EFFECT OF IRRIGATION LEVELS AND WATER SAVING PRACTICES ON BT AND NON BT COTTON (*Gossypium* spp.) HYBRIDS WITH SPECIAL REFERENCE TO *PARAWILT*

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA

in partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRONOMY

by

Udhav Nilabhau Alse
(Reg. No. 06/01)

DEPARTMENT OF AGRONOMY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
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2009

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APPROVED BY

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2009

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

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Dated :

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Dean (F/A) and Director of Instructions,
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Rahuri – 413 722, Dist. Ahmednagar,
Maharashtra State (INDIA)

CERTIFICATE

This is to certify that the thesis entitled, "**Effect of irrigation levels and water saving practices on Bt and non Bt cotton (*Gossypium* spp.) hybrids with special reference to *parawilt***" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, (M.S.) for the award of the degree of **DOCTOR OF PHILOSOPHY** (AGRICULTURE) in **AGRONOMY**, embodies the results of a bonafide research carried out by **MR. UDHAV NILABHAU ALSE**, under my guidance and supervision and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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Place : MPKV, Rahuri **(R.S. Patil)**

Dated :

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Place : MPKV, Rahuri

Dated : **(U.N. Alse)**

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LIST OF ABBREVIATIONS

@	:	At the rate of
^{O}C	:	Degree celsius
CD	:	Critical difference
cm^2	:	Square centimetre
CPE	:	Cumulative pan evaporation
mm hr^{-1}	:	Milimetre per hour
cm	:	Centimetre
DAS	:	Days after sowing
dSm^{-1}	:	Deci simemen per meter
e.g.	:	Exampli gratia (For example)
EC	:	Electric conductivity
et al.	:	And others
etc.	:	Et cetra
Fig.	:	Figure
g	:	Gram
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potassium
kg	:	Kilogram
Kc	:	Crop coeficient
km hr^{-1}	:	Kilometre per hour
lph	:	Litre per hour
m	:	Metre
mm	:	Millimetre
MW	:	Meteorological week
N	:	Nitrogen
N.S.	:	Non significant
P	:	Phosphorus
q	:	Quintals
RDF	:	Recommended dose of fertilizer
R.H.	:	Relative humidity
Rs.	:	Rupees
S.E.	:	Standard error
t	:	Tonne
viz.,	:	Namely
WUE	:	Water use efficiency
%	:	Per cent
/	:	Per

ABSTRACT

"EFFECT OF IRRIGATION LEVELS AND WATER SAVING PRACTICES ON BT AND NON BT COTTON (*Gossypium* spp.) HYBRIDS WITH SPECIAL REFERENCE TO *PARAWILT*"

by

UDHAV NILABHAU ALSE
A candidate for the degree
of
DOCTOR OF PHILOSOPHY (AGRICULTURE)
in
Mahatma Phule Krishi Vidyapeeth, Rahuri.
Dist. Ahmednagar (M.S.)
2009

Research Guide	:	**Dr. A.S. Jadhav**
Department	:	**Agronomy**

An investigation on "Effect of irrigation levels and water saving practices on Bt and Non Bt cotton (*Gossypium* spp.) hybrids with special reference to *Parawilt*" was conducted on vertisol at AICRP on Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, (Maharashtra) during 2007 and 2008.

The experiment was laid out in split plot design with three replications. The total 24 treatment combinations comprising three irrigation levels (50, 75 and 100 mm CPE) on the basis of cumulative pan evaporation with constant depth (7.2 cm), two water saving practices (alternate and every furrow irrigation) were allotted to main plot and four cotton hybrids viz., Dhroov Bt, Dhroov non Bt, Kashinath Bt and Nathbaba non Bt were assigned to sub plot.

The important growth and yield attributes were significantly higher with irrigation scheduled at 75 mm CPE than 50 and 100 mm CPE irrigation schedules. However, plant height and monopodial branches were significantly higher under 50 mm CPE than rest of the irrigation schedules. The severe water stress imposed with irrigation scheduled at 100 mm CPE produced significantly the lowest values for growth and yield attributes of cotton. The phonological growth stages, *viz*. squaring, flowering, boll formation and boll opening hastened due to water stress, while, it was delayed due to excess water.

The seed cotton yield, stalk yield, gross and net monetary returns and B:C ratio were significantly the highest under 75 mm CPE, moderate under 50 mm and the lowest under 100 mm CPE.

The quality parameters such as 2.5 per cent span length, fibre strength, fibre fineness, elongation percentage, uniformity ratio and ginning percentage were not significantly influenced by the irrigation levels during both the years of study except fibre fineness and ginning percentage during 2007 and 2008, respectively, where these quality parameters were significantly improved with 75 mm and 50 mm than 100 mm CPE irrigation level.

The *parawilt* incidence was significantly lower under irrigation scheduled at 75 mm CPE at all growth stages than 50 mm and 100 mm CPE irrigation. However, it was the highest under 50 mm CPE during 2007 and 100 mm CPE during 2008 than former irrigation schedule.

The profile water depletion, consumptive use and irrigation water requirement was maximum under 50 mm CPE than 75 mm and 100 mm CPE, however, the consumptive use efficiency was more under 75 mm CPE irrigation.

The maximum nutrients (NPK) were removed under 75 mm CPE irrigation schedule than 50 and 100 mm CPE irrigations schedules. The stress at 100 mm CPE irrigation schedule removed less nutrients than rest of the irrigation schedules.

The water saving practices did not show significant impact on growth and yield attributes, yield, quality parameters, gross and net monetary returns and B:C ratio, cotton *parawilt* and nutrient uptake during both the years of investigation. However, water use efficiency and water saving was comparatively more under alternate furrow irrigation than every furrow irrigation.

Kashinath Bt recorded significantly the highest growth attributes, however, Dhroov Bt produced significantly the highest yield attributes and yield resulting in more monetary returns than rest of the cotton hybrids.

All the quality parameters were significantly superior under Kashinath Bt, while ginning percentage was significantly more with Dhroov Bt than rest of the cotton hybrids.

The water requirement, profile water depletion, consumptive use and nutrient uptake were higher with Kashinath Bt followed by Dhroov Bt, Dhroov non Bt and Nathbaba non Bt. However, water use efficiency was more with Dhroov Bt than rest of the cotton hybrids.

Kashinath Bt was free from the *parawilt*, however, its incidence was significantly more on Dhroov Bt than Dhroov non Bt and Nathbaba non Bt cotton hybrids.

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1. INTRODUCTION

Cotton plays a key role in the national as well as farmer's economy in terms of both employment generation and foreign exchange earnings. It generates employment for about 60 million people either directly or indirectly involved in the agricultural and industrial sectors of cotton production, processing, textiles and related activities.

Foreign exchange earnings from cotton is about Rs. 50,000 crore, which is nearly one third of the total foreign exchange earnings of our country (Khadi, 2006). It is expected to increase significantly in the coming years with the termination of quota regime in the liberalised trade scenario.

India has the largest acreage (95.30 lakh ha) under cotton at global level and has the productivity of 553 kg lint ha^{-1} and ranks second in production (310 lakh bales) after China during 2007-08 (Anonymous, 2009). The productivity of the country (642 kg ha^{-1}) is still below the world average. The Maharashtra state is having the largest cotton growing area of 31.91 lakh ha and production of 60 lakh bales with productivity of 320 kg lint ha (Anonymous, 2006).

The area under Bt cotton hybrids has gradually increased from 38,038 ha in 2002-03 to 5.60 lakh ha by 2005-06 and showed steep increase to 13.00 lakh ha in 2006-07, an increase of 160 per cent over 2004 followed by a phenomenal enhancement to 37.21 lakh ha in

2007-08 (Anonymous, 2009). Notably, India's Bt cotton area in 2006 (3.8 million ha) exceeded for the first time, that of China (3.5 million ha), the third largest cotton producer in the world (Khadi *et al.*, 2007).

The current irrigated area under cotton is around 40 per cent in the country. In the Central Zone, Maharashtra remains a major rainfed growing state with only 3 per cent area under irrigation as against 36 per cent in Madhya Pradesh and 34 per cent in Gujarat. Out of 78100 ha total area in Maharashtra, 6600 ha area is under irrigation from Pune region comprising Deccan canal tract of Phaltan, Baramati, Solapur and Ahmednagar region (Anonymous, 2006).

This shows that the major reason behind low productivity in the Maharashtra state is the cotton cultivation under rainfed condition. Productivity of cotton could be increased with irrigation at critical growth stages compared to rainfed situation (Mehetre, 1997).

Cotton crop is susceptible to water logging or water stress. It requires timely and equal distribution of irrigation water. Siag and Verma (1994) reported that scheduling of irrigation at 100 mm CPE recorded the higher seed cotton yield and found significantly superior over irrigation scheduled at 150 and 200 mm CPE.

The optimum planting time of irrigated summer cotton is 15th March to 1st week of May when there is acute shortage of water. This is major limitation for increasing the area under irrigated cotton in Western Maharashtra, one of the ways to increase the area under irrigated cotton is to introduce the water saving practices like irrigating the crop in alternate furrows alternatively. Saving of irrigation water to the extent of 27 to 51 per cent with alternate furrow irrigation was reported by Keflemarian (1976) and Sivanappan *et al*. (1976). These findings indicate that the additional cotton area can be brought under irrigation during summer months.

At the time of independence, mostly short and medium staple cottons were produced. Today, India produces widest range of cotton from 6 to 120s counts, from non-spinnable coarse to medium, long, extra long, and superfine cotton.

With rapid advances in plant biotechnology, new varieties of cotton have been evolved that are endowed with unusual but highly useful characteristics not found in their naturally existing parent species. The crops produced through genetic engineering containing a gene or genes usually from unrelated organisms are called transgenic crops, often referred to as genetically modified crops. Now Bt cotton, the first commercialised transgenic crop in India, is being cultivated by cotton growing farmers of almost all cotton growing states of the country.

Bt cotton refers to transgenic cotton which contains, endotoxin protein inducing gene from soil bacterium *Bacillus thuringiensis* var Kurstaki. The synthesised crystalline proteins (endotoxins) are toxic to lepidopteran insects. They kill the insect by acting on the epithelium tissues of midgut of caterpillars. This resulted in loss a activity in the pest leading to death (Singh, 2007).

Genetically modified cotton protect not only from the insect, but also from the weeds, an advance versions of cotton like NuCOTON(R), Roundup Ready Flex™ cotton. Wide strike™ cotton, liberty link®

cotton, Vegetative Insecticidal Protein (VIP) cotton are waiting for the approval from GEAC (Ahuja, 2006). Other notable technologies which had significant bearing on cotton production are supply of quality seeds, Integrated Nutrient Management (INM), water conservation methods, intercropping systems, Insecticide Resistance Management (IRM), Integrated Pest Management (IPM), Irrigation Water Management (IWM) etc. With the availability these technologies, India's productivity could be increased upto a world level.

The 'white gold', the cotton is being suffered from several wilt diseases of fungal, bacterial, viral origin affecting cotton crop are well known. *Parawilt* a new disease/disorder of cotton, was first reported in rainy season of 1978 on an *intra hirsutum* hybrid JKHY-1 from Andhra Pradesh (Srinivasan, 1984). In Maharashtra, the sporadic incidence of *parawilt* was noted on DCH-32 during 1982 (Mali *et al*., 1984) became a matter of concern as *parawilt* occurred on 10 to 20 per cent area regularly since then on several high yielding hybrids.

Since last few years a *parawilt* disorder severely occurring on cotton especially a few *intrahirsutum* and *hirsutum* x *barbedence* hybrids in central and southern zones.

Several theories are advanced for cause of *parawilt* of cotton. Amongst biotic causes, the role of fungi, bacteria, viruses, viroids has been unequivocally ruled out (Mayee *et al*. 1989). Mandloi *et al*. (1985) claimed that *parawilt* was a genetically controlled physiological disorder expressed in certain restrictive environment.

The possibility of biotic causes has been sufficiently examined of which water stagnation, prolonged drought, lack of oxygen to roots, soil temperature below 28^{O}C are some of the reasons for cotton wilt.

Management of *parawilt* by scheduling proper irrigation and saving of water by water saving practices is essential to enhance the productivity of cotton. Therefore, the present study entitled, "Effect of irrigation levels and water saving practices on Bt and Non-Bt cotton (*Gossypium* spp.) hybrids with special reference to *parawilt* " was planned and conducted at Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, Dist. Ahmednagar during 2007-08 and 2008-09 with following objectives.

Objectives

i. To study the effect of different irrigation levels on growth, seed cotton yield and quality of Bt and Non Bt cotton hybrids.

ii. To study the effect of water saving practices on growth, seed cotton yield and quality of Bt and Non Bt cotton hybrids.

iii. To evaluate the performance of Bt and Non Bt cotton hybrids in respect of growth, seed cotton yield and quality.

iv. To find out the comparative performance of Bt and Non Bt cotton hybrids with irrigation levels and water saving practices.

v. To estimate the consumptive use and water use efficiency for various treatments.

vi. To study the impact of irrigation levels and water saving practices on *parawilt* of Bt and Non Bt cotton hybrids.

2. REVIEW OF LITERATURE

The review of the relevant research work carried out by various investigators in respect of irrigation levels and water saving practices on Bt and Non Bt cotton hybrids with special reference to *parawilt* are presented in this chapter.

Information on cotton *parawilt* in relation to the irrigation water and water saving practices is very limited. However, an attempt has been made to review the work done on the overleaf mentioned aspects and their effects on growth, yield and quality parameters.

2.1 Effect of irrigation levels

Water is one of the most important inputs in an assured crop production programme in all such areas where crop production suffers due to scarcity and/or irregular distribution of rainfall. Water is required in large quantities for crop production and also needs to be supplied at regular intervals to meet the water demands of the crop. An efficient utilization of available irrigation water is, therefore essential in an assured crop production programme.

Cotton is grown in areas that differ widely in temperature, elevation, rainfall, soil and length of crop growing season. The actual quantity of water used by plant can be expected to vary between locations and may vary between years at any one location.

The consumptive use of water to *Savitri* cotton was 95.4, 91.8, 61.3 and 60.97 cm during 1978-79, 1979-80, 1980-81 and 1981-82 respectively at Rahuri, Maharashtra (Anonymous, 1983[a]). Out of 4 years only during 1979-80, the highest seed cotton yield (22.25 q ha^{-1}) was obtained when irrigation was applied at 0.90 IW/CPE ratio throughout the crop growth period. This was significantly superior to the treatments of application of irrigation at 0.45 and 0.60 IW/CPE ratios and alternate furrow irrigation at 0.60 IW/CPE ratios throughout the crop growth period.

From the studies of water requirement for summer cotton MCU-7, it was observed that minimum irrigation to the crop an IW/CPE ratio of 0.4 gave increased return of Rs. 15.16 mm^{-1} ha^{-1} as against Rs. 4.86 mm^{-1} ha^{-1} under highly moisture regime IW/CPE ratio 1.0 (Anonymous, 1983[b]).

Phene *et al*. (1984) in San Joaquin Valley of California reported that an evapotranspiration of 63.3 $\pm$ 5.0 cm gave maximum yield with drip irrigated cotton compared to 64.5 cm for furrow irrigated cotton. In another study, for narrow row of cotton (0.5 m), evapotranspiration was between 65.0 and 70.0 cm for maximum lint production (Howell *et al*., 1984).

Magar and Sonawane (1987) reported that water requirement for cotton under drip irrigation was 38.7 cm as compared to 90 cm by surface irrigation.

2.1.1 Effect of irrigation levels on growth attributes

Ayars *et al*. (1991) conducted a field experiment in San Joaquin Valley of California and evaluated 4 different levels of water application (0.7, 0.9, 1.1 and 1.3 crop evapotranspiration, ET_C). The leaf area index, plant height and total above ground dry matter all exhibited a row-by-row response for the three lowest irrigation treatments. While Verma *et al*. (1991) found that growth and yield contributing characters which were significantly superior under 0.8 IW/CPE ratio as compared to 0.6 and 0.4 IW/CPE ratio.

Orgaz *et al*. (1991) suggested that cotton squares production was highly sensitive to water stress, while boll retension was only affected by severe stress. The higher number of bolls plant^{-1} and boll weight was recorded by scheduling irrigation at 100 mm CPE as compared to irrigation applied at 150 and 200 mm CPE (Siag and Verma, 1994).

Sethi *et al*. (1995) reported that the wet regime recorded more growth i.e. height, sympodial branches, total dry matter, number of squares, flowers and green bolls plant^{-1} as compared to moderately wet and dry regime.

Kaswala *et al*. (2000) conducted a field experiment on cotton at Khandka, Gujarat Agricultural University on cotton with three irrigation levels viz. 0.3, 0.5 and 0.7 IW/CPE ratios and found that irrigation scheduled at 0.7 IW/CPE ratio recorded higher growth and yield contributing characters during both the years of investigation. These findings corroborate the results of Khan *et al*. (2000) in wheat.

Singh and Brar (2000) found that plant height, leaf abscission, number of bolls plant^{-1} and boll opening percentage remained unaffected by different soil moisture regimes (0.6, 0.8 and 1.0 IW/CPE).

Rao *et al*. (2000) revealed that autumn planted sugarcane suffers due to water stress in its tillering phase. If once this stage exposed to water stress it reduced photosynthesis leaf area, number of tillers and length and girth of cane.

Ramesh (2000) in field experiment conducted at Coimbatore to study the effect of three levels of drought (severe, moderate and control) during formative phase on growth determinants and their relationship with dry matter accumulation. The reduction in dry matter content was 60.8, 52.4 and 25.9 per cent in sever draught and 46.3, 36.3 and 15.1 per cent in moderate drought at the ends of formative, grand growth and maturity phases, respectively.

Dahatonde and Deshmukh (2001) observed that scheduling of irrigation at 0.8 IW/CPE found superior over irrigation applied at 0.6 and 0.4 IW/CPE ratio in respect of monopodial, sympodial branches plant^{-1} and number of picked bolls plant^{-1}. Similar results were obtained by Pawar *et al*. (2001) in mustard crop.

Ahmet and Riza (2003) depicted a linear relationship between cotton yield and water consumption and between shedding rate and boll number. It was observed that a shortage of water generally increases the shedding rate and decreases the boll number and results in lower yield.

2.1.2 Effect of irrigation levels on yield and quality of cotton

Abraham *et al*. (1980) found that the fibre properties of *Varalakshmi* hybrid cotton grown under irrigated and rainfed conditions, the fibre length and fibre fineness were slightly affected in rainfed cultivation but there was no significant difference on bundle strength and maturity co-efficient between irrigated and rainfed conditions.

In field trials on an alluvial eutrophic soil in Ceara, Brazil, *G.hirsutum* Cv. BR-1 grown 0.2 m apart with 1.0 m between rows was irrigated by furrow at 6 days intervals to 40, 60, 80 or 100 per cent of potential evapotranspiration. Seed cotton yields ranged from 1.41 and 1.89 t ha^{-1} following irrigation at 60 and 80 per cent potential evapotranspiration, respectively. Irrigation at 100 per cent potential evapotranspiration gave a seed cotton yield of 1.70 t ha^{-1} (Aragao *et al*., 1989).

Jadhav *et al*. (1989) reported that dry pod yield of groundnut was increased significantly with 1.0 IW/CPE ratio (80 mm CPE) and irrigation applied at 10 days interval as compared to scheduling of irrigation at 0.6 IW/CPE ratio. Further it was noticed that irrigation scheduled at 1.0 IW/CPE ratio also gave significantly more dry pod yield over 0.8 IW/CPE (100 mm CPE) during the same year. However, the fibre length and strength were not affected by surface, drip and furrow irrigation on cotton (Constable and Hodgson, 1990).

Verma *et al*. (1991) conducted a field experiment on 3 irrigation levels viz. 0.8, 0.6 and 0.4 IW/CPE ratio's and found that the seed cotton yields were significantly higher at 0.8 IW/CPE and 0.6 IW/CPE as compared to the irrigation applied at 0.4 IW/CPE ratio. This increase in yield was 17.9 and 15.0 per cent when irrigation was given at 0.8 and 0.6 IW/CPE, respectively over 0.4 IW/CPE ratio. Similar results were observed by Verma and Deo (1992).

Sethi *et al*. (1995) from Akola, Maharashtra observed that the ginning percentage, uniformity ratio, bundle strength and fineness were not affected by irrigation levels. Irrigation increased only span length in 1986-87. However, increasing levels of irrigation resulted in non significant differences with respect to different quality parameters (Srinivasareddy and Thimmegowda, 1997).

Shelke *et al*. (1997) indicated that pre-monsoon (May) planted cotton required one irrigation of 75 mm as presowing followed by two post sowing light irrigations (50 mm each) for satisfactory emergence and crop establishment and thereafter, it required irrigation at 250 mm CPE till onset of monsoon.

