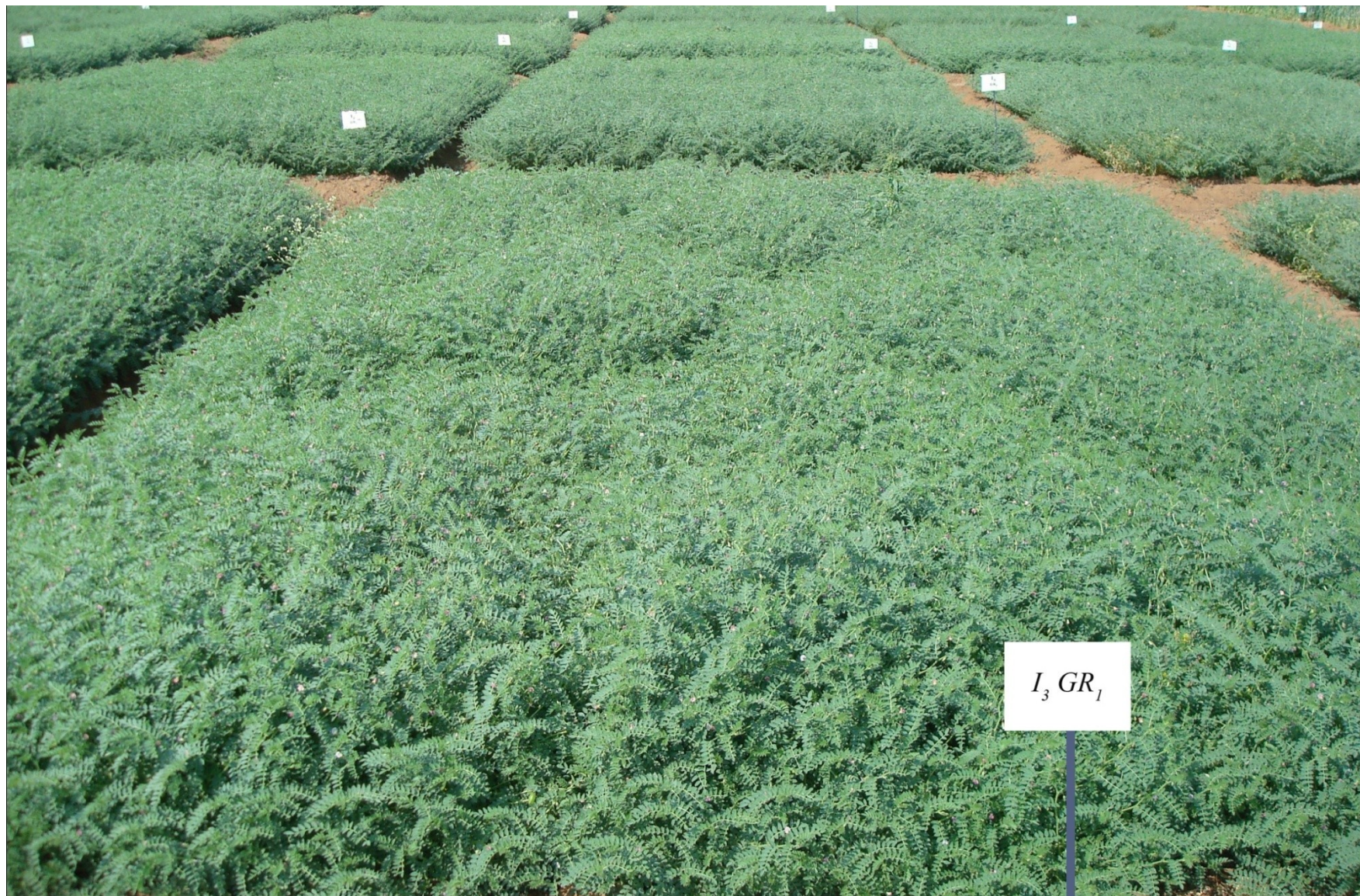


**Plate 5.4 : Crop growth under treatment combination $I_3 GR_1$.
(I_3)-At branching + flowering + pod formation
 GR_1 - NAA @25 ppm at 40 DAS**

Table 4.23 Gross realization, total cost of production and net realization of chickpea as influenced by different irrigation schedules based on critical growth stages and growth regulators.

Treatment	Seed yield (Kg ha⁻¹)	Dry gotar yield (Kg ha⁻¹)	Gross realization (Rs ha⁻¹)	Total cost of cultivation (Rs ha⁻¹)	Net Realization (Rs ha⁻¹)
A.Irrigation schedules					
I₁ : at branching	1956	3542	60451	8580	51871
I₂ : at branching + at flowering	2308	3819	71150	9080	62070
I₃ : at branching + at flowering + at pod formation	2570	4633	79417	9580	69837
I₄ : 0.6 IW:CPE ratio	2442	4340	75430	9580	65857
B. Plant Growth regulators					
GR₀ : Control (Water spray)	2195	4247	67974	7580	60394
GR₁ : NAA @ 25 ppm at 40DAS	2404	3884	74062	7934	66128
GR₂ : IBA @ 25ppm at 40 DAS	2278	4040	70360	9629	60731
GR₃ : Ascorbic Acid @ 20 ppm at 40 DAS	2400	4162	74081	7996	66085

Table 4.24 Gross realization, total cost of production and net realization of chickpea as influenced by different irrigation schedules based on critical growth stages and growth regulators treatment combinations.