Tekale *et al*. (1999) reported that application of irrigation at 0.8 ET_C recorded significantly higher seed cotton yield (2336 kg ha^{-1}) over 0.4, 0.6 and 1.0 ET_C during both years of investigation. Similar trend was observed by Shelke *et al*. (1999) at Marathwda Agricultural University, Parbhani (Maharashtra).

Singh (2000) conducted a field experiment at Shriganganagar, Rajasthan and found that when cotton was irrigated at 3 or 5 growth stages and 50 DAS with 0.5 and 0.7 IW/CPE ratio, the seed cotton yield was highest with 5 irrigations.

A field trial conducted during 1998 at Halfway, Texas, USA, on Cv. PM2200RR and PM2326RR, grown with three skip patterns at a constant density of 52272 plants $acre^{-1}$. The same study was expanded in 1999 to include 3 plant densities (52273, 39204 and 26126 plants $acre^{-1}$) and two irrigation regimes (50 and 100 per cent evapotranspiration replacement). No significant differences were noticed in yield due to plant density, skip pattern or irrigation levels in either years. Differences were observed for the lint strength and micronaire in 1998 but no cause and effect relationship could be identified (Franklin *et al*., 2000).

Singh and Brar (2000) concluded that seed cotton yield, fibre properties such as span length, bundle strength, micronarie value and maturity co-efficient were not affected by different soil moisture regimes under Ludhiana, Punjab conditions. However, Singh *et al*. (2001) suggested that application of irrigation water at critical growth stages of cotton (25 + 35 + 55 + 65 + 130 DAS) increased seed cotton yield (1723 kg ha^{-1}) and improved the quality of cotton.

Donald *et al*. (2002) conducted the studies at Texas Agricultural Experiment Station Lubbock and reported that the maximum yield was obtained at an irrigation input of 58 cm and estimated to peak at a total water input of 74 cm and lowest lint yield was obtained at 45 cm irrigation input.

Sagarka *et al*. (2002) conducted a field experiment at Junagadh, Gujarat with three drip irrigation levels (0.4, 0.6 and 0.8 CPE), alternate furrow and surface irrigation methods. They found that application of irrigation at 0.8 CPE through drip recorded significantly higher seed cotton yield and lint index than other irrigation levels. The quality parameters such as 2.5 per cent length, fibre fineness and bundle strength did not differ due to irrigation levels.

Singh (2002[a]) conducted a field trial on sugarcane at Sriganganagar, Rajasthan and found that the highest cane yield of 57.7 and 58.2 tonnes ha^{-1} recorded at 0.9 and 1.2 IW/CPE, respectively and which was at par with each other and significantly superior over 0.6 IW/CPE ratio. Similar trend was found in sugarcane ratoon by Singh (2002[b]).

Halemani *et al*. (2003) observed that irrigation applied at 100 per cent ET through drip was found to be more beneficial than 75 and 50 per cent ET levels. Same trend was noticed in both the years of investigation.

Shelke and Giri (2003) at Marathwada Agricultural University, Parbhani (M.S.) showed that irrigation through drip gave significantly higher seed cotton yield over ridges and furrow method. Irrigation scheduled at 0.6, 0.8 and 1.0 ET_C were at par with each other indicating that 0.6 ET_C was found beneficial.

Ravikumar *et al*. (2004) concluded that irrigation scheduling with irrigation interval corresponding to 60 mm CPE before onset of square formation and 50 mm CPE in the subsequent period @ 17 litres $plant^{-1}$ for each irrigation gave maximum yield. Fibre length was affected by the moisture content at 16 to 20 days after flowering (Venugopalan *et al*., 2004).

Pettigrew (2004) observed that the fibre quality response to irrigation was inconsistant throughout the duration of this experiment. Irrigation increased micronaire (11 %), fibre elongation (6 %) and fibre maturity (13 %) with increase in irrigation water.

Shaikh *et al*. (2004) conducted a field experiment on groundnut and reported that irrigation scheduled at 75 and 100 CPE and 10 days interval found to be at par with each other, but significantly increased the dry pod and creeper yield as compared to scheduling of irrigation at 125 mm CPE. Similar results were recorded by Mehmet *et al*. (2005) in cucumber at Turkey.

Subbaramamma and Ratnakumari (2006) reviewed that, in cotton, moisture makes or breaks fibre quality.

A field trial was conducted at Marathwada Agricultural University, Parbhani (M.S.) under TMC Project data regarding growth and yield of cotton showed that the application of irrigation to Bt cotton at 0.8 ET_C (3277.7 kg ha^{-1}) and 1.0 ET_C (3289.7 kg ha^{-1}) were found at par and recorded significantly higher seed cotton yield as compared to scheduling of irrigation at 0.6 ET_C and 0.6 IW/CPE ratio. Whereas, scheduling of irrigation in furrow at 0.6 IW/CPE ratio recorded higher seed cotton yield (2382.7 kg ha^{-1}) over irrigation applied through drip at 0.6 ET_C (Anonymous, 2007).

Jukte *et al.* (2007) reported that the irrigation scheduled at 1.0 IW/CPE (1612 kg ha^{-1})recorded the highest seed yield of French bean over irrigation applied at 0.8 IW/CPE ratio (1509 kg ha^{-1}) and 0.6 IW/CPE ratio (1065 kg ha^{-1})

Patil *et al*. (2008[a]) carried out a field experiment at Agriculture Research Station, Dharwad for three years (1998-99 to 2000-01) with two irrigation methods i.e. alternatively alternate furrow irrigation and drip irrigation. They observed that out of 3 years, the yield of cotton during 1999-00 and 2000-01 was marginally better with drip irrigation whereas during first year cotton yield was significantly superior with Alternatively Alternate Furrow Irrigation (AAFI) as compared to drip irrigation. Similar results were obtained by Patil *et al*. (2008[b]) at Agriculture Research Station, Arabhavi, Dharwad, Karnataka.

Dagdelen *et al*. (2009) reported that the irrigation applied at 100 per cent soil water depletion produced significantly higher yield (5760 kg ha^{-1}) than 75 per cent (4775 kg ha^{-1}) and 50 per cent (3800 kg ha^{-1}) soil water depletion.

2.1.3 Effect of irrigation levels on soil moisture studies

Khade *et al*. (1988) from Mahatma Phule Krishi Vidyapeeth, Rahuri, (M.S.) revealed that the consumptive use of moisture by cotton varies with the irrigation levels. On four years average based, it was observed that the consumptive use of moisture ranged from 54.46 to 80.51 cm. The consumptive use was 77.37 and 80.51 cm under the treatments when irrigation was schedule at 0.75 and 0.90 IW/CPE ratios, respectively. Incidently these treatments yielded more seed cotton ha^{-1}.

Consumptive use of moisture by crops increased with the frequency of irrigation. Average values of consumptive use under irrigation at IW/CPE ratio of 0.8, 0.6 and 0.4 were 681, 610 and 544 mm respectively (Verma *et al*., 1991). Water use efficiency decreased as frequency of irrigation increased. Similar trend was observed by Verma and Deo (1992).

Singh and Bhan (1993) opined that the highest water use efficiency was observed in low frequency (200 mm) of irrigation and the lowest in higher frequency (80 mm) of irrigation in the summer crop.

Siag and Verma (1994) showed that the scheduling of irrigation at 100 mm CPE gave maximum consumptive use of water 990.7 mm which was higher 865.3 and 763.2 mm than that recorded with the scheduling of irrigation at 150 and 200 mm, respectively. Whereas, similar trend was found in water use efficiency by cotton. Studies conducted at Cotton Research Station, Surat, Gujarat indicated that application of irrigation at 0.8 IW/CPE ratio saved irrigation water to the tune of 40 per cent through drip without affecting the yield (2799 kg ha^{-1}) over 0.4 IW/CPE ratio (Anonymous, 1996).

Viridia and Patel (2000) observed that the higher consumptive use of 376 and 317 mm was with 0.7 IW/CPE ratio than 0.5 of 331 and 263 mm and 0.3 IW/CPE of 208 and 139 mm ratio during 1992-93 and 1993-94, respectively.

Shinde *et al*. (2001) reported that the surface method of irrigation required 85.14 cm of irrigation water as against 49.12 cm in drip method. Thus, the irrigation water saving due to drip was 42.30 per cent over surface method of irrigation in cotton. The 70 per cent probability value of ET for sugarcane and cotton were 2065.30 and 856.63 mm, respectively. The total water requirement deficit was 1633.41 and 503.58 mm for sugarcane and cotton, respectively (Zade *et al*., 2003).

Halemani *et al*. (2003) showed that water use efficiency increased with decreasing ET levels from 100 to 50 per cent during both the years of experimentation. Yield obtained was highly related with quantity of water applied irrespective of planting pattern.

Shelke and Giri (2003) reported that application of irrigation @ 0.6 ET_C through drip saved 40 per cent water over ridge and furrow method.

Tennakoon and Milroy (2003) from CSIRO, Australia concluded that the average consumptive water use efficiency across all the regions and seasons was 2.5 kg ha^{-1}-mm with large variability across the regions.

Aujla *et al*. (2005) estimated the quantity of water and N through drip and showed that decrease in quantity of water applied was accompanied by corresponding decrease in seed cotton yield resulting into change in water use efficiency. When the cotton was grown in check-basin, water use efficiency decreased from 17.6 to 14.6 kg ha^{-1} (17 per cent) over drip.

Dagdelen *et al*. (2009) conducted a field experiment on drip irrigated cotton at ARS, Adnan Menderes University, Ayolin, Turkey and concluded that the water use efficiency at 25 per cent soil moisture depletion was highest 0.96 kg m^{-3} as compared to 50 and 100 per cent.

2.2 Effect of water saving practices

2.2.1 Effect of water saving practices on growth and yield attributes

Brar and Singh (1983) observed that the plant height, number of bolls $plant^{-1}$ and boll weight were not influenced significantly due to various methods of irrigation. Similar trend was observed in yield attributing characters.

Gaikwad (1985) observed that growth and yield attributing characters were not adversely affected due to alternate and every furrow irrigation. On the contrary dry matter production was increased due to alternate furrow irrigation.

Rasmussen and Berg (1986) reported that the irrigation methods did not show significant effects on number of bolls $plant^{-1}$ and stalk weight per $plant^{-1}$.

Solaiappan *et al*. (1991) conducted a trial on irrigation methods on summer cotton at Shrivilliputtur on clay loam soil and found that the differences in growth and yield attributes of cotton due to every furrow and alternate furrow methods of irrigation were found to be not significant.

Solaiappan *et al*. (1993) from Shrivilliputtur, Tamil Nadu observed that the plant height, number of sympodia plant^{-1} and number of bolls plant^{-1} were not affected due to irrigation methods. The alternate furrow system of irrigation could be preferred as there was saving of irrigation water without scarifying yield attributes.

Sethi *et al*. (1995) reported that the yield contributing characters with wet regime were higher than moderately wet and dry regime.

Christopher and Chinaswami (1996) from Coimbatore, Tamilnadu reported that the alternate furrow irrigation resulted in reduction of plant height, dry matter production and number of bolls as compared to every furrow irrigation. However, number of monopodial branches and boll weight were not affected by irrigation methods.

Virdia and Patel (2000) studied the effect of methods and scheduling of irrigation on growth yield and yield contributing characters and found that irrigation in every furrow and in alternate furrow alternatively were at par with each other and continuous furrow irrigation produced less number of monopodia, sympodia plant^{-1} and plant height over alternate furrow irrigation. However, number of good bolls plant^{-1}, number of bad bolls plant^{-1} and boll weight were found higher in every furrow irrigation (Halemani *et al*., 2003).

2.2.2 Effect of water saving practices on Yield and quality parameters

Earson *et al*. (1980) showed that the alternate furrow irrigation could reduce water use without reducing crop yields, but successful water use requires row width of 75 cm or less in slowly permeable clay loam soils and was not practicable on many soils.

Sivanappan and Chandrasekaran (1984) observed that there was no significant difference in yield of cotton both in alternate and skip furrow methods when compared to conventional furrow method irrigation.

Howell *et al*. (1984) observed that fibre fineness and 50 per cent span length were increased with increased application of irrigation water for narrow row cotton. Whereas 2.5 per cent span length, uniformity index, elongation percentage and strength had no effect due to irrigation treatment.

Gaikwad (1985) reported that the quality of seed cotton remained unchanged due to alternate furrow irrigation. However, ginning percentage and staple length tended to decrease and seed oil content and lint index tended to increase by alternate furrow irrigation.

The results obtained from water management project, Navsari, Gujarat revealed that there was no significant difference in yield of irrigated cotton in flat beds, in furrows or in alternate furrows with or without plastic. However, Raman *et al*. (1990) observed that the seed cotton yield increased with N in alternate furrow irrigation, a method which used 50 per cent of the water in commonly practiced flood irrigation system. On the other hand the seed cotton yield was not differed significantly due to irrigation treatments viz. flood irrigation, furrow irrigation, alternate furrow irrigation and paired row irrigation in Bhatinda, Punjab (Nimbole and Bonde, 1991).

Singh and Bhan (1993) from Kanpur, Uttar Pradesh reported that the fibre quality was not generally affected by irrigation frequency for either summer or winter crops.

Shethi *et al*. (1994) from Akola, Maharashtra observed that the ginning percentage, uniformity ratio, bundle strength and fibre fineness were not affected by irrigation methods.

Jadhav *et al*. (1995) from Parbhani, Maharashtra observed that the alternate furrow irrigation system (AFI) produced comparable seed cotton yield with that of every furrow irrigation (EEI) and flat bed irrigation (FBI) systems. However, Christopher and Chinaswami (1996) reported that the reduction in seed cotton yield (15.5 %) due to alternate furrow irrigation compared to every furrow irrigation.

Reddy and Thimmegowda (1998) reported that the span length, fineness and tenacity of fibre were not affected due to different methods of irrigation. While, Deshmukh (1999) reported that the quality parameters *viz*., ginning percentage and fibre strength were almost identical in drip and surface method of irrigation.

Viridia and Patel (2000) did not find significant effect on seed cotton yield and lint quality due to every furrow and alternate furrow irrigation method.

Sagarka *et al*. (2002) found that application of irrigation through drip method at 0.8 CPE recorded significantly higher seed cotton yield of 1486, 1585 and 1535 kg ha^{-1} during 1994-95, 1995-96 and in pooled results respectively, but it was at par with at 0.6 CPE during individual years. The drip irrigation at 0.4 CPE, alternate furrow and surface method were remained statistically at par with each other. There was no significant difference due to irrigation methods and moisture regimes on 2.5 per cent fibre length, fibre fineness and bundle strength.

Lisong and Zhang (2005) reported that seed cotton yield of alternate furrow irrigation (AFI) and fixed furrow irrigation (FFI) were 92 and 84 per cent higher as compared to conventional furrow irrigation (CFI) and concluded that AFI was effective water saving irrigation method and seed cotton yield can be sustained with less water.

Ghadge *et al*. (2005) reported that irrigation techniques did not influence the seed cotton yield and quality parameters of cotton. These results were confirmed by Thukkaiyannan *et al*. (2005).

Patil *et al*. (2008[a]) showed that alternatively alternate furrow irrigation (AAFI) was given 15.8 per cent higher seed cotton yield than drip irrigation. However, the quality parameters like staple length, uniformity ratio, micronaire value and tenacity were not influenced significantly by any of the irrigation methods.

2.2.2 Effect of water saving practices on soil moisture studies

Singh and Kairan (1973) reported the irrigation methods *viz*., flood, every furrow and alternate furrow irrigation that use of alternate furrow irrigation system recorded the highest saving of water to the extent of ¼ to ½ of the quantity without any loss of yield and/or in any way over flood irrigation system.

Stewart and Musick (1982) observed that planting of hybrid cotton on ridges with every and alternate furrow irrigation might have provided favourable soil moisture environment in root zone due to drainage of excess water during high rainfall season and conservation of rain water during normal and sub normal seasons.

Erie *et al*. (1982) showed the average seasonal consumptive use to be 103 cm for the Phoenix area for obtaining maximum yield.

Brar and Singh (1983) from Punjab Agricultural University, Ludhiana reported that on an average of three years, furrow and alternate furrow irrigation method resulted in 16.4 and 31.7 per cent saving of water over flat bed method respectively.

Sivanappan and Chandrasekaran (1984) reported that the alternate furrow method was capable for saving irrigation water to the tune of 27 per cent and skip furrow method to the extent of 51 per cent compared to the control furrow method of irrigation.

The consumptive use efficiency was increased by 0.10 kg ha^{-1}-mm due to alternate furrow irrigation over normal planting (Gaikwad, 1985).

While studying drip and furrow irrigation systems for cotton variety *Savitri* at Rahuri, Maharashtra, Bangal *et al*. (1987) reported that 71.90 cm water was required in furrow system whereas drip required 41.90 cm.

Raman *et al*. (1990) reported an economy of 50 per cent of irrigation water by adopting alternate furrow irrigation alongwith the use of plastic mulch in cotton crop.

Mukharji *et al*. (1990) reported that there was a saving of 50 per cent water by following the alternate furrow irrigation system over every furrow and flood irrigation.

Aujla *et al*. (1992) reported that irrigation to each furrow and furrows between paired rows gave almost same yield as the flood irrigation but caused a mean saving of about 9.3 – 13.5 cm (25-36 per cent) irrigation water as compared to flood irrigation, the alternate furrow slightly suppressed seed cotton yield but irrigation water economy was substantial (39 per cent). Consequently irrigation to each furrows and paired rows caused a large increase in irrigation water use efficiency.

Singh and Bhan (1993) observed that the highest water use efficiency (200 mm CPE) in low frequency of irrigation and the lowest in higher frequency of irrigation.

Stone and Nofziger (1993) concluded that the water use efficiency (WUE) of cotton in general was higher under ridges and furrow irrigation system than conventional flat bed system.

The highest seed cotton yields were attained under drip irrigation. The drip, sprinkler, mobile and subsurface irrigation used

31, 28, 28 and 27 per cent, respectively less water than furrow irrigation (Cetin *et al.*, 1994).

Singh and Kairan (1994) reported that saving in water could be effected to the extent of 25 to 50 per cent of the quantity with the adoption of furrow or alternate furrow irrigation method without any deleterious effect in the yield of cotton.

Christopher and Chinaswami (1996) reported that the alternate furrow irrigation saved 35 per cent of irrigation water compared to every furrow irrigation but resulted both in lower yields.

Two varieties of cotton (Niab-78 and Niab-92) were tested under every furrow and alternate furrow method. The yields were higher under every furrow irrigation than alternate furrow irrigation, whereas water use efficiency in both the varieties were 22 and 21 per cent higher with alternate furrow irrigation (Khan *et al.*, 1999).

Shelke and Giri (2003) suggested that irrigation through every furrow and alternate furrow was at par with each other. However, 25 per cent saving of irrigation was realized in alternate furrow irrigation.

Bhunia (2007) from Sriganganagar, Rajasthan proved that the flood irrigation method gave significantly higher seed cotton yield (16.96 q ha^{-1}) over every furrow (16.08 q ha^{-1}) and alternate furrow in rotation (14.34 q ha^{-1}). However, the highest WUE of 4.87 q ha^{-1}-mm was recorded with irrigation in alternate furrow in rotation.

The research consisted comparing surge and continuous flood in long furrow and adopting alternate furrow irrigation (Horst *et al.*, 2007). The best results were achieved with surge flood irrigation applied to alternate furrow (0.61 kg m^{-3} water productivity), which reduced irrigation water use by 44 per cent (390 mm) and led to high application efficiency, near 85 per cent.

Patil *et al*. (2008[b]) did not find significant differences under drip (1928 kg ha^{-1}) and alternatively alternate furrow irrigation (AAFI) (1973 kg ha^{-1}) methods in respect of yield. However, 50-60 per cent water can be saved under drip irrigation over AAFI method, which helps in increasing the additional area under irrigation with available water.

Water use efficiency of cotton (8.0 kg ha^{-1}-mm^{-1}) and maize (36.7 kg ha^{-1}-mm^{-1}) was increased due to alternate furrow irrigation over irrigation in every furrow with slight reduction in yield of cotton and maize (Bhaskar, 2004). Veeraputhiran and Suresh (2005), suggested that alternate furrow irrigation is the best way to enhance the cotton productivity.

2.3 Effect of cotton hybrids

Comparing the methods of irrigation *viz*., strip, border, furrow and check basin for their adoptability on MCU-5 cotton at Coimbatore, Sivanappan *et al*. (1973) found that furrow method of irrigation was more efficient for MCU-5 cotton hybrid.

Constable and Hodgson (1990) found that among D1-90 and Siokra cotton cultivars, Siokra yielded 16 per cent more under surface drip and buried drip than furrow irrigation. Similarly the varieties of cotton (Niab-78 and Niab-92) were tested under each furrow and alternate furrow irrigation. The higher yield was produced under each furrow irrigation, whereas water use efficiency in both the varieties was 22 and 21 per cent higher with alternate furrow irrigation (Khan *et al*., 1999).

A major cost escalation factor in lowered cost of production and if quality attributes are effectively managed can become the most sought after technology input in coming years (Manjunath and Mohan, 1999).

Mayee and Rao (2002) concluded that the basic strategy hereafter in the field of cotton production will lay stress on quality and cost competitiveness to match the quality and price levels operative in the international market. In this context, Bt hybrids with the potential of reduced expenditure on plant protection will play an important role.

Barwale *et al*. (2002) conducted a multi-locational trial in six states and found that Bt cotton hybrids recorded the highest seed cotton yield and was significantly superior over Non-Bt cotton hybrids. However, Sahai and Rahman (2005) observed that the Non Bt cotton hybrids were found significantly superior over Bt hybrids in respect of yield and economics.

The percentage yield increase of Bt over it's counter part ranges between 16 to 60 per cent. The average boll weight (3 g $boll^{-1}$) was very less as compared to Non Bt (550 to 600 g/100 boll) and staple length was short, which fetches the lower price in market as compared to other popular hybrids (Anonymous, 2003).

Halemani *et al*. (2003) reported that the *intra-hirsutum* DHH-11 performed better than inter-specific hybrid DHB-105 at all the spacing and also with continuous furrow irrigation.

Wankhede *et al*. (2003) from Punjabrao Deshmukh Krishi Videepth, Akola indicated that all hybrids recorded similar seed cotton yield i.e. PKVH-4 (14.11 q ha^{-1}), PKVH-2 (13.71 q ha^{-1}) and NHH-44 (12.99 q ha^{-1}) at 0.7 IW/CPE ratio. At ARS, Dharwad, DHH-11 cotton hybrid gave significantly higher seed cotton yield (2372 kg ha^{-1}) than other genotypes (Patil *et al*., 2004).

Singh *et al*. (2003) observed that the seed cotton yield was the highest in MECH-184 Bt (17.18 q ha^{-1}) followed by MECH-163 Bt (17.17 q ha^{-1}), over their Non Bt counter parts (yielded 2 to 3.5 q ha^{-1} less). Similarly the check, NHH-44 (14.74 q ha^{-1}) had less yield 2.49 q ha^{-1} than two Bt cotton hybrids.

Qaim and Zilberman (2003) based on one year's trial claimed that genetically modified plant could dramatically increase the yield upto 87 per cent in developing countries. For Bt cotton in USA the increase in yield was 10-15 per cent, in China, it was the same.

Nehra *et al*. (2004) indicated that Bt cotton hybrids MECH-162 Bt (1095 kg ha^{-1}) and MECH-915 Bt (997 kg ha^{-1}) produced significantly higher seed cotton yield and yield attributes in comparison to their respective Non Bt hybrids and local check (Anonymous, 2004). These results are in conformity with findings of Garg *et al*. (2004).

Bennet *et al*. (2004) from South Africa showed substantial and significant financial benefits to small holder cotton growers of adopting Bt cotton over three seasons in terms of increased yields, lower insecticide spray costs and higher gross margins than those with larger holdings.

Pettigrew (2004) proved that the Bt gene containing genotypes (DPL 20B and Pay Master 1220 BR) produced significantly higher yields than their recurrent parent lines. The lint yield response averaged across years differed significantly among genotypes. In addition the response of two soil moisture regimes (dryland and irrigated) was similar among genotypes, demonstrating the lack of significant interaction.

Pradeep and Sumalini (2005) reported that the performance of ten multiple cross hybrids of cotton observed significant variation in the hybrid population as compared to single cross check hybrid *viz.*, NHH-44, Brahma and Straight varieties L-604, ADB-329, LRA-5166 and Narsimha for the nine parameters of plant growth and yield.

Reddy *et al*. (2005) taken the intervention on Bt and Non Bt cotton hybrids (MECH-12 Bt, MECH-184 Bt and their two counter parts) at different villages (24 farmers) and found that the average yield of Bt cotton hybrids was higher (12.09 q acre^{-1}) than Non Bt (11.33 q acre^{-1}) cotton hybrids.

Jeughale *et al*. (2005) were found non significant differences amongst the various cotton hybrids as regards seed cotton yield. However, the highest seed cotton yield was obtained from MECH-162 Bt (10.71 q ha^{-1}) followed by MECH-184 Bt (10.30 q ha^{-1}), MECH-12 (9.12 q ha^{-1}), NHH-44 (8.98 q ha^{-1}) and PKVH-2 (8.63 q ha^{-1}).

Rao (2006) from two years field experiments at CSIRO Plant Industry, Australia, showed that under normal full irrigation, Bollgard-II cotton needed 10 per cent less water than an equivalent conventional variety and had higher yields.

Sinha and Choudhary (2006) claimed that cultivation of Bt cotton led to additional net profit at least about Rs. 12000 ha^{-1} and 40.50 per cent savings in pesticide use. Also as Bt hybrids mature early, they enable double cropping in previously single cropped areas.

Srinivasulu *et al*. (2006) observed variation in fibre length among different hybrids. Maximum uniformity ratio was observed in RCH-317 and Ankur-651 (86.8 %) and minimum was recorded in RCH-134 (85.3 %). Further they reported that neither the elongation ratio nor the strength of the fibre was influenced by the hybrids.

Buttar and Singh (2006) showed that both the Bt hybrids RCH-134 (2834 kg ha^{-1}) and RCH-317 (3610 kg ha^{-1}) produced significantly higher seed cotton yield in comparison with their Non Bt hybrids i.e. RCH-134 (2096 kg ha^{-1}) and RCH-317 (1621 kg ha^{-1}). Similar trend was observed by Bhatade *et al*. (2006).

Singh *et al.* (2007) evaluated the performance of six Bt cotton hybrids and indicated that among different hybrids RCH-134 recorded the highest yield (3729 kg ha^{-1}) though it was statistically on par with RCH-317 (3673 kg ha^{-1})) and MRC-6301 (3610 kg ha^{-1}) but significantly superior to Ankur-651 (2297 kg ha^{-1}), Ankur-2534 (2893 kg ha^{-1}) and MRC-6304 (3118 kg ha^{-1}). Ankur-651 recorded significantly lower yield as compared to all other hybrids, while Ankur-2534 and MRC-6304 were on par with each other.

Singh and Kaushik (2007) reported that in India, Bt cotton hybrids were approved for commercial cultivation in 2002. These hybrids are resistant to all three bollworms. However, these are not essentially resistant to sucking pests and may require chemical control.

Significant variation among Bt cotton hybrids was observed by Deosarkar *et al*. (2008) for seed cotton yield and it was ranged from 1336 kg ha^{-1} (Ankur 2226) to 2681 kg ha^{-1} (Akka). All the Bt cotton hybrids recorded significantly higher seed cotton yield than their conventional version. On mean basis, Bt cotton hybrids recorded 48.5 per cent higher seed cotton yield than their conventional versions and the percentage increased range from 18.2 to 86.7.

Patil *et al*. (2008[a]) recorded the significant difference in interaction effects of irrigation methods and genotypes and DHH-11 with drip irrigation produced highest seed cotton yield (2437 kg ha^{-1}). On the other hand, Sahana (2438 kg ha^{-1}) followed by DHH-11 (2306 kg ha^{-1}) were the top yielders under alternatively alternate method of irrigation. DCH-32 hybrid recorded lowest yield under both methods of irrigation. Further more studies revealed that methods of irrigation had no significant influence on all the fibre quality parameters, at all the pickings. However, Patil *et al*. (2008[b]) revealed that the interaction effect of irrigation methods and genotypes were non significant with respect to seed cotton yield.

2.4 Cotton *parawilt*

Bhale (1984) found *G. barbedense* cultivars free from *parawilt* syndrome but the susceptible inter species combination of H x B hybrids was primarily influenced by their *hirsutum* female parent which probably carries certain lethal genes.

Mandloi *et al*. (1985) reported that the *parawilt* of cotton which is referred by various names such as *Adilabad wilt*, *New wilt*, as it was first reported from Adilabad district in Andhra Pradesh and Khandwa in Madhya Pradesh.

Pundarikakshudu (1988) showed non contributory role of soil pH and soil nutrition in the incidence of *parawilt*, whereas, Mane *et al*. (1989) observed positive but undesirable heteorosis for *parawilt* resistance which is highest in JKHV-1 followed by DCH-32 and NHH-44.

Mayee (1988) demonstrated regeneration of healthy plants from *parawilted* root and stem cuttings. Natural recovery from some *parawilted* plants in field was a characteristic feature of *parawilt* of cotton. It was concluded that the cause of *parawilt* may not be the conventional biotic pathogens.

Sahay (1988) suggested that the synthetic pyrethroid has a role to play in the incidence of new wilt disorder in susceptible hybrids of cotton.

Sahay *et al*. (1988) observed that the induction like symptoms by the foliar application of ethephon and partial recovery of naturally wilted plants by the application of silver nitrate (an inhibitor of ethylene action) and suggested the association of ethylene in causing *new wilt* in upland cotton (*Gossypium hirsutum* Linn.).

Narayanan *et al*. (1989) reported that the wilt affected plants recorded considerable reduction in boll weight, seed oil content and seed index of cotton as compared to healthy plants in cultivars as well as hybrids. However, hybrids were more susceptible to the incidence of *new wilt*.

Since the cause of disease itself is a complex so also is the management strategy. Preventive measures like planting cotton in well drained soils, application of organic manures, optimum inorganic fertilizer use, continuous soil pulverization during drought period and application of limited irrigation through alternate rows are recommended (Mayee *et al*., 1989).

Chauhan *et al*. (1989) found that prolonged drought in the field followed by irrigation or rains, imbalanced fertilizer application and continuous use of synthetic pyrethroids predisposed cotton to attack by *parawilt*.

Raj and Meshram (1990) concluded that the incidence of *new wilt* in sandy loam soil was 2-3 times higher than in black cotton soils during both the years, irrespective of the hybrids. However, the application of synthetic pyrethroids did not induce the *new wilt*.

Mayee *et al*. (1990) indicated that the infection source of *new wilt* could be exogenous, or endogenous it is very weak parasite such as flagellate protozoa where only a few plants express the symptoms even when many more may be carrying the inoculums.

Besides the yield loss, *parawilt* also affects quality characters, *viz.*, staple length, fineness, bundle strength, ginning percentage, seed weight, maturity co-efficient and vigour index (Mayee, 1992 and Mayee *et al.*, 1992).

In continuous histo pathological work, Mayee (1992), Mayee *et al.* (1992) and Mayee (1993) confirmed the association of flagellates like organism with phloem tissues of *parawilt* affected cotton.

Shashtry *et al.* (1995) concluded that xylem emboli were formed in root, stem and petiole portions of the *parawilt* affected cotton plants. They provided evidence of impaired water uptake in the *parawilt* affected plants both under moisture stress and water logged conditions. As a result reduced water uptake, xylem water comes under tension and the water column begins to rupture, forms gas filled emboli that render the vessel inactive.

Survey carried out between 1986 and 1990 revealed that the disease was well distributed irrespective of eco-units and that the *G. arboreum* cultivars escaped from the damage. The disease manifests on the adult plants at any time after flowering. Potential losses in yield in the range of 42 to 71 per cent were recorded in NHH-44 and DCH-32 (Mayee and Mukewar, 2001).

Many complaints about susceptibility of wilting were received from Amravati, Yeotmal and Nanded districts of Maharashtra on Bt cotton varieties. As per the report of CICR it was not a pathogenic wilt and was not caused by fungi, bacteria and virus. The wilting was a characteristics of *parawilt* and was a physiological disorder which normally occurred when the cotton hybrids exposed to prolong dryspell followed by rains (Anonymous, 2003).

Hebbar and Mayee (2004) conducted a field experiment during 2002-03 at Nagpur to study the effect of water logging on different genotypes of cotton (*Gossypium* spp.) and showed that imposition of water-log treatment under bright sunlight and high temperature elicited wilt symptoms in plants with large canopy and heavy boll load, similar to *parawilt* observed in farmers field. While confirming these results, Hebbar (2005) supported that the environmental conditions such as high temperature and bright sunshine followed by heavy rainfall were found to favour the occurrence of wilt.

2.5 Economic studies

Solaiappan *et al*. (1993) concluded that sole cotton crop when raised in close spacing and alternate furrow irrigation system gave maximum monetary returns under summer irrigated conditions.

The mean gross, net return and return rupee^{-1} were obtained at high irrigation level and the lowest were recorded at low irrigation levels (Narkhede *et al*., 1996).

Kaswala *et al*. (2000) observed that the highest net return of Rs. 17525 ha^{-1} was obtained with irrigation applied at 0.7 IW/CPE ratio (5 irrigation of 80 mm depth) over Rs. 16053 ha^{-1} at 0.5 IW/CPE and Rs. 14895 ha^{-1} at 0.3 IW/CPE ratio. Similar results were recorded by Verma and Deo (1992) under cotton.

Genetically engineered cotton increased yields, profits and reduced pesticide use by farmers in US (Carlson *et al*., 1998), China (Pray *et al*., 2001) and India (Surulivelu *et al*., 2003).

The highest net returns (Rs. 35317) and benefit cost ratio (2.44) were obtained when sugarcane ratoon was irrigated at 0.9 IW/CPE ratio. The net returns per unit of water applied decreased with an increase in irrigation regimes i.e. Rs. 30.95 ha^{-1}-mm^{-1} under 0.6 IW/CPE to Rs. 24.85 and Rs. 19.72 ha^{-1}-mm^{-1} under 0.9 and 1.2 IW/CPE ratios respectively (Singh, 2002[a]).

Barwale *et al*. (2002) obtained the highest economic benefit per hectare from Bt cotton over non Bt by 32.54 per cent.

Singh (2002[a]) reported that the net returns of Rs. 3215 ha^{-1}-mm of water applied to sugarcane was considerably low in irrigation to all furrows as compared to alternate furrow in rotation (Rs. 47.63 ha^{-1}-mm^{-1}) mainly due to 33 per cent saving in irrigation water in later method. The net return and benefit cost ratio recorded at 0.9 and 1.2 IW/CPE ratios were almost equal and substantially higher than 0.6 ratio.

Reddy *et al*. (2005) proved that there was net gain of Rs. 4820 $acre^{-1}$ and Rs. 4150 $acre^{-1}$ in case of MECH-12 Bt and MECH-184 Bt respectively over checks. However, Jeughale *et al*. (2005) found the reverse trend in Bt and non Bt cotton hybrids in respect of net monetary returns and C:B ratio. They proved that the highest net monetary returns and cost benefit ratio was obtained from check hybrids i.e. NHH-44 and PKVHY-2 as compared to Bt cotton hybrids due to high seed cost of Bt cotton hybrids.

Sahai and Rahman (2005) conducted survey in six states of India and reported that the net profit from Bt cotton was lower per acre compared to Non Bt cotton in all type of fields (low to high yielding). In fact 60 per cent of the farmers cultivating Bt cotton were not even able to recover their investment and incurred losses averaging Rs. 79 $acre^{-1}$.

Kumar (2006) reported that growing of Bt cotton reduced cost of bollworm control up to 60 per cent with corresponding saving from plant protection cost and increase in seed cotton yield.

Sinha and Choudhary (2006) claimed that the cultivation of Bt cotton led to additional net profit of at least about Rs. 12000 ha^{-1} and 40-50 per cent saving in pesticide use.

The highest gross monetary returns (Rs. 6711 ha^{-1}) recorded by scheduling irrigation at 1.0 ET_C which was at par with 0.8 ET_C (Rs. 66865 ha^{-1}) and both these treatments were significantly superior over other treatments (0.6 ET_C and 0.6 IW/CPE furrow irrigation). Similar trend was observed in net returns and B:C ratio (Anonymous, 2007).

Bhunia (2007) reported that the highest benefit cost ratio was found under flood irrigation (2.45) which was at par with all furrow irrigation (2.35) over irrigation was applied in alternate furrow in rotation (2.11) and alternate furrow (2.08). However the water use efficiency was higher when irrigation applied at alternate furrow in rotation (4.87 kg ha^{-1}-mm^{-1}).

Giri and Kapse (2007) reported that the pooled average of net returns of three years from Bt cotton was Rs. 13881 ha^{-1} whereas from non Bt cotton was Rs. 7573 ha^{-1}. Thus additional net returns from Bt cotton, it was Rs. 6304 ha^{-1} over Non Bt cotton, with cost benefit ratio of 1.71 from Bt against 1.39 from Non Bt cotton.

Karthikeyan and Lavanya (2007) reported the economic advantage of Bt cotton hybrids to Rs. 10,100 ha^{-1} over Non Bt.

Prasad *et al*. (2008) reported that Bt hybrids realized higher cost benefit ratio (1:2.6) as compared to its non Bt Version (1:1.3) under IPM with higher net income (Rs. 38553 ha^{-1}).

Bhunia (2008) conducted a field experiment at Hanumangarh, Rajasthan under shallow water table and reported that higher irrigation frequency (45 DAS + flowering + boll development) gave higher benefit: cost ratio of 3.45. However two irrigations (45 DAS + flowering) gave higher water use efficiency (6.92 kg ha^{-1} mm^{-1}).

Dudhare and Deshmukh (2009) proposed that the lower input costs often contribute to a higher net return from Bt cotton compared to conventional hybrids. Bt cotton farmers in US earned an incremental $99 million as a result of decreased pesticide costs and/or increased yield.

3. MATERIALS AND METHODS

The details of the materials used and methods adopted during the conduct of the present investigation are given in this chapter.

3.1 Details of the experimental material

3.1.1 Experimental site

The experiment was conducted at All India Co-ordinated Research Project on Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahemadnagar (M.S.) on survey no 133/6 A during two years, 2007-08 and 2008-09.

3.1.2 Soil

The topography of the experimental field was fairly uniform and leveled. The soil was black in colour, well drained and fairly deep. In order to understand the physical nature and fertility status of the soil a representative composite soil samples from 0-30 cm soil layer were taken from ten randomly selected spots before conduct of the experiment during two years of the investigation. These soil samples were analysed for various physico-chemical properties of the soil. The relevant data obtained on those attributes are given in Table 1.

From the data presented in Table 1, it could be seen that the soil of the experimental plot was clayey in texture and slightly alkaline in nature. The chemical composition indicated that the soil was low in available nitrogen (216.38 kg ha^{-1}), medium in available phosphorus (22.8 kg ha^{-1}) and high in potassium content (330 kg ha^{-1}). Total soluble salt content was normal (electrical conductivity 0.24 dSm^{-1}).

Table 1: Physical and chemical properties of experimental field

Sr. No.	Soil properties	Composition	Method adopted	Reference
A.	**Physical properties**			
1.	Coarse sand (%)	4.96	Buoyoucos	Buoyoucos (1962)
2.	Fine sand (%)	13.94	Hydrometer	
3.	Silt (%)	23.86		
4.	Clay (%)	57.22		
5.	Textural class	Fine clayey		
B.	**Chemical properties**			
1.	Organic carbon (%)	0.56	Walkley and Black	Piper (1966)
2.	Organic matter (%)	0.97	Rapid titration method	Piper (1966)
3.	Available nitrogen (kg ha^{-1})	216.38	Modified Kjeldahl Method	Olsen (1954)
4.	Available phosphorous (kg ha^{-1})	22.80	Olsen's Method	Hanway and Heidal (1967)
5.	Available potassium (kg ha^{-1})	330	Flame photometer	Jackson (1973)
6.	Electrical conductivity (dSm^{-1})	0.24	Solabridge Method	Jackson (1973)
7.	pH	8.3	Glass electrode Method	
B.	**Single value physical Constants**			
1.	Moisture at 1/3 bar (%)	37.2	Pressure membrane apparatus	Richards (1947)
2.	Moisture at 15 bar (%)	16.9	-- do --	
3.	Bulk density (Mg m^{-3})	1.12	Core sampler	Dastane (1972)

3.1.3 Climatic conditions

3.1.3.1 General

Geographically Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between 19^{O} – 48’ and 19^{O} 57’ North latitude and 74^{O} – 52’ and 74^{O} – 19’ East longitude, and its mean height above sea level is 500 meters. This tract is lying on the eastern side of Western Ghat and falls under rain shadow area. It comes under transition belt having semi-arid climate. It receives most of the rainfall from the South-West monsoon, commencing from middle of June. The mean annual precipitation approximates to about 520 mm receives in about 15 to 45 rainy days from the middle of June to middle of October. About 75 per cent of the total rainfall is received from South-West monsoon between June and September while the rest from North-East monsoon between October and November.

At Rahuri, the mean maximum temperature is 37.9 ^{O}C with a range between 33 ^{O}C to 43 ^{O}C and annual mean minimum temperature is 17.2 ^{O}C with a range between 3 to 18 ^{O}C. The temperature fluctuations starts from the commencement of monsoon it falls down to about 28.0 ^{O}C and fluctuates between 26.0 to 29.9 ^{O}C during the months of July and August. But again, it rises to about 38.8 ^{O}C in months of September and October until cold season begins. From November to January the mean maximum temperature ranges between 26.5 and 33.3 ^{O}C. But again it rises from about 33.0 ^{O}C, in the month of February to about 41.0 ^{O}C in May. The mean minimum temperature is about 13.3 ^{O}C in the month of October after which it gradually drops down to about 4.8 ^{O}C in the coldest months of December and January. Again it rises gradually from about 9.7 ^{O}C in the month of February to about 33.0 ^{O}C in the month of March.