Treatment combination	Seed yield (kg ha⁻¹)	Seed yield (Rs ha⁻¹)	Dry gotar yield (kg ha⁻¹)	Dry gotar yield (Rs ha⁻¹)	Gross realization (Rs ha⁻¹)	Total cost of cultivation (Rs ha⁻¹)	Net Realization (Rs ha⁻¹)
1	2	3	4	5	6	7	8
I₁GR₀	1683	50475	3611	1806	52281	8580	43701
I₁GR₁	1823	54687	3194	1597	56284	8934	47350
I₁GR₂	2091	62916	3889	1944	64860	10629	54231
I₁GR₃	2222	66666	3333	1667	68333	8996	59337
I₂GR₀	2220	66594	4028	2014	68608	9080	59528
I₂GR₁	2242	73437	4167	2083	75520	9434	66086
I₂GR₂	2326	69792	3472	1736	71528	11129	60399
I₂GR₃	2340	70185	4306	2153	72338	9496	62842
I₃GR₀	2535	76056	4722	2361	78417	9580	68837
I₃GR₁	2841	85416	6389	3194	88610	9934	78676
I₃GR₂	2442	73437	5278	2639	76076	11629	64447
I₃GR₃	2442	73437	4583	2292	75729	9996	65733
I₄GR₀	2535	76041	4306	2153	78194	9580	68614
I₄GR₁	2639	79182	4306	2153	81335	9934	71401
I₄GR₂	1910	57291	4305	2153	59444	11629	47815
I₄GR₃	2692	80745	4583	2292	83037	9996	73041

Seed selling price Rs. 30/kg

Straw selling price Rs.0.50/kg

WEATHER CHART

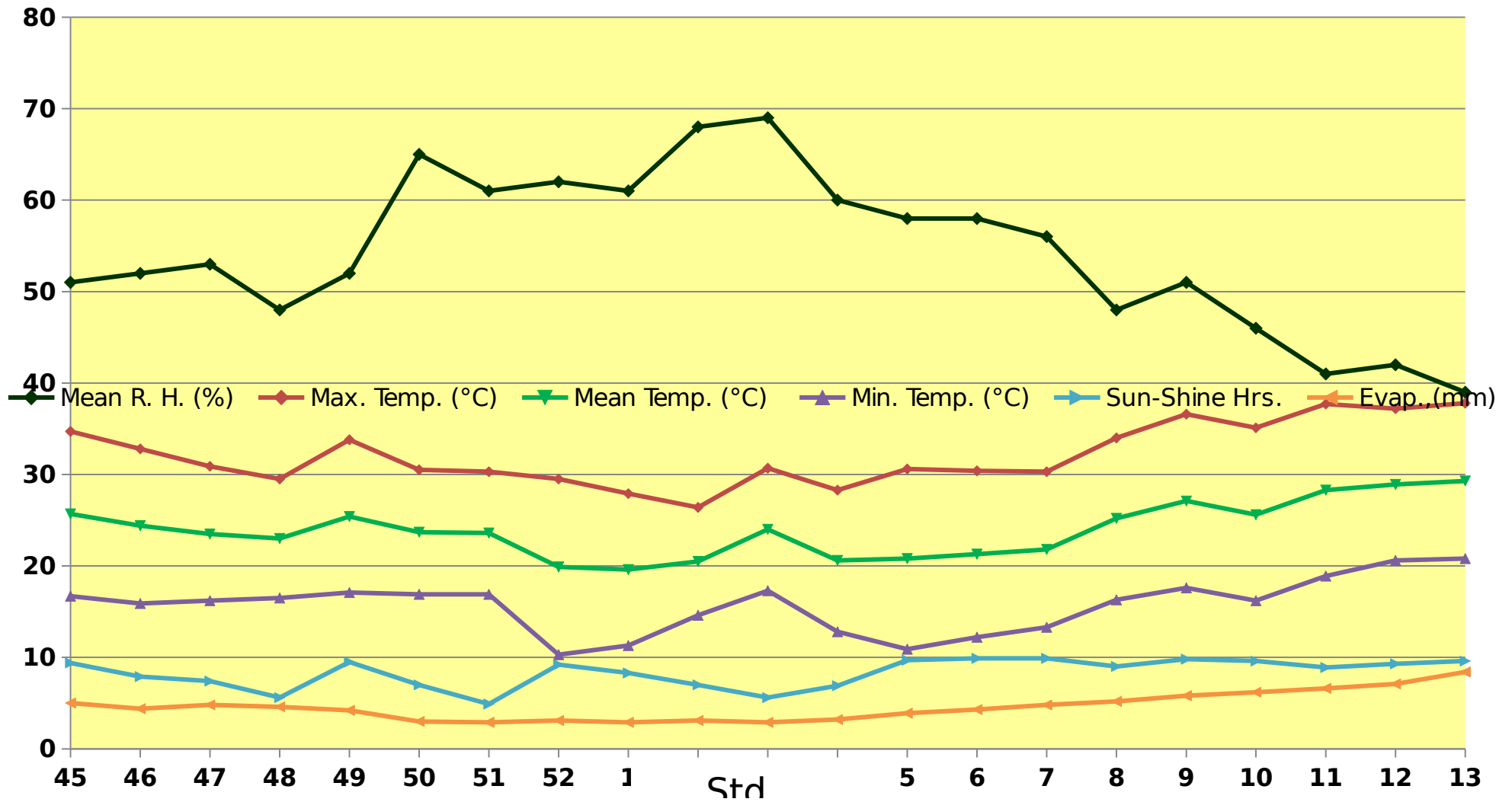


Fig. 3.1: Mean weekly weather parameters during the crop growth period of *rabi* season 2009-2010