The morning humidity during monsoon period i.e. from June to September is quite high i.e. 85 to 93 per cent, the evening humidity generally ranges between 43 to 84 per cent. However, from October onwards there is a gradual decline in morning humidity from 80 per cent in the month of October to about 50 per cent in March. The evening humidity shows a sudden decline from October onwards. Mean pan evaporation per day is about 4 to 4.5 mm during the month of December and it rises up to about 10 to 12.4 mm per day during April and May.

3.1.3.2 Nature and season during the experimental period

In order to get an idea about the climatic conditions prevailed during the period of present investigation, the meteorological data recorded on the important weather parameters during both the cropping seasons are presented in Table 2 and 3 and depicted in Fig. 1 and 2. The total rainfall received during 2007 and 2008 was 852.4 mm (in 30 rainy days) and 674.4 mm (in 29 rainy days), respectively, which was 54.77 and 29.69 per cent higher than average annual rainfall of 520 mm. In the year 2007, the rainfall received in 23, 25, 35 and 38 meteorological week (MW) was 469.8 mm, the continuous rainfall in every MW was received from 20 to 39 MW in grand growth stage of cotton, which help for better growth and development of bolls during this year.

The weekly maximum temperature in the year 2007 ranged between 39.8 and 28.5^{O}C while minimum temperature ranged between 23.5 and 8.5^{O}C. The mean weekly morning humidity ranged between 90 and 48 per cent and evening humidity ranged between 74 and 14 per cent. The total pan evaporation in this year was 1914.9 mm. The daily maximum pan evaporation was 12.4 mm on 12.5.2007 and minimum was 1.0 mm on 2.11.2007.

In the year 2008, there was late onset of monsoon in 23rd MW with insufficient rainfall. Thereafter, there was well distributed rainfall up to 44th MW. The rain received during 36 and 37th MW was 308.2 mm.

The weekly maximum temperature in the year 2008 ranged between 40.9 and 24.8^{O}C while minimum temperature ranged between 24.2 and 7.6^{O}C. The mean weekly morning relative humidity ranged between 88 and 44 per cent and evening humidity ranged between 80 and 13 per cent. The total pan evaporation during the year was 1919 mm. The daily maximum and minimum pan evaporation was 12.6 mm on 5.5.2008 and 0.2 mm on 11.08.2008, respectively.

Table 2: Meteorological data for the year 2007

Met. Week	Date	Rain fall (mm)	Rainy days	Temperature (°C)		Humidity (%)		Evapo-ration (mm/day)	Wind velocity (kmhr^{-1})	Sun shine (hrs)
				Max.	Min.	Morn.	Even.			
	Jan. 2007									
1	01-07	0.0	-	28.5	10.1	75	36	2.7	0.5	8.9
2	08-14	0.0	-	29.1	11.3	81	38	2.2	0.5	8.7
3	15-21	0.0	-	30.1	11.0	72	33	3.0	0.4	9.2
4	22-28	0.0	-	31.2	12.2	54	35	3.2	0.2	9.3
5	29-04	0.0	-	31.9	14.6	59	35	3.7	0.4	9.0
	Feb.									
6	05-11	0.0	-	31.6	12.5	67	27	4.6	0.8	9.5
7	12-18	0.0	-	28.9	12.2	70	32	4.6	1.2	9.7
8	19-25	0.0	-	32.6	14.1	64	23	4.5	1.1	9.9
9	26-04	0.0	-	32.3	12.3	71	26	5.4	1.4	9.9
	Mar.									
10	05-11	0.0	-	33.3	13.3	62	23	6.2	1.3	9.3
11	12-18	0.0	-	33.6	15.2	58	24	6.0	1.3	8.2
12	19-25	0.0	-	35.8	17.3	50	25	7.4	1.4	8.9
13	26-01	0.0	-	37.7	18.3	53	18	7.9	1.0	8.7
	Apr.									
14	02-08	0.0	-	38.9	18.9	51	14	8.3	1.1	9.2
15	09-18	0.0	-	38.1	18.7	48	16	8.3	0.8	9.3
16	16-22	20.6	1	36.8	20.3	61	26	7.5	1.9	9.3
17	23-29	0.0	-	38.8	19.8	69	48	9.2	2.4	10.6
18	30-06	0.0	-	30.9	22.2	48	18	13.5	4.2	10.0
	May									
19	07-13	0.0	-	39.8	21.8	64	24	11.3	4.6	10.2
20	14-20	27.0	1	38.0	21.4	59	26	10.1	3.6	10.8
21	21-27	0.0	-	37.6	21.8	63	32	9.3	2.2	10.4
22	28-03	90.8	2	36.9	23.4	67	36	7.3	2.2	6.8
	Jun.									
23	04-10	113.0	4	35.2	23.1	77	45	6.1	2.4	8.2
24	11-17	6.2	1	34.8	23.9	70	57	5.2	1.3	7.5
25	18-24	120.0	3	32.6	23.2	80	67	4.9	3.5	5.5
26	25-01	7.6	1	29.7	23.3	80	69	5.4	10.0	3.5

Table 2: Contd…….

Met. Week	Date	Rain fall (mm)	Rainy days	Temperature (°C)		Humidity (%)		Evapo-ration (mm/day)	Wind velocity ($kmhr^{-1}$)	Sun shine (hrs)
				Max.	Min.	Morn.	Even.			
	Jul.									
27	02-08	11.4	2	28.8	23.5	77	67	3.4	7.5	2.0
28	09-15	0.0	-	30.4	23.4	75	59	5.0	5.1	3.4
29	16-22	0.0	-	31.9	22.3	74	51	5.0	2.2	3.7
30	23-29	19.2	1	33.0	22.6	78	63	4.2	1.3	4.6
31	30-05	12.6	1	31.4	22.8	81	63	4.8	4.1	2.4
	Aug.									
32	06-12	1.0	-	29.4	22.7	80	63	4.1	5.2	2.7
33	13-19	3.4	-	30.4	22.4	79	57	4.8	4.1	3.7
34	20-26	59.8	3	30.8	20.8	83	61	3.5	1.1	4.7
35	27-02	120.0	3	29.9	22.1	86	69	2.7	2.1	3.8
	Sept.									
36	03-09	65.4	2	30.2	22.0	86	62	3.8	1.8	4.2
37	10-16	11.6	1	31.7	21.9	85	58	3.8	0.6	6.7
38	17-23	116.8	2	29.5	21.5	90	74	2.9	1.0	2.6
39	24-30	27.0	1	31.0	21.5	82	57	3.4	1.8	4.7
	Oct.									
40	01-07	0.0	-	33.0	18.2	82	32	5.1	0.8	7.8
41	08-14	0.0	-	33.2	19.2	84	32	5.1	0.5	7.3
42	15-21	0.0	-	32.8	14.2	75	28	5.3	0.3	9.3
43	22-28	0.0	-	31.4	13.1	76	28	5.1	1.3	10.0
44	29-04	22.0	2	30.1	17.8	85	55	3.1		6.2
	Nov.									
45	05-11	0.0	-	33.3	18.3	81	39	3.7	1.0	8.6
46	12-18	0.0	-	31.0	12.7	73	25	3.8	0.4	8.4
47	19-25	0.0	-	28.6	8.2	67	25	3.9	0.9	9.2
48	26-02	0.0	-	29.6	10.6	78	34	3.7	0.6	8.1
	Dec.									
49	03-09	0.0	-	27.4	11.0	76	39	3.2	0.8	6.5
50	10-16	0.0	-	29.1	13.5	71	43	3.0	0.1	7.4
51	17-23	0.0	-	28.6	13.2	71	35	2.9	0.3	7.4
52	24-30	0.0	-	32.0	12.2	67	30	3.6	0.1	9.2

Table 3: Meteorological data for the year 2008

Met. Week	Date	Rain fall (mm)	Rainy days	Temperature (°C)		Humidity (%)		Evapo-ration (mm/day)	Wind velocity ($kmhr^{-1}$)	Sun shine (hrs)
				Max.	Min.	Morn.	Even.			
	Jan. 2008									
1	01-07	0.0	-	31.7	11.2	79	29	3.3	0.2	8.7
2	08-14	0.0	-	30.2	11.6	82	32	3.1	0.3	8.4
3	15-21	0.0	-	30.9	11.4	73	27	3.8	0.2	9.4
4	22-28	0.0	-	27.0	7.6	71	22	4.0	0.9	9.7
5	29-04	0.0	-	28.8	8.2	69	29	4.3	1.3	9.7
	Feb.									
6	05-11	0.0	-	24.8	8.1	71	33	4.1	1.1	9.6
7	12-18	0.0	-	31.6	13.6	59	29	5.0	0.9	9.8
8	19-25	0.0	-	33.6	13.0	62	20	5.6	0.5	9.8
9	26-04	0.0	-	33.3	12.0	47	17	6.2	0.8	10.2
	Mar.									
10	05-11	0.0	-	35.6	11.6	54	19	6.7	0.5	7.9
11	12-18	0.0	-	36.3	15.9	53	22	6.5	1.0	8.2
12	19-25	24.2	1	35.1	19.1	66	33	7.2	1.5	7.6
13	26-01	4.6	1	35.0	20.0	76	25	6.1	1.2	8.7
	Apr.									
14	02-08	0.0	-	34.6	16.8	65	24	7.4	1.5	9.0
15	09-18	0.0	-	37.8	20.3	60	18	7.9	1.0	9.4
16	16-22	0.0	-	39.6	20.2	53	14	9.4	1.0	10.2
17	23-29	0.0	-	40.9	19.4	48	13	9.8	1.5	9.9
18	30-06	0.0	-	39.0	18.9	44	18	11.1	3.9	9.8
	May									
19	07-13	0.0	-	32.8	19.5	67	24	10.4	3.3	12.0
20	14-20	0.0	-	38.3	19.7	68	23	11.0	5.4	11.3
21	21-27	0.0	-	38.3	22.8	68	25	10.4	2.7	10.3
22	28-03	0.0	-	38.7	22.6	59	24	10.5	4.3	10.6
	Jun.									
23	04-10	33.8	2	37.4	23.3	74	49	7.3	5.9	5.7
24	11-17	1.2	-	32.0	24.2	71	51	6.7	8.7	2.2
25	18-24	0.0	-	31.7	23.5	71	45	8.6	8.5	0.9
26	25-01	15.6	2	31.8	19.8	74	57	6.6	6.5	2.5

Table 3: Contd…….

Met. Week	Date	Rain fall (mm)	Rainy days	Temperature (^{O}C)		Humidity (%)		Evapo-ration (mm/day)	Wind velocity ($kmhr^{-1}$)	Sun shine (hrs)
				Max.	Min.	Morn.	Even.			
	Jul.									
27	02-08	0.0	-	31.3	23.8	73	37	6.0	8.6	2.8
28	09-15	1.0	-	31.2	23.0	75	52	6.8	7.6	3.4
29	16-22	2.4	-	34.1	21.8	76	42	7.6	2.6	5.8
30	23-29	53.2	2	30.8	22.7	84	63	3.7	2.8	0.7
31	30-05	0.0	-	29.7	22.3	82	66	4.4	4.5	1.3
	Aug.									
32	06-12	55.2	3	26.8	22.0	88	80	1.5	3.7	0.2
33	13-19	1.8	-	29.6	22.1	77	61	4.2	4.2	3.1
34	20-26	7.0	1	31.8	19.7	76	51	4.7	1.1	7.2
35	27-02	7.6	1	32.4	22.4	80	59	4.1	0.6	5.8
	Sept.									
36	03-09	189.2	5	29.3	21.8	87	68	3.7	1.0	4.9
37	10-16	119.0	3	28.5	21.7	88	73	2.5	3.3	2.0
38	17-23	27.0	1	29.7	20.9	80	64	3.6	3.8	3.8
39	24-30	0.0	-	31.8	18.1	85	39	3.5	0.5	8.6
	Oct.									
40	01-07	29.8	3	32.2	20.3	82	49	5.0	0.4	6.6
41	08-14	71.8	1	31.4	18.6	81	52	5.1	0.6	7.4
42	15-21	0.0	-	31.8	15.5	76	32	5.2	1.2	8.4
43	22-28	0.0	-	31.6	12.8	74	27	5.3	1.4	8.9
44	29-04	0.0	-	32.5	13.1	76	25	3.5	0.4	9.7
	Nov.									
45	05-11	0.0	-	31.7	12.8	74	27	3.6	0.3	9.6
46	12-18	0.0	-	30.5	16.0	80	35	3.8	0.8	6.3
47	19-25	6.8	1	32.1	17.0	75	32	3.7	0.7	8.8
48	26-02	23.2	1	27.5	14.9	75	47	3.9	2.5	6.4
	Dec.									
49	03-09	0.0	-	30.0	13.7	76	32	3.2	0.7	8.7
50	10-16	0.0	-	30.1	14.2	71	38	3.1	0.2	7.4
51	17-23	0.0	-	29.9	13.8	69	34	3.0	0.8	6.4
52	24-30	0.0	-	30.1	10.0	68	28	3.5	0.2	9.6

3.1.4 Cropping history of the experimental plots

Information regarding the crops grown on the experimental plots during previous three years of the investigation is presented in Table 4.

Table 4: Cropping history of experimental site

Year	*Kharif*	Fertilizer	*Rabi*	Fertilizer
2004-05	Soybean	50:75:0	Sugarcane	250:115:115
2005-06	Sugarcane	250:115:115	Sugarcane	250:115:115
2006-07	Sugarcane ratoon	250:115:115	Sugarcane ratoon	250:115:115

3.1.5 Seed material

The seed of cotton hybrids viz; Dhroov Bt, Dhroov Non Bt, Kashinath Bt and Nathbaba Non Bt was obtained from Senior Cotton breeder, Mahatma Phule Agricultural University, Rahuri, Dist. Ahmednagar during first year and during second year it was brought from respective seed companies.

3.1.6 Insecticides and fungicides

There was an attack of jassids, aphids, thrips, whitefly bollworm and disease like alternaria blight. The incidence was controlled by spraying the insecticides like Diamethate 30 EC, Acefate 70 SP, Trizophos (40 EC), Spinasad (45 EC), Endosulphan 35 EC, etc. Reddening was also observed in later stage of the crop in all four hybrids and was controlled by spraying DAP @ 2 per cent. Fungicide blue copper was used to control leaf disease.

3.1.7 Fertilizers

Urea, single super phosphate and muriate of potash were used as the sources of N, P_2O_5 and K_2O at the rate of 100 kg, 50 kg and 50 kg ha^{-1}, respectively.

3.2 Methods

3.2.1 Experimental details

For studying the effects of irrigation levels and water saving practices on the growth, yield and quality of cotton hybrids and occurrence of *parawilt* a split plot design was used. The details of the main and sub-plot treatments and symbols used are given below.

Table 5: Treatment details and symbols used for the experiment

Sr. No.	Treatment details	Symbols
	Main plot treatments	
A.	**Irrigation levels**	
1.	50 mm CPE	I_1
2.	75 mm CPE	I_2
3.	100 mm CPE	I_3
B.	**Water saving practices**	
1.	Alternate furrow irrigation	W_1
2.	Every furrow irrigation	W_2
	Sub plot treatments	
C	**Cotton hybrids**	
1.	Dhroov Bt	V_1
2.	Dhroov Non Bt	V_2
3.	Kashinath Bt	V_3
4.	Nathbaba Non Bt	V_4

In all, there were six main plot treatments of irrigation levels and water saving practices and four sub-plot treatments of cotton hybrids replicated three times.

3.2.2 Layout of the experiment

The experimental field was laid out in 72 unit plots, each plot measuring 34.02 square meters 6.30 x 5.40 m^2. There were seven rows of cotton crop in each plot and six hills in each row. One row of crop from both sides of length and also both sides of breadth were left as guard rows. The net plot consisted of five rows with four hills per row (4.50 x 3.60 m^2). The plan of randomization of the treatments adopted for the first year was also followed for subsequent year. The plan of layout of the experiment for two years with necessary details is given in Fig. 3.

3.2.3 Cultural operations

Cultural operations were adopted uniformly for all plots and plant protection measures were followed as per requirement. Picking of cotton was followed as and when bolls bursted. The details of the cultural operations carried out for cotton are given in Table 6.

3.2.3.1 Sowing, gap filling and thinning

Two seeds of cotton were dibbled @ 2.5 kg ha^{-1} with the spacing of 90 cm between rows and 90 cm between plants on 20th and 16th April in two seasons, 2007 and 2008, respectively. At the time of planting the cotton seeds, 4 to 5 granules of phorate insecticide @ 10 kg ha^{-1} were dropped $hill^{-1}$ and then 2 to 3 seeds of cotton $hill^{-1}$ were dibbled on the side of ridges and irrigation was given in furrows.

Table 6: Schedule of field operations carried out during 2007 and 2008

Sr. No.	Cultural operation	Date of operation	
		2007	2008
1.	Ploughing	09.04.2007	23.03.2008
2.	Clod crushing	11.04.2007	03.04.2008
3.	Spreading of compost and harrowing	11.04.2007	11.04.2008
4.	Layout	15.04.2007	13.04.2007
5.	Preparation of ridges and furrows	16.04.2007	14.04.2008
6.	Mending the ridges and furrows	17.04.2007	14.04.2008
7.	Fertilizer application	18.04.2007	15.04.2008
8.	Dibbling of cotton seed	20.04.2007	16.04.2008
9.	Irrigation	20.04.2007	16.04.2008
10.	Filling the polythene bags	20.04.2007	16.04.2008
11.	Gap filling	26.04.2007	23.04.2008
12.	Thinning	10.05.2007	07.05.2008
13.	First top dressing	15.05.2007	15.05.2008
14.	Second top dressing	15.06.2007	12.06.2008
15.	Common irrigation	25.06.2007 01.05.2007	22.04.2008 28.04.2008
16.	**Hand weeding with weeding hook**		
	First hand weeding	20.05.2007	12.05.2008
	Second hand weeding	20.06.2007	11.06.2008
	Third hand weeding	19.07.2007	30.07.2008
17.	**Plant protection**		
	a. Rogor 35 EC (Dimethoate)	20.05.2007	17.05.2008
	b. Acefate 70 SP (Asataf)	04.06.2007	01.06.2008
	c. Blue copper + Confidor + Endosulfan 35 EC	20.06.2007	16.06.2008
	d. Sulphur (80 WP)+DAP (2%) + Dimethoate (30 EC)	05.07.2007	01.07.2008
	e. DAP (2%)+Trizophos (40 EC)+Cypermethrin (2.5 EC)	20.07.2007	16.07.2008
	f. Metasystox + Spinosad (45)	04.08.2007	31.07.2008
18.	**Picking of cotton**		
	First picking	04.08.2007	31.07.2008
	Second picking	19.08.2007	20.08.2008
	Third picking	06.09.2007	10.09.2008
	Fourth picking	26.09.2008	22.09.2008
19.	Uprooting of cotton stalks	10.10.2007	07.10.2008

Gap filling with seedlings from polythene bags was done at such hills where seeds did not germinate and also where the young seedlings died due to root-rot. One thinning operation was carried out at 20 days after planting. Two healthy seedlings hill^{-1} were kept after thinning operation.

3.2.3.2 Fertilizer application

A dose of 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} through urea, single superphosphate and muriate of potash was applied. A basal dose of 20 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied at the time of cotton planting by spot application and covered with soil. Second dose of nitrogen i.e. 40 kg ha^{-1} was given at square formation stage (25-30 days after planting) and the remaining third dose of nitrogen i.e. 40 kg ha^{-1} was applied at flowering stage (50-60 days after planting). FYM 10 t ha^{-1} was mixed in the soil with harrowing.

3.2.3.3 Weeding

To control the weeds in experimental plot, the herbicide fluchloralin (45 %) @ 1.125 kg a.i. ha^{-1} was applied after dry seeding and before the application of irrigation water. After 30 days of planting three hand weeding were carried out to control the weeds during both the years of experimentation.

3.2.3.4 Scheduling of irrigation

Immediately after planting the crop was irrigated followed by second irrigation within 6 days of planting to all the treatments. Irrigation water was applied through Parshal flume and flow was measured at each irrigation. Subsequently plots were irrigated as per treatments.

3.2.3.5 Alternate furrow irrigation

At each and every irrigation treatment the alternate furrow of cotton was irrigated. During first irrigation even number of furrows were irrigated, while at the second irrigation, odd number of furrows were irrigated. This pattern was adopted up to last irrigation to the cotton crop.

3.2.3.6 Plant protection

There was an attack of jassids, aphids, thrips, whitefly and bollworm. The incidence was reduced by spraying the insecticides like Diamethoate, Endosulphan 35 EC, Pyrethroids etc. Reddening in cotton was also observed in later stage of the crop in all four hybrids and was controlled by spraying DAP @ 2 per cent.

3.3 Biometric observations

3.3.1 Sampling technique

For various biometric observations of cotton, five plants were selected randomly from each net plot and the growth observations were recorded at an interval of 28 days commencing from 28 days after planting till the harvest during two seasons. The observations on dry matter accumulation were also recorded from 28 days after planting. For dry matter (aerial parts) studies, one plant from each net plot was uprooted at random at each observation. These plants were also used for number of leaves and leaf area studies before they were oven dried.

The details of observations recorded during the year 2007 and 2008 are given in Table 7.

Table 7: Details of biometric observations recorded during growth period of cotton crop during 2007 and 2008

Sr. No.	Particulars	Frequ-ency	Size of sample	Days after planting
1	2	3	4	5
A.	**Pre-harvest studies**			
1.	Plant count	1	All plants	20
2.	Plant height (cm)	5	5	28, 56, 84, 112 and 140
3.	Number of branches plant^{-1} (Monopodial and sympodial)	5	5	28, 56, 84, 112 and 140
4.	Number of squares plant^{-1}	5	5	28, 56, 84, 112 and 140
5.	Number of functional leaves	5	5	28, 56, 84, 112 and 140
6.	Leaf area (dm^2)	5	5	28, 56, 84, 112 and 140
7.	Leaf area index	5	5	28, 56, 84, 112 and 140
8.	Dry matter plant^{-1} (g)	5	1	28, 56, 84, 112 and 140
9.	No. of *parawilt* affected plants	9	All plants	28, 42, 56, 70, 84, 98, 112, 126 and 140
10.	Days for first square formation	1	All plants	--
11.	Days for first flowering	1	All plants	--
12.	Days for first boll appearance	1	All plants	--
13.	Days for physiological maturity	1	All plants	--
14.	Number of bolls plant^{-1}	3	5	56, 112 and at harvest
B.	**Growth studies**			
1.	Absolute growth rate	5	1	28, 56, 84, 112 and 140
2.	Relative growth rate	5	1	28, 56, 84, 112 and 140

Table 7: Contd……

1	2	3	4	5
C.	**Post harvest studies**			
1.	Seed cotton weight boll^{-1} (g)	4	5	At all pickings
2.	Seed weight boll^{-1} (g)	4	5	At all pickings
3.	Lint weight boll^{-1} (g)	4	5	At all pickings
4.	Hundred seed weight (g)	1	5	At harvest
5.	Seed cotton yield plant^{-1} (g)	4	5	At all pickings
6.	Stalk weight plant^{-1} (g)	1	5	At harvest
7.	Number of picked bolls plant^{-1}	4	5	At all pickings
8.	Number of green bolls remained	1	5	At harvest
9.	Seed cotton yield ha^{-1} (q)	1	--	At harvest
10.	Stalk yield ha^{-1} (q)	1	--	At harvest
D.	**Quality studies**			
1.	Ginning percentage	1	-	Bulk of sample
2.	Fibre fineness (Micronaire value)	1	-	Bulk of sample
3.	Uniformity ratio	1	-	Bulk of sample
4.	Staple length	1	-	Bulk of sample
5.	Elongation percentage	1	-	Bulk of sample
6.	2.5 per cent span length	1	-	Bulk of sample
E.	**Soil moisture studies**			
1.	Soil moisture determination	-	Gross plot	Before and after irrigation
2.	Depth of water applied	-	Gross plot	-
3.	Determination of consumptive use	-	Gross plot	-
4.	Water use efficiency	-	-	-
F.	**Chemical studies**			
1.	Plant analysis	1	1	At harvest
2.	Soil analysis	1	1	At harvest
G.	**Economic studies**			
1.	Gross monetary returns	1	1	
2.	Net monetary returns	1	1	
3.	Cost of cultivation	1	1	
4.	B:C ratio	1	1	

3.3.2 Plant count

Initial plant count was recorded at 20 days after planting and final plant count was taken at last peaking. It was recorded from gross plot.

3.3.3 Plant height

Plant height was measured from the ground level up to the base of apical bud till the harvest of crop.

3.3.4 Number of branches

Number of monopodial and sympodial branches were counted from each observation plant.

3.3.5 Number of functional leaves

Number of functional leaves was recorded from the plants taken out for dry matter studies.

3.3.6 Leaf area

Leaf area per plant was worked out from the plants taken out for dry matter studies. Leaves were separated out from the plant and grouped into three different categories *viz.*, big, medium and small, according to the size. Number of leaves in each category was counted and from each group, one representative leaf was taken randomly. The area of these leaves was measured with the help of leaf area meter (dm^2).

3.3.7 Leaf area index (LAI)

The leaf area index was calculated from the data on leaf area per plant at various growth stages according to the following formula given by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}} \quad \text{(Expressed in the same units)}$$

3.3.8 Number of squares

Number of squares was counted from each observation plant.

3.3.9 Number of bolls

Number of fully developed green bolls was recorded from each observation plant after 84 days.

3.3.10 Dry matter studies

First observation for dry matter (aerial parts) study was recorded at 28 days after planting and the same was continued till the harvest of crop at frequent interval. From the whole plant, leaves, stem, branches, squares and bolls were separated and dried, first in open air and later on in the thermostatically controlled oven at $50^{O} \pm 2^{O}C$ till the constant weight was recorded. Stem, branches and bolls were chopped to small pieces before they were put for drying.

3.4 Phenological growth stages

3.4.1 Days to first square formation

Number of days required for first square appearance was recorded from each net plot.

3.4.2 Days to start of flowering

Number of days required for first flower appearance in each net plot was recorded.

3.4.3 Days to boll formation

Number of days required for boll formation was recorded per net plot.

3.4.4 Days to physiological maturity

Number of days required for first boll opening was recorded per net plot.

3.5 Cotton *parawilt*

For studying the *parawilt* percentage the whole plot was observed and the percentage was recorded by visual rating during both the years at 14 days interval after 28 days of planting.

3.6 Growth studies

Studies on growth parameters of plants included the determination of Absolute Growth Rate (AGR), and Relative Growth Rate (RGR). These studies were carried out with a view to study the way in which the treatments affected these physiological determinants of plant growth.

3.6.1 Absolute Growth Rate (AGR)

It was determined with the help of following formula:

$$\underset{(\text{cm plant}^{-1}\ \text{week}^{-1})}{\text{AGR}} = \frac{(H_2 - H_1)}{(t_2 - t_1)} \quad \text{for height} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

$$\underset{(\text{g plant}^{-1}\ \text{week}^{-1})}{\text{AGR}} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \quad \text{for total dry matter plant}^{-1} \ldots .2$$

Where, H_2 and H_1 and W_2 and W_1 refer to height and weight of total dry matter plant^{-1} at time t_2 and t_1, respectively.

3.6.2 Relative Growth Rate (RGR)

The relative growth rate at which a plant incorporates additional material into its substance is measured by RGR of dry matter accumulation. Blackman (1919) considered the increase in the dry matter of the plants as a process of continuous compound interest where in the increment in any interval adds to the capital for the subsequent growth. The rate of increment is known as relative growth rate and was calculated from the following formula given by Briggs *et al*. (1920).

$$RGR = \frac{(\text{Log}_e\ w_2 - \text{Log}_e\ w_1)}{(t_2 - t_1)}$$

Where, w_1 and w_2 represent total dry weight plant^{-1} of time t_1 and t_2, respectively.

3.7 Post harvest studies

3.7.1 Boll study

Boll characters like number of seeds boll^{-1}, lint weight, seed weight and seed cotton weight boll^{-1} were studied. These observations were recorded at each picking.

The observations on number of picked bolls plant^{-1} and seed cotton weight plant^{-1} were also recorded at each picking.

3.7.2 Unopened (Green) bolls plant^{-1}

After last picking, the observation on number of unopened bolls remained on the plant was recorded during both the years. The unopened bolls were counted from each observation plant.

3.7.3 Hundred seed weight (Seed Index)

A representative sample from four pickings was taken and from that 100 seeds were counted and the weight was recorded.

3.7.4 Seed cotton yield

The weight of different pickings from net plot area was recorded treatment wise and the total seed cotton yield ha^{-1} was calculated.

3.7.5 Stalk yield

The stalks of cotton were uprooted from net plot area of each treatment and dried in the sun and the weight was recorded. The stalk yield ha^{-1} was worked out.

3.7.6 Quality studies

3.7.6.1 Ginning percentage

Ginning percentage was worked out by taking a representative sample from each plot was ginned and the percentage of ginning was recorded on ginning percentage balance with the help of seed and ginned cotton.

3.7.6.2 2.5 per cent span length

2.5 per cent span length is one of the most important characteristics and the market price is determined to a large extent on the staple length. It was determined by the Digital Fibrograph instrument in the cotton Technological Research Laboratory, Bombay.

In this method, the amount of light transmitted through fibre beard prepared on special combs is measured along the length of the fibre and using integrating circuits the span length is measured. The 2.5 per cent span length is the distance in mm spanned by longest 2.5 per cent in test specimen.

3.7.6.3 Fibre fineness

Fibre fineness is another important quality characteristic which plays a prominent roll in determining the spinning value of cottons. Fibre fineness is usually expressed in terms of weight per unit length of fibre in units of 10^6 0^2/in or 10^6 g/in or-millitex. Millitex is the weight in milligrams of one kilometer length of the fibre. The fibre fineness was measured by Micronaire instrument in which 50 g of the sample was taken and compressed in a cylinder of specified dimension. Air at specified pressure is passed through the material. The amount of air flow is measured on a scale calibrated directly to read the weight per unit length of the fibres.

3.7.6.4 Fibre strength

Fibre strength tests are generally carried out by using fibre bundles. It was determined by Stelometer in which a tuft of fibres was taken between two special clamps and breaking strength was determined. The broken fibres were taken and weighed. The values were expressed in terms of g per tex which tex denoted weight in g of one km of the fibre.

3.7.6.5 Uniformity ratio

It is the ratio (expressed as per cent) between 50 per cent span length and 2.5 % span length. Generally trade requires uniformity ratio around 47-48 per cent for long staple cotton and 49-50 per cent for medium and short staple cotton.

3.7.6.6 Elongation percentage

Elongation per cent was determined by using a Stelometer. It was calculated as the elongation of the fibres at the breaking load as a percentage of the original length.

3.8 Chemical studies

3.8.1 Soil analysis

The composite soil samples from 0-30 cm layer were collected before sowing from experimental site. After harvesting, the soil samples from each treatment were collected for assessment of chemical properties of soil. The appropriate methods of estimation were used (Table 1) and the concentrations of these nutrients in the soil samples were worked out and from these observations ha^{-1} availability of nutrients was computed.

3.8.2 Plant analysis

The observation plants collected at harvest were used for chemical analysis. These plant samples were dried in oven at 65^0 C and the samples were made composite and after the grinding into fine powder, used for analysis of nitrogen, phosphorus and potassium content and also to estimate the nutrients removed from the soil by computing these uptake values.

3.8.3 Nutrient uptake

The uptake of nitrogen, phosphorus and potassium was calculated by using per cent N, P and K in cotton plant.

3.8.4 Nutrient balance

The balance of available N, P and K in soil was calculated as nutrient balance. [Initial available nutrient in soil + nutrient added through FYM and fertilizers] –[total nutrient uptake by crop + Nutrient balance in soil after harvest of crop].

Net loss or gain (kg ha^{-1}) = Actual balance at harvest – computed balance. Gain = Actual balance at harvest > computed balance

Loss = Actual balance at harvest < computed balance.

3.9 Soil moisture studies

3.9.1 Moisture percentage

The soil samples were collected before and after irrigation from planting till harvesting and used for determination of profile water depletion, consumptive use of water, consumptive use efficiency and water loss day^{-1} in the soil from 0-15, 0-30, 30-45, 45-60, 60-75 and 75-90 cm depths. The moisture percentage was worked out on oven dry basis by keeping in the electric oven at $105^{O} \pm 2^{O}C$ till constant weight was obtained. The moisture percentage was worked out by the formula out lined by Dastane (1972).

$$\text{Moisture percentage} = \frac{W_1 - W_2}{W_2} \times 100$$

Where, W_1 = Weight of moist soil

W_2 = Weight of oven dry soil

3.9.2 Bulk density determination

The bulk density of six layers for both the years at an interval of 15 cm depth was determined by the method prescribed by Dastane

(1972) with the help of core sampler at field capacity. The relevant data for both the years are presented in Table 8.

3.9.3 Profile water depletion

The moisture deficit or the depth of moisture depleted from the different soil layers during irrigation cycle or between two samplings taken after 48 hours of irrigation and just before the next irrigation by using the following equation.

$$d = \sum_{i=1}^{n} \frac{Pfci - Pbi}{100} \times Asi \times Di$$

d = Soil moisture depletion in the root zone (mm)

Pfci = Field capacity of the i^{th} layer moisture content two days after irrigation

Pbi = Moisture content just before irrigation

Asi = Bulk density of the i^{th} layer

Di = Depth of the i^{th} layer

$d = \sum_{i=1}^{n}$ = Summation of n – number of layers in the root zone

3.9.4 Consumptive use of water

Consumptive use of water has been calculated as per method out-lined by Dastane (1972) as given below:

$$U = u \text{ and } u = (Eo \times 0.8) + (M_1 + M_2) + ER$$

Where, U = Total seasonal consumptive use

Eo = Evaporation from the U.S. weather Bureau class pan during the interval from first sampling to second sampling.

0.8 = A constant to be used with the above evaporimeter.

M_1 = Soil moisture in the profile on the day of sampling.

M_2 = Soil moisture in the profile on the day of next sampling.

ER = Effective rainfall during the interval.

3.9.5 Consumptive use day^{-1}

It is the water used by the plant day^{-1} during it's growth period and was therefore, worked out by the formulae.

$$\text{CU day}^{-1} = \frac{\text{CUM (mm)}}{\text{Crop period (days)}}$$

Where, CU day^{-1} = Consumptive use day^{-1}.

CUM = Consumptive use of water (mm).

3.9.6 Consumptive use efficiency

Consumptive use efficiency (CUE) is the yield of marketable produce per unit of water used in evapotranspiration and therefore worked out to be as:

Y

$$CUE = \frac{}{ET}$$

Where Y = Yield of marketable produce (kg ha^{-1})

ET= Evapotranspiration mm.

3.9.7 Irrigation scheduling

Scheduling of irrigation was based on climatological approach. Evapotranspiration is the function of climatic parameters and is more accurate in estimating short term fluctuations in ET than empirical formulae. USWB class A pan was used for measurement of daily pan evaporation (E_O). It was computed as the difference between observed level adjusted for any precipitation measured in a standard rain guage. Water was added each day to bring the level to a fixed point in the stilling well.

The daily pan evaporation recorded from USWB class A pan was summed up. When cumulative pan evaporation (CPE) attained the values of 50, 75 and 100 mm, the irrigations were given with a constant depth of irrigation (7.2 cm). The details of number of irrigation applied alongwith dates of these applications and total depth of water applied inclusive of common irrigations as per the treatments given in Appendix I.

Two common irrigations totaling of 14.4 cm during 2007 and 2008 were given after planting for ensuring the better establishment and uniform stand of crop.

3.9.8 Depth of irrigation

A constant depth of irrigation (7.2 cm) was applied during both the years. The soils under experimentation during both the years, possessed near about similar relative capacity of moisture, the depth of irrigation for different treatments was kept constant. The irrigations were applied to a desired depth by measuring through Parshall flume during both the years.

Table 8: Soil moisture constants (%) and bulk density (Mgm^{-3}) of different soil layers

Sr. No.	Particular	Depth of layer (cm)					
		0-15	15-30	30-45	45-60	60-75	75-90
2007							
1.	FC	37.50	36.70	35.20	33.70	34.00	33.50
2.	PWP	17.90	17.10	16.50	15.30	15.20	14.70
3.	ASM	19.60	20.60	18.70	18.40	18.80	18.80
4.	BD	1.22	1.30	1.36	1.46	1.42	1.47
2008							
1.	FC	38.60	37.60	36.00	35.70	33.80	32.50
2.	PWP	18.20	18.80	16.70	15.30	14.50	14.10
3.	ASM	20.40	18.80	19.30	20.40	19.30	18.40
4.	BD	1.20	1.24	1.26	1.30	1.32	1.48

3.9.9 Water requirement of crop

Water requirement includes the losses due to evapotranspiration plus the losses during application of irrigation and the quantity of water required for special operations such as land preparation, planting and for draining of salts. Numerically water requirement (WR) is given by Michael (1978). Considering major sources, viz. irrigation water (IR), effective rainfall (ER) and soil profile contribution(s) including that from shallow water table as expressed in depth of water for a given time is as below:

$$WR = IR + ER + S$$

As the depth of water table in the soils under experimentation is more than 3 meter, the soil profile contribution to water requirement in the present studies was not considered and hence only irrigation requirement and effective rainfall were taken into account for working out water use by the crop. Irrigation requirement in the present case was the net quantity of irrigation water applied as per the treatments. The same was measured with the help of Parshall flume at the plot head, during both the years.

3.9.10 Effective rainfall

The effective rainfall considered for calculations of water used, was mentioned as follows:

All the rainfall received 48 hours after irrigation and less than cumulative pan evaporation values were considered as effective rainfall. The rains received during 48 hours of irrigation were not considered.

3.9.11 Application and measurement of irrigation water

Cotton seeds were dibbled on the side of ridges and then irrigation was given in furrows. Thereafter, two common irrigations were applied on 6th and 12th day after planting during both the years. Thereafter, irrigations were given as per treatments with the help of Parshall flume.

Measured quantity of irrigation water was applied as per the treatment as below:

Depth of water	-	7.2 cm
Discharge per minute	-	250 ltr
Plot size	-	34.02 sq.m.

Volume of water, therefore, was 34.02 x 0.072 = 2.45 m^3 then it was converted into the litres i.e. 2.45 x 1000 = 2449 litres. Since the discharge rate of the Parshall flume was 250 litres per minute, to apply 2449 litres of water per plot, time required was 10.2 minutes.

3.10 Economic studies

The economic evaluation in terms of cost of cultivation, gross monetary returns, net monetary returns, and B:C ratio were calculated treatment wise.

3.10.1 Cost of cultivation (Rs ha^{-1})

The total cost of cultivation (Cost C) of cotton was estimated by using the data on various aspects such as wages of hired labours, irrigation charges, cost of inputs, plant protection measures, machinery charges with implements and interest on working capital etc.

3.10.2 Gross monetary return

The final prices of seed cotton and stalk for the year 2007-08 and 2008-09 were obtained from marketing federation, and were considered for calculation of gross monetary returns. The treatment-wise gross monetary returns (Rs ha^{-1}) were worked out by multiplying seed cotton yield and stalk yield (q ha^{-1}) for both the seasons by market rates of respective years as per the formula given.

Gross monetary returns (Rs ha^{-1}) = [(Seed cotton yield (q ha^{-1}) x price) + Stalk yield (q ha^{-1}) x price]

3.10.3 Net monetary returns (Rs ha^{-1})

The treatmentwise net monetary returns (Rs ha^{-1}) were worked out by subtracting treatmentwise cost of cultivation from treatmentwise gross monetary returns as per formula given below.

Net monetary returns (Rs ha^{-1}) = GMR (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1}).

3.10.4 Benefit cost ratio (B : C ratio)

Estimates of gross income ha^{-1}, net income ha^{-1}, net return $rupee^{-1}$ invested and B: C ratio were computed based on total cost of cultivation (Cost C). Return $rupee^{-1}$ invested was calculated as follows.

$$\text{Returns rupee}^{-1} = \frac{\text{Gross Monetary Returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

The treatment wise B : C ratio was worked out by dividing the treatmentwise gross monetary returns with the treatmentwise cost of cultivation.

3.11 Statistical analysis

All the data collected on various characters studied were statistically analyzed as suggested by Panse and Sukhatme (1995) by using the design split plot technique fed in computer and transformation of data were also made whenever required. Whenever results were found significant the critical difference (C.D.) values at 5 % level of probability were worked out. 'NS' denoted the treatment differences, which were not significant at 5 % level.

4. RESULTS AND DISCUSSION

A field experiment entitled, "Effect of irrigation levels and water saving practices on cotton (*Gossypium* spp.) hybrids with special reference to *parawilt*" was conducted at All India Coordinated Research Project on Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri during summer 2007 and 2008. The results obtained during the course of investigation are presented and discussed in this chapter under appropriate headings.

4.1 Plant count

The data regarding the mean initial and final plant count as influenced by different treatments during summer 2007 and 2008 are presented in Table 9.

The data indicated that the mean initial and final plant count per plot was 41.70, 41.62 and 41.07, 41.12 during 2007 and 2008, respectively. This indicated that there was 99.29 and 99.09 per cent of crop stand when initial count was recorded and 97.79 and 97.91 per cent of crop stand when final plant count was recorded during 2007 and 2008 seasons, respectively.

Effect of irrigation levels

The differences in initial and final plant count due to irrigation levels were found to be non significant under study. This might be due to better germination which resulted in uniform plant stand.

Table 9: Mean Initial and final plant count plot^{-1} as influenced by different treatments during 2007 and 2008

Treatments	Initial plant count	Final plant count

	2007	2008	2007	2008
Irrigation levels (I)				
50 mm CPE	41.75 (99.41)	41.62 (99.10)	41.03 (97.69)	41.13 (97.93)
75 mm CPE	41.60 (99.05)	41.53 (98.88)	41.11 (97.88)	41.08 (97.81)
100 mm CPE	41.76 (99.43)	41.70 (99.29)	41.07 (97.78)	41.15 (97.97)
SE ±	0.12	0.09	0.11	0.24
CD at 5 %	N.S.	N.S.	N.S.	N.S.
Water saving practices (W)				
Alternate furrow irrigation	41.75 (99.41)	41.68 (99.24)	41.09 (97.84)	41.11 (97.88)
Every furrow irrigation	41.65 (99.17)	41.56 (98.95)	41.05 (97.74)	41.13 (97.13)
SE ±	0.10	0.07	0.09	0.25
CD at 5 %	N.S.	N.S.	N.S.	N.S.
Cotton hybrids (V)				
Dhroov Bt	41.78 (99.48)	41.70 (99.29)	41.12 (97.91)	41.08 (97.81)
Dhroov Non-Bt	41.59 (99.03)	41.57 (98.98)	41.15 (97.98)	41.13 (97.13)
Kashinath Bt	41.80 (99.53)	41.53 (97.79)	41.07 (97.79)	41.12 (97.91)
Nathbaba Non-Bt	41.62 (99.09)	41.68 (97.48)	40.94 (97.48)	41.15 (97.98)
SE ±	0.18	0.08	0.16	0.30
CD at 5 %	N.S.	N.S.	N.S.	N.S.
Interactions				
I x W				
SE ±	0.17	0.12	0.07	0.40
CD at 5 %	N.S.	N.S.	N.S.	N.S.
I x V				
SE ±	0.12	0.08	0.09	0.38
CD at 5 %	N.S.	N.S.	N.S.	N.S.
V x W				
SE ±	0.09	0.09	0.10	0.42
CD at 5 %	N.S	N.S.	N.S.	N.S.
I x W x V				
SE ±	0.17	0.10	0.09	0.23
CD at 5 %	N.S.	N.S.	N.S.	N.S.
General Mean	**41.70 (99.29)**	**41.62 (99.09)**	**41.07 (97.79)**	**41.12 (97.91)**

Effect of water saving practices

The mean initial as well as final plant count at harvest was not significantly influenced due to application of irrigation at alternate furrow and every furrow irrigation owing to two common irrigations hastened the better germination and uniform plant stand.

Effect of cotton hybrids

The data in respect of initial and final plant count of cotton was found to be non significant under different cotton hybrids during both the seasons of investigation. This might be due to good germination percentage of all genotypes owing to optimum plant stand.

Effect of interaction

The interaction effects due to different factors under study were found to be not significant during both the years of experimentation.

4.2 Growth studies

4.2.1 Plant height

The data in respect of mean plant height (cm) as influenced periodically by different treatments are presented in Table 10 and graphically depicted in Fig. 4. The plant height was progressively increased with enhancement in crop age and reached maximum at 140th day.

Effect of irrigation levels

Plant height was significantly increased due to irrigation levels at all the growth stages. The application of irrigation at 50 mm and 75 mm CPE irrigation were found to be at par on 28th day after planting during both the years of experimentation and 56th day during 2008. However, application of irrigation at 50 mm CPE produced significantly taller plants than 75 and 100 mm CPE irrigation at rest of the growth stages.

Further, it was observed that the application of irrigation at 100 mm CPE produced the lowest plant height at all the growth stages during 2007 and 2008 except at 28 DAP in 2008 where 100 mm CPE exhibited the tallest plant height. This showed that the excess moisture under 50 mm CPE resulted in more vegetative growth, whereas, inadequate moisture supply under 100 mm CPE irrigation level created moisture stress resulting in low plant height. Similar results were recorded by Ayars *et al*. (1991), Sethi *et al*. (1995) and Singh and Brar (2000).

Effect of water saving practices

Water saving practices did not influence the plant height significantly at any of the crop growth stages during both the seasons. The plant height was more under every furrow irrigation at all the growth stages than alternate furrow irrigation practice. Brar and Singh (1983) and Gaikwad (1985) also reported similar observations in respect of plant height.

Effect of cotton hybrids

Kashinath Bt recorded significantly more plant height than other three cotton hybrids during both the years of investigation. This indicate that the Kashinath Bt possess genetical character of tall plant type and another reason might be due to close spacing tends to increase the height. The second highest was Nathbaba non Bt followed by Dhroov non Bt and Dhroov Bt during both the years of experimentation.

Effect of interaction

The interaction effects of irrigation levels, water saving practices and cotton hybrids were non significant throughout the crop growth stages from 28th day till harvest except those at 140th day of planting where the interaction effects were significant during 2007. The interaction between application of 50 mm CPE irrigation to Kashinath Bt recorded significantly higher plant height over other interaction combinations (Table 11).

Table 11: Interaction effect between different irrigation levels and cotton hybrids on Plant height (cm) during 2007

Cotton Hybrids	Irrigation levels		
	50 mm CPE	75 mm CPE	100 mm CPE
Dhroov Bt.	130.10	125.35	103.05
Dhroov Non-Bt.	136.00	130.90	109.40
Kashinath Bt.	229.25	220.95	197.10
Nathbaba Non Bt.	153.95	157.70	153.70
	SE ±	CD at 5%	
C at same level of A	0.37	1.03	
A at same level of C	0.40	1.21	

The excessive irrigation at 50 mm CPE significantly increased plant height as compared to 75 mm and 100 mm CPE irrigation levels. In respect of cotton hybrids, Kashinath Bt was given good response to excessive irrigation as compared to other cotton hybrids. Further it was observed that Nathbaba non Bt when irrigated at 75 mm CPE irrigation attended the second highest in plant height amongst cotton hybrids. In confirmation with this result Sethi *et al*. (1995) reported that the wet regime recorded more height as compared to moderately wet dry regime.

4.2.2 Absolute growth rate (AGR) of plant height

The data regarding the mean AGR of plant height cm plant^{-1} week^{-1} as affected periodically by different treatments are presented in Table 12. The data were not analysed statistically. Inferences were drawn on mean values. The mean maximum AGR plant^{-1} at 28th and 56th days was observed to be 10.73 cm and 12.08 during 2007 and 2008, respectively. Subsequently AGR values for plant height decreased from 56th days onwards during both the years of experimentation. Similar trend was observed by Gaikwad (1985).

Effect of irrigation levels

The AGR values for height were the highest in 50 mm CPE irrigation as compared to 75 mm and 100 mm CPE irrigation levels at all the growth stages of cotton except 112 and 140 during 2007.

At this crop growth period the AGR values were higher under 75 mm and 100 mm CPE. This period coincides with the effective rainfall during 30th to 39th meteorological week which was helpful for the better growth of cotton. Further, it was noticed that the highest AGR values were attended at 56th days and gradually decreased up to 140th days of crop growth during 2008.

Effect of water saving practices

The water saving practices did not influence the AGR of plant height. However, the AGR cm plant^{-1} week^{-1} was more under every furrow irrigation throughout the growth period during 2007 and 2008. Further, it was noticed that the AGR value was the highest at 28th day and thereafter decreased gradually from 56th day till harvest of the crop during 2007. While during 2008, the maximum AGR was observed at 56th day and decreased gradually thereafter. This might be the high and low rainfall effect during corresponding years on plant height. This confirms the findings of Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

The AGR for plant height was maximum under Kashinath Bt cotton hybrid up to 84 DAP and 56 DAP during 2007 and 2008 respectively, followed by Nathbaba non Bt owing to maximum plant height in Kashinath Bt. Further, it was observed that the maximum AGR was attained at 56th day by Dhroov Bt and Dhroov non Bt and gradually decreased up to 140th day.

4.2.3 Number of functional leaves plant^{-1}

The data regarding mean number of functional leaves plant^{-1} as affected periodically by different treatments during both the seasons are presented in Table 13.

The data from Table 13 revealed that the mean number of functional leaves increased progressively with increase in age of crop up to 112th day after planting and declined thereafter till harvest due to senescence of leaves. The maximum leaf number 232.09 and 236.57 was recorded at 112 days after planting during 2007 and 2008, respectively. At harvest the leaf number plant^{-1} viz; 178.50 and 173.35 was recorded during corresponding seasons.

Effect of irrigation levels

The number of functional leaves plant^{-1} at early stage i.e. 28th day was not significantly influenced by different irrigation levels. But from the 56th day onwards, 75 mm CPE irrigation recorded significantly higher leaf number as compared to 50 mm and 100 mm CPE till 112th day after planting and thereafter it was reduced due to senescence of leaves. Further, it was noticed that the application of irrigation at 100 mm CPE produced significantly the lowest mean number of functional leaves plant^{-1} during both the years of experimentation. Significant reduction in leaf number under 100 mm CPE irrigation might be due to water stress during formative (early) stage of crop growth. Similar results were observed by Kaswala *et al*. (2000) in cotton and Khan *et al*. (2000) in wheat.

Effect of water saving practices

Data from Table 13 indicate that the mean leaf number was not affected significantly due to different water saving practices at all the stages of crop growth in both the years of study. These findings corroborate the results of Gaikwad (1985) and Ghadge (2003). However, every row irrigation recorded higher leaf number after 56th day of planting during both the years of study.

Effect of cotton hybrids

Kashinath Bt produced significantly higher leaf number than other cotton hybrids at all the growth stages during both the seasons of investigation. However, at 28th day after planting Dhroov Bt, Dhroov non Bt and Nathbaba non Bt were found to be at par with each other during 2007 and 2008. This indicate that Kashinath Bt utilised fully natural resources i.e. bright sunshine hours, optimum temperature, humidity, well distributed rainfall for the higher production of leaf number. The significant variation among Dhroov Bt and non Bt cotton was observed in present study. Similar results were recorded by Barwale (2002) and Nehra *et al*. (2004) regarding leaf number plant^{-1}.

Effect of interaction

The mean leaf number plant^{-1} was not differed significantly with different interactions between irrigation levels, water saving practices and cotton hybrids.

4.2.4 Leaf area plant^{-1}

Data pertaining to mean leaf area plant^{-1} as affected periodically by different treatments are presented in Table 14 and graphically depicted in Fig 5.

Data from the Table 14 indicated that the mean leaf area plant^{-1} was found to increase with increase in the age of the crop up to 112 days during both the years of experimentation. The highest leaf area values were 86.76 and 84.80 sq. dm. during 2007 and 2008, respectively. The drastic reduction in leaf area plant^{-1} was observed there after due to senescence of leaves.

Effect of irrigation levels

The mean leaf area plant^{-1} was significantly higher at normal irrigation schedule (75 mm CPE) than rest of the irrigation schedules during all the growth stages of the crop except at 28 and 140 DAP during both the seasons. No significant effect of irrigation level was observed at 28 DAP owing to seedling stage of the crop. Further it was noticed that the leaf area was significantly reduced at 100 mm CPE irrigation over 50 and 75 mm CPE at all the growth stages from 56 days onwards during both the years. This might be due to water stress during the growth period. However, application of irrigation at 50 mm CPE could not increase the leaf area significantly than other irrigation schedule owing to water logging condition during growth stages of cotton. The results corroborate with the findings of Khan *et al*. (2000) in wheat.

Effect of water saving practices

The water saving practices did not show any significant impact on leaf area per plant during both the years of investigation. Similar results were observed by Gaikwad (1985).

Effect of cotton hybrids

Kashinath Bt produced significantly more leaf area as compared to other cotton hybrids during both the years of experimentation. Dhroov non Bt produced significantly more leaf area than Dhroov Bt at 112 DAP and at harvest during 2007 and 56 DAP and at harvest during 2008. The significant differences in leaf area among the cotton hybrids might be due to varietal character.

Effect of interaction

The differences due to interaction effect were found to be non significant at all the growth stages of the crop during both the years of investigation.

4.2.5 Leaf area index (LAI)

Data regarding leaf area index plant^{-1} as affected periodically by different treatments during 2007 and 2008 are presented in Table 15. Inferences are based on mean values.

It would be seen from Table 15 that the LAI values went on increasing with increase in the age of the crop up to 112 DAP during both the seasons and thereafter the values decreased up to the harvest of the crop. The maximum leaf area index values were 1.071 and 1.046 during 2007 and 2008, respectively.

The LAI values were increased from 56 days after planting which was the juvenile phase of the crop attained maximum number of leaves. It continued up to 112 DAP during which period maximum boll development takes place.

Effect of Irrigation levels

Scheduling of irrigation at 75 mm CPE produced the maximum leaf area index than other irrigation schedules at all the crop growth stages, during both the seasons except at 140 DAP during 2007. The leaf area index is a reliable index of crop productivity which was thus favourably influenced under this irrigation schedule. However, scheduling of irrigation at 100 mm CPE decreased the leaf area index throughout the crop growth period during both the years of investigation. Reduction in leaf size and leaf curling resulted in reduction in leaf area under water stress condition 100 mm CPE and thereby reduced the leaf area index. This confirms the findings of Rao *et al.* (2000) in sugarcane.

Further, it was noticed that irrigation scheduled at 50 mm CPE also decreased leaf area index value as compared to 75 mm CPE owing to excess moisture during growth phases inhibit the growth and translocation of nutrients to the plant. The results confirmed the findings of Ayars *et al.* (1991).

Effect of water saving practices

The leaf area index was not affected due to water saving practices during both the years of investigation because there was no significant difference in number of functional leaves and leaf area under both the water saving practices. Similar results were observed by Gaikwad (1985).

Effect of cotton hybrids

The maximum leaf area index was produced by Kashinath Bt at all the growth phases as compared to other cotton hybrids during both the years of investigation. Whereas, the lowest leaf area index was observed under Dhroov Bt.

4.2.6 Mean number of branches plant^{-1}

4.2.6.1 Mean number of monopodial branches plant^{-1}

Data pertaining to mean number of monopodial branches plant^{-1} as influenced periodically by different treatments during both the seasons are presented in Table 16.

The mean number of monopodial branches plant^{-1} increased with the advanced age of crop up to 140th day. The maximum number of monopodial branches plant^{-1} was on the 140th day of growth i.e. 2.65 and 3.68 during the years 2007 and 2008, respectively.

Effect of irrigation levels

The mean number of monopodial branches plant^{-1} was not significantly influenced at all the growth stages of crop except at 140 days after planting during 2007. At this stage application of irrigation at 50 mm CPE produced significantly higher number of monopodial branches than 75 mm and 100 mm CPE irrigation levels. Further, it was noticed that the application of irrigation at 75 mm and 100 mm CPE were at par with each other in producing monopodial branches plant^{-1} during first season. However, during second season, the application of irrigation at 50 mm CPE produced significantly higher number of monopodial branches than 75 mm and 100 mm CPE irrigation levels after 56 days onwards owing to adequate soil moisture under former irrigation schedule.

Effect of water saving practices

The water saving practices did not influence significantly mean number of monopodial branches plant^{-1} at all the stages of growth during both the years. The maximum number of monopodial branches plant^{-1} were 2.67 and 3.69 from every furrow irrigation during 2007 and 2008, respectively. This confirms the findings of Ghadge (2003).

Effect of cotton hybrids

Cotton hybrids showed the significant influence on mean number of monopodial branches plant^{-1}. Kashinath Bt produced significantly more number of monopodial branches throughout the growth period than other cotton hybrids during both the year of study. However, Dhroov Bt, Dhroov non Bt and Nathbaba non Bt were found to be at par with each other at all growth stages during first year. While during second year with the advancement of age of the crop from 84 DAP onwards. Nathbaba non Bt produced significantly higher number of monopodial branches than Dhroov Bt and Dhroov non Bt cotton hybrids till harvest.

This shows that Kashinath Bt produced the higher number of monopodial branches plant^{-1} than other cotton hybrids. This might be due to genetical characteristics of Kashinath Bt because it was only *hirsutum* x *barbedense* group and others were from *hirsutum* x *hirsutum* group.

Effect of interaction

None of the interaction between factors under study influenced the mean number of monopodial branches plant^{-1} at all growth stages of crop during both the years of study. This indicates that all cotton hybrids behaved similar with irrigation levels and water saving practices.

4.2.6.2 Mean number of sympodial branches plant^{-1}

The data on mean number of sympodial branches plant^{-1} as influenced periodically by different treatments during 2007 and 2008 seasons are presented in Table 17 and graphically depicted in Fig. 6.

The data from Table 17 showed that the mean number of sympodial branches plant^{-1} increased with the advanced age of the crop up to harvest. The rate of increase in number of sympodial branches was observed to be more up to 84 days during both the years of experimentation. The mean number of sympodial branches plant^{-1} at harvest was 17.48 and 21.76 during 2007 and 2008, respectively.

Effect of irrigation levels

The number of sympodial branches plant^{-1} was found to be significant. The higher number of sympodial branches plant^{-1} were produced when irrigation was applied at 75 mm CPE over 50 mm and 100 mm CPE, except at 28 DAP during both the years. Further, it was observed that irrigation scheduled at 50 mm CPE also produced significantly more number of sympodial branches plant^{-1} than it scheduling at 100 mm CPE during both the years from 56th days after planting onwards owing to availability adequate soil moisture. Dahatonde and Deshmukh (2001) in cotton and Pawar *et al*. (2001) in mustard reported that scheduling of irrigation at 0.8 IW/CPE found significantly superior over 0.6 and 0.4 IW/CPE ratio in respect of sympodial branches plant^{-1}.

Effect of water saving practices

The mean number of sympodial branches plant^{-1} was not significantly influenced due to water saving practices at all the growth stages of the crop during both the years of experimentation. However, every furrow irrigation produced higher number of sympodial branches than alternate furrow irrigation. Gaikwad (1985), Rasmussen and Berg (1986) and Halemani (2003) supported the findings of the present study.

Effect of cotton hybrids

The number of sympodial branches plant^{-1} was significantly more in Dhroov Bt hybrid than Dhroov non Bt, Kashinath Bt and Nathbaba non Bt at all the crop growth stages during both the years of experimentation. Further, it was observed that Kashinath Bt produced late branching at 56 DAP.

Further, it was noticed that all cotton hybrids gradually increased the number of sympodial branches as the age advances till harvest. Similar results were observed by Singh *et al*. (2003), Wankhede *et al*. (2003) and Jeughale *et al*. (2005).

Effect of interaction

Mean number of sympodial branches were not differed significantly due to interactions between irrigation levels, water saving practices and cotton hybrids. The interaction effect of irrigation methods and genotypes were found to be non significant observed by Patil *et al*. (2008[b]).

4.2.7 Dry matter production plant^{-1}

The data on total dry matter production plant^{-1} as influenced periodically by different treatments during both the seasons are presented in Table 18 and graphically depicted in Fig. 7.

The dry matter production increased with advancement in crop growth. The process of dry matter accumulation was very slow at initial stage of crop and reached its peak at 112th day of planting but in later stage of growth declined slightly due to senescence. The mean dry matter accumulation plant^{-1} at initial stage (28 DAP) was 40.03 and 41.00 g plant^{-1} during 2007 and 2008, respectively. It increased progressively with advancement of age and reached maximum 423.52 and 435.84 g plant^{-1} at 112th DAP during 2007 and 2008, respectively.

Effect of irrigation levels

The dry matter production is an index of potential crop yield. The dry matter production plant^{-1} was significantly increased with irrigation scheduling of 75 mm CPE as compared to 50 mm and 100 mm CPE at all the crop growth stages except initial stage of 28th day during both the years of study owing to no or excess moisture stress. The dry matter production plant^{-1} was lower under 100 mm CPE than 50 mm CPE irrigation level from 56th day after planting onwards which may be attributed to moisture stress during formative stage (flowering combined with early stage 56-112 DAP) which is most critical for water demand period and the stress during this period affects dry matter production and finally the seed cotton yield (Kaswala *et al.*, 2000). However, Singh and Brar (2000) found that the dry matter production at 0.6, 0.8 and 1.0 IW/CPE ratio remained unaffected.

Effect of water saving practices

Application of irrigation at alternate furrow and every furrow did not affect significantly the dry matter production throughout the crop growth period during both the years of investigation, however, higher dry matter production was observed under every furrow irrigation. The results are in conformity with the findings of Virdia and Patel (2000) and Ghadge (2003). However, Christopher and Chinaswami (1996), from Coimbtore reported that alternate furrow irrigation resulted in reduction of dry matter production as compared to every furrow irrigation. Halemani *et al.* (2003) also confirm the findings of former scientists.

Effect of cotton hybrids

Kashinath Bt produced significantly the highest dry matter plant^{-1} throughout the crop growth period during both the years of experimentation followed by Nathbaba non Bt and Dhroov non Bt. The lowest dry matter was produced by Dhroov Bt. The plant height and monopodial branches were maximum along with strong and healthy branches under Kashinath Bt which leads to higher dry matter production in this cotton hybrid.

Effect of interaction

The mean dry matter plant^{-1} as influenced periodically by different interaction combinations were found to be non significant.

4.2.8 Growth functions

The higher net assimilation rate, optimum leaf area index, high crop growth rate and early shift in dry matter allocation to boll are desirable for higher biomass production.

4.2.8.1 Absolute growth rate for dry matter (AGR)

The data on mean absolute growth rate (AGR) g plant^{-1} week^{-1} as influenced periodically by different treatments during 2007 and 2008 are presented in Table 19 and graphically in Fig. 8. The inferences are based on mean values.

The mean absolute growth rate increased gradually from planting and reached its peak in between 85th to 112th day after planting. The mean maximum absolute growth rate was 52.32 and 51.57 g plant^{-1} week^{-1} during 2007 and 2008, respectively.

Effect of irrigation levels

Water stress imposed during crop growth period (100 mm CPE) resulted in lower AGR values than rest of the irrigation schedules in both the seasons. Reduced growth rate of crop due to deficit soil moisture condition could be attributed to the reduced dry matter accumulation per plant due to reduced moisture and nutrient uptake by the crop. Similar findings were reported by Ramesh (2000) in sugarcane crop. However, the absolute growth rate was maximum under irrigation schedule of 75 mm CPE as compared to 50 and 100 mm CPE irrigation schedule during both the seasons (Table 19). This might be due to optimum moisture provided during crop growth former irrigation schedule. Further it was noticed that irrigation scheduled at 50 mm CPE also recorded lower absolute growth rate than 75 mm CPE irrigation schedule owing to optimum moisture available under both the irrigation practices.

Effect of water saving practices

Either every furrow or alternate furrow irrigation did not affect the absolute growth rate during both the years of investigation owing to optimum moisture available under both the irrigation practices. The results are confirmed by the findings of Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

The maximum absolute growth rate was observed under Kashinath Bt during both the years of study due to higher dry matter accumulation in the plant at all the growth stages of the crop. However, Dhroov Bt recorded the lowest values for absolute growth rate at all the growth stages, whereas, Dhroov non Bt and Nathbaba non Bt was found to be moderate in values of AGR during both the seasons of investigation.

Further, it was noticed that Dhroov Bt completely ceased the growth between 113 to 140th days as compared to other cotton hybrids. This might be due to synchronized boll bursting in early two pickings than Dhroov non Bt and Nathbaba non Bt near by equal duration cotton hybrids, while Kashinath Bt was late hybrid.

4.2.8.2 Relative growth rate (RGR)

The data pertaining to mean relative growth rate of dry matter as influenced periodically by different treatments are presented in Table 20 and graphically in Fig. 9. The data are not analysed statistically and inferences are drawn on the basis of mean values.

The mean RGR in terms of dry matter accumulation was highest during 28 to 56 days of crop age and was 0.922 and 0.928 g plant^{-1} week^{-1} in 2007 and 2008, respectively. It was -0.032 and -0.034 g plant^{-1} week^{-1} at harvest during corresponding years.

Effect of irrigation levels

The RGR values recorded with irrigation schedule at 75 mm CPE were more than 50 and 100 mm CPE irrigation schedules at all the growth stages of crop except at 28 DAP during first year where irrigation scheduled at 50 mm CPE recorded slightly more RGR values during both the years. Further, it was noticed that the RGR values were increased between 57-84 DAP. This might be due to increase in dry matter accumulation at this stage during both the years and again it was decreased at 85-112 DAP. At 113-140 DAP the drastic reduction in RGR values took place due to crop senescence.

Effect of water saving practices

The effect of water saving practices did not differ the values of RGR at all the growth stages during both the seasons. However, the growth rate increased at 84 DAP and thereafter it decreased.

Effect of cotton hybrids

The relative growth rate was maximum under Kashinath Bt as compared to other cotton hybrids. However, the minimum relative growth rate was observed under Dhroov Bt than rest of the cotton hybrids. Dhroov non Bt and Nathbaba non Bt was found similar in dry matter accumulation except at 84 DAP. The Nathbaba non Bt produced maximum dry matter.

Further it was observed that Dhroov Bt recorded the lowest dry matter accumulation at 140 DAP due to synchronous boll bursting. The maximum seed cotton yield was obtained from first two pickings.

4.2.9 Phenological growth stages

Data on days to first square formation, days to flowering, days to boll formation and days to physiological maturity are presented in Table 21.

The data in Table 21 show that the mean days required for first square formation, days to flowering, days to boll formation and days to physiological maturity were 31.83, 55.90, 79.14 and 134.08 days during 2007 and 31.73, 53.58, 77.40 and 131.43 days during 2008, respectively.

Effect of irrigation levels

Statistically different irrigation levels did not influence the days to first square formation but numerically high frequency of irrigation (50 mm CPE) delayed the square formation than 75 and 100 mm CPE irrigation levels. However, days to flowering, boll formation and physiological maturity significantly influenced due to irrigation levels. Impact of high frequency irrigation (50 mm CPE) tended to increase the number of days required to first flower opening as compared to 75 mm and 100 mm CPE irrigation schedules.

Further, it was observed that application of irrigation at 100 mm CPE produced significantly early flowering than 50 mm and 75 mm CPE irrigation during first year and during second year it was at par with 75 mm CPE irrigation level required significantly less number of days for flowering.

The number of days required for bolls formation and physiological maturity were significantly more under high frequency irrigation schedule of 50 mm CPE than low frequency irrigation schedules of 75 and 100 mm CPE during both the years of experimentation owing to excess soil moisture might have delayed these stages. Further, it was observed that significantly less number of days were required for boll formation and physiological maturity under irrigation schedule of 100 mm CPE owing to moisture stress which might have hasten the maturity. These results corroborate with the findings of Orgaz *et al*. (1991)

Effect of water saving practices

Application of irrigation at an alternate furrow and every furrow did not show any significant difference in days required to first square formation, flowering, boll formation and physiological maturity, however, higher values were recorded under every furrow irrigation than alternate furrow during both the years of experimentation. This confirms the findings of Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

All the cotton hybrids differed with respect to their phenological stages. The square formation, flowering, boll formation and physiological maturity started early under Dhroov Bt and required significantly the less number of days for these phenological growth stages than rest of the cotton hybrids during both the years of investigation. Further, it was observed that Kashinath Bt recorded significantly higher number of days for phenological growth stages as compared to other cotton hybrids followed by Nathbaba non Bt and Dhroov non Bt. However, Dhroov non Bt and Nathbaba non Bt were found at par with each other in respect of days to square formation during both the years of study and days to flowering and boll formation during first year of study. In respect of physiological maturity Dhroov Bt was 6 days earlier than Dhroov non Bt. This showed that due to earliness of Bt cotton hybrid it could fit in sequence cropping (Sinha and Choudhary, 2006).

Effect of interaction

The phenological growth stages were not significantly differed by the interaction combinations of the factors during both the seasons of experimentation.

4.2.10 Mean number of squares plant^{-1}

Data pertaining to mean number of squares plant^{-1} as influenced periodically by different treatments are presented in Table 22.

The mean number of squares plant^{-1} was maximum at 84th day of growth i.e. 23.19 and 28.05 during 2007 and 2008, respectively. The mean number of squares plant^{-1} was gradually increased with the advancement of age of the crop upto 84th day and thereafter, it was declined during both the years of experimentation. The peak period of square formation was 56 to 84 days after planting.

Effect of irrigation levels

The data from Table 22 indicated that the number of squares plant^{-1} was significantly influenced by different irrigation levels throughout the growth stages except at 28 days after planting, owing to just square initiation started at this stage.

The application of irrigation at 75 mm CPE produced significantly the higher number of squares plant^{-1} than 50 mm and 100 mm CPE irrigation levels. However, irrigation scheduled at 100 mm CPE produced significantly the lowest number of squares plant^{-1} than 50 mm and 75 mm CPE irrigation during both the years of investigation. Though the high frequency of irrigation was applied through 50 mm CPE level but the mean number of squares was significantly low as compared to 75 mm CPE irrigation level. This indicate that either excess or deficit of irrigation water declined the number of squares plant^{-1}. Orgaz *et al*. (1991) and (Sethi *et al*., 1995) also reported that cotton square production was highly sensitive to water stress and excess water at square formation stage. However, Kaswala *et al*. (2000) found that irrigation scheduled at 0.7 IW/CPE showed higher mean number of squares plant^{-1} compared to 0.3 and 0.5 IW/CPE ratios.

Effect of water saving practices

The number of squares plant^{-1} at different stages was not affected significantly by every furrow and alternate furrow irrigation during both the seasons. However, every furrow irrigation produced numerically higher number of squares plant^{-1}. Similar results were observed by Ghadge (2003).

Effect of cotton hybrids

Dhroov Bt produced significantly the highest number of squares plant^{-1} over rest of the cotton hybrids up to 84 DAP. However, at 112 DAP, Kashinath Bt proved to be the best.The second highest in order of sequence was Dhroov non Bt followed by Nathbaba non Bt and Kashinath Bt during both the seasons of study.

Further, it was noticed that Dhroov non Bt and Nathbaba non Bt were on par with each other and found significantly superior over Kashinath Bt at 28th day during 2007 and 2008. Kashinath Bt started square formation at 39th day onwards. However, Nathbaba non Bt, Kashinath Bt and Dhroov non Bt were on par with each other and found significantly inferior over Dhroov Bt at 56th day after planting during first year. The peak period for square formation was in between 84th to 112th DAP in all the cotton hybrids except Kashinath Bt, which started late squaring and extended up to 112 DAP.

This indicated that Dhroov Bt, Dhroov non Bt and Nathbaba non Bt bears synchronous squaring while Kashinath Bt observed indeterminate type.

Bt cotton hybrids produced significantly higher number of squares to their counter part (Nehra *et al*., 2004). This results are confirmed in the present study and with the findings of Garg *et al*. (2004).

Effect of interaction

The mean number of squares plant^{-1} was not significantly influenced by any of the interactions of the factors under study at all the stages of growth during both the seasons.

4.2.11 Mean number of bolls plant^{-1}

Data pertaining to mean number of bolls plant^{-1} as influenced periodically by different treatments are presented in Table 23 and depicted in Fig. 10.

The data from Table 23 indicate that the mean number of bolls plant^{-1} was increased with the advancement in the age of the plant up to 112 days and thereafter decreased during both the years of experimentation. The maximum numbers of bolls plant-1 were 17.52, 25.09 and 11.98 during 2007 on 84th, 112th and 140th day, respectively. The corresponding figures during 2008 were 18.13, 38.18 and 10.65.

Effect of irrigation levels

The mean number of bolls plant^{-1} was found significantly more under 75 mm CPE than 50 mm and 100 mm CPE irrigation level throughout the boll development stages during both the years of experimentation except at 140 DAP in 2007. However, irrigation applied at 100 mm CPE produced significantly less number of bolls than other irrigation levels. This indicates that application of normal irrigation (75 mm CPE) produced more number of bolls plant^{-1} owing to optimum moisture regime during the crop growth stages. Similar results were obtained by Kaswala *et al*. (2000) and Singh and Brar (2000).

Effect of water saving practices

Water saving practices did not significantly affected the total number of bolls plant^{-1} during both the seasons of investigation. Rasmussen and Berg (1986) reported that irrigation methods i.e. alternate furrow, every furrow and skipped row did not show any significant effect on number of bolls plant^{-1}. These results were also in agreement with Virdia and Patel (2000) and Halemani *et al*. (2003).

Effect of cotton hybrids

Dhroov Bt produced significantly the highest number of bolls plant^{-1} over its counter part and rest of the cotton hybrids at all the growth stages during both the seasons of experimentation. Further, it was noticed that Kashinath Bt produced significantly the lowest number of bolls plant^{-1} though it was statistically on par with Nathbaba non Bt at 84th and 112th DAP during 2007. However, during 2008 Dhroov non Bt was at par with Nathbaba non Bt at 84th and 140 DAP and ranked second in order of sequence. Buttar and Singh (2006) reported that the Bt cotton hybrids (RCH-134 and RCH-317) produced significantly the higher number of bolls plant^{-1} than their non Bt cotton hybrids. These results are in conformity with findings of Reddy *et al*. (2005). However, Sahai and Rahman (2005) proved that non Bt cotton hybrids were found significantly superior over Bt cotton hybrids in respect of number of bolls plant^{-1}.

Effect of interaction

The interaction effects between various factors under study were found to be non significant.

4.3. Post harvest studies

4.3.1 Mean number of picked bolls plant^{-1}

Data regardeing mean number of picked bolls plant^{-1} at different pickings as influenced by different treatments are presented in Table 24 and depicted in Fig. 11.

The data presented in Table 24 revealed that the mean maximum number of bolls were picked at second picking during both the seasons of experimentation. The mean number of picked bolls were 12.80, 13.02, 11.15, 5.56 and 20.17, 20.71, 11.61 and 6.78 at first, second, third and fourth pickings during 2007 and 2008, respectively. The total picked bolls plant^{-1} were 42.55 and 59.26 during 2007 and 2008, respectively.

Effect of irrigation levels

Application of irrigation at 75 mm CPE produced significantly the highest number of picked bolls plant^{-1} at second picking than 50 mm and 100 mm CPE irrigation levels during both the seasons of investigation owing to adequate soil moisture throughout the crop growth stages. However, the irrigation applied at 75 and 100 mm CPE were found on par with each other at first and third picking during first year. Further, it was noticed that significantly the lowest number of picked bolls were found at 100 mm CPE level than 50 mm and 75 mm irrigation level. The reduction in number of picked bolls plant^{-1} due to water stress might be attributed to the shedding of squares due to deficit moisture conditions which directly affected the water and nutrient uptake adversely. The present study also confirmed the findings of Dahatonde and Deshmukh (2001). Similar results were observed by Orgaz *et al*. (1991), Sethi *et al*. (1995), and Ahmet and Riza (2003).

Furthermore, observations from present study showed that near about 70 to 80 per cent bolls were picked from first two pickings under 75 mm and 100 mm CPE irrigation. However, only 42 to 50 per cent bolls were picked from 50 mm CPE irrigation. This showed that application of irrigation with high frequency (50 mm CPE) delays the picking of cotton as compared to moderate (75 mm) and low (100 mm CPE) frequency of irrigation (Ahmet and Riza, 2003).

Effect of water saving practices

Application of irrigation at an alternate furrow and every furrow did not show any significant influence on number of picked bolls plant^{-1} during both the years of experimentation. Similar findings were reported by Brar and Singh, 1983.

However, Christopher and Chinaswami (1996) reported that the alternate furrow irrigation resulted in reduction in number of picked bolls plant^{-1} as compared to every furrow irrigation.

Effect of cotton hybrids

The total number of picked bolls plant^{-1} was significantly more in Dhroov Bt than other hybrids during both the seasons. However, Kashinath Bt produced significantly the lowest number of picked bolls plant^{-1} at first picking during both the years of experimentation. Early boll production at I and II pickings in Dhroov Bt might be lead to higher percentage of picked bolls plant^{-1} during both the years of investigation (Sinha and Choudhary, 2006).

Further, it was noticed that the maximum number of bolls (72.78 %) were picked in Dhroov Bt followed by Nathbaba non Bt (62.73 %), Dhroov non Bt (63.69 %) and Kashinath Bt (42.52 %) from first two pickings. The number of picked bolls plant^{-1} was the highest in kashinath Bt at III picking indicating that it was late hybrid as compared to other cotton hybrids. The number of picked bolls plant^{-1} was significantly lower in Nathbaba non Bt at III and IV pickings during first of experimentation.

Effect of interaction

Dhroov Bt cotton hybrid produced significantly more number of picked bolls plant^{-1} than other cotton hybrids followed by Dhroov non Bt cotton hybrid, however no significant difference was noticed in cotton hybrid Kashinath Bt and Nathbaba non Bt under both the water saving practices during 2007 (Table 25). Kashinath Bt produced significantly more picked bolls at alternate furrow irrigation. However, Dhroov non Bt produced significantly more picked bolls at every furrow irrigation.

Table 25: Interaction effect between different water saving practices and cotton hybrids on mean number of picked bolls plant^{-1} during 2007

Water saving practices	**Dhroov Bt.**	**Dhroov Non-Bt.**	**Kashinath Bt.**	**Nathbaba non-Bt.**
Alternate Furrow	53.37	44.96	36.78	35.42
Every Furrow Irrigation	53.13	48.17	32.77	35.80
	SE ±	CD at 5%		
B at same level of C	0.88	2.53		
C at same level of B	0.91	2.73		

Table 26: Interaction effect between different irrigation levels and water **saving practices on mean number of picked bolls plant^{-1} during 2007**

Water Saving practices	Irrigation levels		
	50 mm CPE	75 mm CPE	100 mm CPE
Alternate Furrow	43.83	45.29	38.78
Every Furrow Irrigation	41.42	47.92	38.05
	SE	CD at 5%	
B at same level of A	0.62	1.79	
A at same level of B	070	2.15	

The application of irrigation at 75 mm CPE produced significantly the highest number of picked bolls plant^{-1} and significantly lowest under 100 mm CPE irrigation levels under both the water saving practices during 2007 (Table 26) owing to adequate soil moisture former irrigation schedule and water stress under later irrigation schedule. However, water saving practices did not show any significant effect on number picked bolls plant^{-1} under any irrigation schedules during 2007.

4.3.2 Mean number of unopened bolls (green bolls) plant^{-1}

Data regarding the mean number of green bolls plnat^{-1} as influenced by different treatments are presented in Table 27.

The mean number of green bolls plant^{-1} after last picking was 11.83 and 7.70 during 2007 and 2008, respectively.

Table 27: Mean number of unopened green bolls plant^{-1} at harvest as influenced by different treatments during 2007 and 2008

Treatments	Number of unopened green bolls plant^{-1}	
	2007	2008
Irrigation levels (I)		
50 mm CPE	15.19	8.83
75 mm CPE	12.98	8.13
100 mm CPE	7.33	6.12
SE ±	0.26	0.13
CD at 5 %	0.83	0.43
Water saving practices (W)		
Alternate furrow irrigation	11.99	7.16
Every furrow irrigation	11.67	8.23
SE ±	0.21	0.11
CD at 5 %	N.S.	0.35
Cotton hybrids (V)		
Dhroov Bt	6.97	5.67
Dhroov Non-Bt	7.59	7.47
Kashinath Bt	19.05	10.37
Nathbaba Non-Bt	13.71	7.27
SE ±	0.37	0.19
CD at 5 %	1.17	0.61
Interactions		
I x W		
SE ±	0.26	0.42
CD at 5 %	N.S.	N.S.
I x V		
SE ±	0.37	0.33
CD at 5 %	N.S.	N.S.
V x W		
SE ±	0.47	0.38
CD at 5 %	N.S.	N.S.
I x W x V		
SE ±	0.39	0.31
CD at 5 %	N.S.	N.S.
General Mean	**11.83**	**7.70**

Effect on irrigation levels

The mean number of green bolls plant^{-1} after last picking was significantly influenced by different irrigation levels and it was observed that application of irrigation at 50 mm CPE retained significantly the more number of green bolls plant^{-1} than 75 mm and 100 mm CPE irrigation levels during both the years of experimentation. However, significantly the lowest mean number of green bolls plant^{-1} was retained on plant was at 100 mm CPE irrigation schedule. This indicates that the high amount of residual soil moisture under 50 mm CPE in soil profile induced to green boll retention on plant. While, low amount of moisture in soil profile under 100 mm CPE irrigation bursted the maximum bolls.

Further, it was noticed that the green bolls plant^{-1} were less during 2008 as compared to 2007, because the rainfall was less during the former season.

Effect of water saving practices

The mean number of green bolls retained on plant was not significantly influenced by water saving practices during 2007. However, during 2008, significantly higher number of unopened bolls were observed under every furrow irrigation. Similar results were observed by Ghadge (2003)

Effect of cotton hybrids

Kashinath Bt cotton hybrid beared significantly the highest green bolls plant^{-1} whereas, Dhroov Bt showed significantly less number of green bolls plant^{-1}. This indicates that early boll formation and boll bursting of Dhroov Bt converted all the food produced in to economic yield efficiently. During second year of field trial both the non Bt cotton hybrids i.e. Nathbaba non Bt and Dhroov non Bt were found to be on par with each other and ranked second in order of sequence.

Effect of interaction

The mean number of green bolls remained on plant at last picking was not significantly influenced due to different factors i.e. irrigation levels, water saving practices and cotton hybrids.

4.3.3 Mean seed cotton weight boll^{-1}

Data regarding mean seed cotton boll^{-1} at each picking for both the years of investigation are presented in Table 28.

It could be seen from Table 28 that the mean seed cotton weight boll^{-1} was maximum at second picking (5.42 g) during 2007 and it was maximum at first picking (5.45 g) during 2008. The mean seed cotton weight boll^{-1} was 5.22 and 5.12 g during 2007 and 2008, respectively.

Effect of irrigation levels

The mean seed cotton weight plant^{-1} was not significantly influenced by different irrigation levels during first year. However, during second year, the application of irrigation at 75 mm CPE was on par with 50 mm CPE and was found significantly superior over 100 mm CPE at all the pickings.

Further, it was noticed that the application of irrigation at 100 mm CPE recorded numerically less mean seed cotton weight boll^{-1} during 2007. Sethi *et al.*(1995) reported that the water stress reduced the seed cotton weight boll^{-1} and wet regime recorded the more seed cotton weight.

Effect of water saving practices

The mean seed cotton weight boll^{-1} was not significantly affected either by alternate furrow or every furrow irrigation during both the years of investigation. Similar results were obtained by Ghadge (2003).

Effect of cotton hybrids

The mean seed cotton weight boll^{-1} was significantly the highest under Dhroov Bt and the lowest in Kashinath Bt, whereas, Dhroov non Bt and Nathbaba non Bt were at par with each other at all pickings first year of experimentation. The mean seed cotton weight boll^{-1} was significantly the lowest under Kashinath Bt at all the pickings during second year of experimentation.

Effect of interaction

The interaction effect due to different treatments on seed cotton weight boll^{-1} was found to be non significant.

4.3.4 Seed weight boll^{-1}

The data on seed weight boll^{-1} at different pickings as influenced by various treatments during 2007 and 2008 are presented in Table 29.

From the data, it could be seen that the seed weight boll^{-1} was maximum at second picking i.e. 3.63 and 3.62 g boll^{-1} whereas it was minimum at fourth picking i.e. 3.03 and 2.91 during 2007 and 2008, respectively.

It was observed that during both the seasons the maximum seed weight boll^{-1} was at second picking and it was declined thereafter. This indicate that the seed weight (g) boll^{-1} was more at first two pickings and declined thereafter. This is the natural phenomenon and hence seed weight boll^{-1} declined at third and fourth pickings due to senescence.

Effect of irrigation levels

The application of irrigation at 75 mm CPE produced significantly the highest seed weight boll^{-1} at all pickings, except IVth picking during 2007. Further, it was noticed that the irrigation applied at 100 mm CPE produced significantly the lowest seed weight (g) boll^{-1} at all pickings during both the seasons except at second picking during 2007. Where, it was second highest in order of sequence. However, application of irrigation at 100 mm CPE and 50 mm CPE were at par in respect of seed weight boll^{-1} during 2008. Similar results were obtained by Saig and Verma (1994).

Effect of water saving practices

The seed weight boll^{-1} was not significantly influenced by either of the water saving practices at all pickings during both the years of investigation. These results corroborate with the findings of Ghadge (2003).

Effect of cotton hybrids

Dhroov non Bt produced significantly the highest seed weight boll^{-1} at all pickings during both seasons, except IVth during second year, while Nathbaba non Bt produced significantly the higher seed weight (g) boll^{-1} at all the pickings except at third picking and it was at par with Dhroov Bt during second season. Further it was observed that Kashinath Bt produced significantly the lowest seed weight boll^{-1} at all pickings during both the seasons.

Effect of interaction

The effect of interaction due to various treatments on seed weight boll^{-1} at different pickings was found to be non significant during both the years of experimentation.

4.3.5 Lint weight (g) boll^{-1}

Data pertaining to lint weight boll^{-1} at different pickings as influenced by various treatments during 2007 and 2008 are presented in Table 30.

It was observed that the mean lint weight boll^{-1} was highest at second picking 1.96 and 2.01 g and it was gradually declined with rest of the pickings during both the seasons of study. The average lint weight boll^{-1} was 1.86 g during both the seasons of experimentation.

The increment rate in first picking was less, then in second picking it reaches to its peak and gradually declined in third and fourth pickings during the period of investigation. Similar trend was observed in seed weight and seed cotton weight boll^{-1}.

Effect of irrigation levels

The lint weight boll^{-1} was significantly more with irrigation applied at 75 mm CPE than other irrigation schedules at all pickings during both years except second picking during 2008. This might be due to optimal moisture available during the growth stages of the crop. The results corroborate with the findings of Saig and Verma (1994). It was noticed that water stress (100 mm CPE) at all growth stages reduced the mean lint weight boll^{-1}.

Effect of water saving practices

During both the years every furrow and alternate furrow irrigation did not show any significant effect on lint weight boll^{-1} at different pickings. The similar results were reported by Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

Dhroov Bt produced significantly the highest lint weight boll^{-1} at all pickings over rest of the cotton hybrids except at first picking during second season, where all the cotton hybrids were at par with each other. The lint weight boll^{-1} was significantly the lowest under Kashinath Bt at all pickings during 2007 and 2008.

Effect of interaction

The interaction effect of various treatments on lint weight boll^{-1} was found to be non significant at all the pickings during both the years of experimentation.

4.3.6 Mean number of seeds boll^{-1}

Data pertaining to mean number of seeds boll^{-1} during 2007 and 2008 are presented in Table 31.

The mean values of number of seeds boll^{-1} were 31.12 and 30.53 during 2007 and 2008, respectively.

Effect of irrigation levels

The mean number of seeds boll^{-1} significantly increased under irrigation scheduled at 75 mm CPE as compared to other irrigation schedules during both the years owing to stress free and water logging free environment available to the crop throughout its growth period. Further, it was noticed that application of irrigation at 100 mm CPE significantly decreased in the number of seeds boll^{-1} than other irrigation schedules during both the years of investigation. These results are in confirmity with the findings of Siag and Verma (1994).

Effect of water saving practices

The water saving practices did not influence significantly in producing the number of seeds boll^{-1} during both the years of experimentation owing equal distribution of moisture to the crop during growth period (Ghadge, 2003).

Table 31: Mean number of seeds boll^{-1} as influenced by different treatments during 2007 and 2008

Treatments	Number seeds boll^{-1}	
	2007	2008
Irrigation levels (I)		
50 mm CPE	31.30	30.49
75 mm CPE	32.01	31.53
100 mm CPE	30.06	29.58
SE $\pm$	0.05	0.26
CD at 5 %	0.16	0.83
Water saving practices (W)		
Alternate furrow irrigation	31.04	30.55
Every furrow irrigation	31.20	30.52
SE $\pm$	0.07	0.22
CD at 5 %	N.S.	N.S.
Cotton hybrids (V)		
Dhroov Bt	31.71	31.23
Dhroov Non-Bt	31.23	30.94
Kashinath Bt	25.41	25.11
Nathbaba Non-Bt	36.13	34.83
SE $\pm$	0.27	0.35
CD at 5 %	0.74	0.96
Interactions		
I x W		
SE $\pm$	0.72	0.37
CD at 5 %	N.S.	N.S.
I x V		
SE $\pm$	0.46	0.61
CD at 5 %	N.S.	N.S.
V x W		
SE $\pm$	0.37	0.49
CD at 5 %	N.S.	N.S.
I x W x V		
SE $\pm$	0.65	0.85
CD at 5 %	N.S.	N.S.
General Mean	**31.12**	**30.53**

Effect of cotton hybrids

The mean number of cotton seeds $boll^{-1}$ was significantly the lowest in Kashinath Bt and the highest in Nathbaba non Bt during both the years of studies. Further, it was noticed that Dhroov non Bt and Dhroov Bt were on par with each other during 2007 and 2008.

Effect of interaction

The interaction effects between different factors under study were absent in case of number of seeds $boll^{-1}$ during both the seasons of experimentation.

4.3.7 Hundred seed weight

The data on hundred seed weight as influenced by various treatments are presented in Table 32.

It was observed that, the hundred seed weight was 9.89 and 9.80 g during 2007 and 2008, respectively.

Effect of irrigation levels

The irrigation scheduled at 50 and 75 mm CPE significantly increased 100 seed weight as compared to irrigation scheduled at 100 mm CPE during both the years owing to adequate soil moisture through out the crop growth period under former irrigation schedules. The results were in confirmity with the findings of Pawar *et al*. (2001) in mustard crop and Jukte *et al*. (2007) in french bean.

Table 32: Mean hundred seed weight as influenced by different

treatments during 2007 and 2008

Treatments	Hundred seed weight (g)	
	2007	2008
Irrigation levels (I)		
50 mm CPE	9.91	9.80
75 mm CPE	9.94	9.84
100 mm CPE	9.81	9.75
SE ±	0.021	0.013
CD at 5 %	0.063	0.040
Water saving practices (W)		
Alternate furrow irrigation	9.89	9.70
Every furrow irrigation	9.89	9.90
SE ±	0.032	0.04
CD at 5 %	N.S.	N.S.
Cotton hybrids (V)		
Dhroov Bt	8.68	8.52
Dhroov Non-Bt	9.58	9.47
Kashinath Bt	11.61	11.56
Nathbaba Non-Bt	9.69	9.65
SE ±	0.052	0.06
CD at 5 %	0.140	0.21
Interactions		
I x W		
SE ±	0.06	0.07
CD at 5 %	N.S.	N.S.
I x V		
SE ±	0.09	0.08
CD at 5 %	N.S.	N.S.
V x W		
SE ±	0.07	0.06
CD at 5 %	N.S.	N.S.
I x W x V		
SE ±	0.12	0.14
CD at 5 %	N.S.	N.S.
General Mean	**9.89**	**9.80**

Effect of water saving practices

The water saving practices either alternate or every furrow irrigation did not show any significant influence on hundred seed weight during the period of investigation. Solaiappan *et al*. (1991) also observed that each furrow and alternate furrow irrigation did not significantly influence the hundred seed weight of cotton.

Effect of cotton hybrids

Kashinath Bt recorded significantly the highest hundred seed weight whereas Dhroov Bt recorded the lowest hundred seed weight during both the years of experimentation. Further, it was noticed that Dhroov non Bt and Nathbaba non Bt were found to be at par with them. Similar results were observed by Singh *et al.* (2003).

Effect of interaction

The interaction effect between various factors were found to be non significant.

4.3.8 Seed cotton weight plant^{-1}

Data pertaining to seed cotton weight plant^{-1} at different pickings and mean seed cotton weight plant^{-1} as influenced by different treatments are presented in Table 33 and graphically depicted in Fig. 12.

The data in Table 33 showed the increase in seed cotton weight plant^{-1} at second picking during both the year. The total weight of seed cotton plant^{-1} was 229.42 and 271.95 g during 2007 and 2008, respectively.

Effect of irrigation levels

The irrigation scheduled at 75 mm CPE significantly increased seed cotton weight plant^{-1} as compared to other irrigation schedules during first and second pickings during both the years owing to adequate soil moisture. The seed cotton weight plant^{-1} was significantly more with 100 mm CPE irrigation schedule than 50 mm CPE irrigation schedule at first and second pickings during both the years. However, reverse trend was noticed at third and fourth pickings where irrigation scheduled at 50 mm CPE significantly increased seed cotton weight as compared to 75 and 100 mm CPE irrigation schedules during both the years which may be attributed to excess moisture under former irrigation schedule which might have delayed maturity consequently increased seed cotton weight plant^{-1}.

Further, it was noticed that irrigation scheduled at 75 mm CPE significantly increased total seed cotton weight plant^{-1} as compared to irrigation scheduled at 50 and 100 mm CPE during both the years owing to adequate soil moisture throughout crop growing period. It was also observed that scheduling of irrigation at 50 mm CPE significantly improved seed cotton weight plant^{-1} as compared to 100 mm CPE irrigation schedules during both the years owing to better soil moisture condition under former schedule and moisture stress conditions under later irrigation schedule. Similar results were reported by Christopher and Chinaswami (1996).

Effect of water saving practices

There was no significant differences observed due to every furrow and alternate furrow irrigation at all the pickings during both the years of experimentation. Similar results were observed by Gaikwad (1985).

Effect of cotton hybrids

Seed cotton weight plant^{-1} of Dhroov Bt cotton hybrid was significantly the highest whereas it was significantly the lowest in Kashinath Bt cotton hybrid at first and second pickings during both the years. It was also noticed that seed cotton weight plant^{-1} of Dhroov non Bt cotton hybrid was significantly more than Nathbaba non Bt cotton hybrid at first and second picking during the year 2007.

The seed cotton weight plant^{-1} was significantly increased in Dhroov non Bt and Kashinath Bt as compared to Dhroov Bt and Nathbaba non Bt cotton hybrid at third and fourth picking during both the years except at fourth picking during first year of experimentation. Where differences were non significant.

Cotton hybrid Dhroov Bt significantly increased total seed cotton weight plant^{-1} as compared to other cotton hybrids whereas, it was significantly decreased with Kashinath Bt cotton hybrid than other hybrids during both the years owing to efficient conversion of dry matter into economic yield under former hybrid and more vegetative growth under later hybrid. Further, it was observed that Dhroov non Bt cotton hybrid also proved significantly superior to Nathbaba non Bt cotton hybrid in respect of seed cotton weight plant^{-1} during first year of experimentation.

Effect of interaction

The interaction effect between various factors under study on seed cotton weight plant^{-1} was found to be non significant during both the years of investigation.

4.3.9 Mean stalk weight plant^{-1}

Data pertaining to stalk weight plant^{-1} as influenced by different treatments are presented in Table 34 and also graphically depicted in Fig. 13.

The data from Table 34 indicate that the stalk weight plant^{-1} was maximum during 2008. The mean stalk weight plant^{-1} was 361.05 and 368.00 g during 2007 and 2008, respectively.

Effect of irrigation levels

The mean stalk weight plant^{-1} at harvest was significantly influenced by different irrigation schedule. Irrigation Scheduled at 75 mm CPE recorded significantly the higher stalk weight plant^{-1} than high (50 mm CPE) and low frequency (100 mm CPE) irrigation schedules during both the years of experimentation. Significant reduction in stalk weight plant^{-1} under 100 mm CPE irrigation schedule might be due to severe stress during formative stage of crop growth. Similar results were reported by Kaswala *et al*. (2000) and Dahatonde and Deshmukh (2001).

Table 34: Mean stalk weight plant^{-1} at harvest as influenced by different treatments during 2007 and 2008

Treatments	Mean stalk weight (g) plant^{-1}	
	2007	2008

Irrigation levels (I)		
50 mm CPE	361.06	363.74
75 mm CPE	376.86	386.29
100 mm CPE	345.23	355.12
SE ±	0.18	2.17
CD at5 %	0.60	6.84
Water saving practices (W)		
Alternate furrow irrigation	360.92	367.92
Every furrow irrigation	361.18	368.85
SE ±	0.16	1.77
CD at.5 %	N.S.	N.S.
Cotton hybrids (V)		
Dhroov Bt	297.38	307.68
Dhroov Non-Bt	314.51	321.50
Kashinath Bt	502.17	511.47
Nathbaba Non-Bt	330.15	322.88
SE ±	0.68	2.62
CD at.5 %	1.89	7.27
Interactions		
I x W		
SE ±	0.27	3.07
CD at.5 %	N.S.	N.S.
I x V		
SE ±	1.18	4.55
CD at 5 %	3.28	N.S.
V x W		
SE ±	0.97	3.71
CD at.5 %	N.S.	N.S.
I x W x V		
SE ±	1.68	6.43
CD at.5 %	N.S.	N.S.
General Mean	**361.05**	**368.00**

Effect of water saving practices

The stalk weight plant^{-1} was not significantly influenced by water saving practices during both the seasons of study. Jadhav *et al*. (1995) reported that the alternate furrow system produced comparable stalk yield with that of every furrow and flat bed irrigation systems. The findings were confirmed by Virdia and Patel (2000) and Ghadge *et al*. (2005).

Effect of cotton hybrids

The Kashinath Bt produced significantly the highest stalk weight plant^{-1} over rest of the cotton hybrids during both the years of investigation. The second highest in order of sequence was Nathbaba non Bt followed by Dhroov non Bt. However, Dhroov Bt produced significantly less stalk weight plant^{-1} during both the seasons of study. The highest stalk weight plant^{-1} under Kashinath Bt might be due to maximum height, monopodial branches number of leaves, leaf area and maximum photosynthates stored in stalk.

Further, it was noticed that Dhroov Bt produced significantly the lowest stalk weight plant^{-1} as compared to its counter part i.e. Dhroov non Bt during both the seasons of study owing to effective translocation of photosynthates into economic part i.e. seed cotton yield which was not happened in Dhroov non Bt. The results corroborate with the findings of Pettigrew (2004) and Jeughale *et al*. (2005).

Effect of interaction

The irrigation scheduled at 75 mm CPE significantly increased the stalk weight plant^{-1} and irrigation scheduled at 100 mm CPE significantly decreased stalk weight plant^{-1} as compared to other irrigations schedules in all the Bt and non Bt cotton hybrids during 2007 owing adequate moisture under former irrigation schedule and moisture stress under later irrigation schedule.

Kashinath Bt irrigated with 75 mm CPE proved to be the best in producing stalk weight plant^{-1} during 2007. Where as it was significantly decreased with Dhroov Bt than other cotton hybrids under all the three irrigation schedules during 2007. Nathbaba non Bt also produced significantly more stalk yield plant^{-1} than Dhroov non Bt hybrid under all the irrigation schedules during the year 2007.

Table 35: Interaction effect between irrigation levels and cotton hybrids on stalk weight plant^{-1} (g) during-2007

Cotton Hybrids	Irrigation levels		
	50 mm CPE	**75 mm CPE**	**100 mm CPE**
Dhroov Bt.	298.30	312.00	281.86
Dhroov Non-Bt.	314.75	328.25	300.52
Kashinath Bt.	499.30	526.20	481.00
Nathbaba Non Bt.	391.90	341.00	317.65
	SE	CD at 5%	
C at same level of A	1.19	3.28	
A at same level of C	1.25	3.80	

4.3.10 Seed cotton yield and stalk yield

Data pertaining to seed cotton yield and stalk yield with pooled means as influenced by different treatments are presented in Table 36 and graphically shown in Fig. 14.

The seed cotton yield was 24.24, 27.62 and 25.94 q ha^{-1} during 2007, 2008 and in pooled data, stalk yield was 111.48, 118.45 and 115.00 q ha^{-1} during 2007, 2008 and in pooled data, respectively.

Effect of irrigation levels

Seed cotton yield and stalk yield were significantly increased with irrigation scheduled at 75 mm CPE as compared to irrigation scheduled at 50 and 100 mm CPE during both the years and in pooled data owing to adequate soil moisture available throughout the crop growth period. This was also ascribed to significant improvement in important growth attributes like plant height, number of monopodial and sympodial branches, leaf area and dry matter production $plant^{-1}$ as well as significant improvement in yield contributing characters like number of squares and bolls $plant^{-1}$, seed cotton weight $boll^{-1}$ and $plant^{-1}$, seed weight $boll^{-1}$ etc. Halemani *et al*. (2003) and Aujla *et al*. (2005) reported that the decrease in quantity of water applied was accompanied by corresponding decrease in seed cotton yield, reported by Ahmet and Riza (2003) also reported that shortage of water generally increases boll shedding rate results in lower yields.

Further, it was noticed that seed cotton and stalk yields were significantly improved with 50 mm CPE than 100 mm CPE during both the years and when the data were pooled over the seasons because of better moisture availability under former schedule and moisture stress under later irrigation schedule.

The important growth and yield attributes also improved under former irrigation schedule which resulted significant improvement in seed cotton and stalk yields. Similar results were reported by Dagdelen *et al*. (2009).

Effect of water saving practices

The water saving practices did not influence the seed cotton yield and stalk yield during both the years of experimentation and when the data were pooled for two seasons. This might be due to better availability of moisture under alternate furrow and every furrow irrigation. The results are in conformity with the findings of Ghadge (2005). However, Halemani *et al*. (2003) reported that the higher stalk yield production was under every furrow irrigation practice.

Effect of cotton hybrids

The seed cotton yield of Dhroov Bt and stalk yield of Kashinath Bt was significantly more than other cotton hybrids during both the seasons and in pooled data owing to increase in growth and yield attributes of Dhroov Bt and more height, dry matter plant^{-1} in Kashinath Bt. These results are conformity with the findings of Earson *et al*. (1980) and Solaippan *et al*. (1993).

Further, it was noticed that Dhroov non Bt and Nathbaba non Bt significantly produced more seed cotton yield than Kashinath Bt during both the years of experimentation and in pooled data owing to less number of bolls and seed cotton weight boll^{-1} in Kashinath Bt.

In present investigation Dhroov Bt produced significantly the higher seed cotton yield and lower stalk yield than its counter part during both the season due to efficient conversion of photosynthates into economic yield under Bt cotton hybrids. These results are similar to those reported by Buttar and Singh (2006), Bhatade *et al*. (2006) and Deosarkar *et al.* (2008).

Effect of interactions

The seed cotton yield and stalk yield was not significantly influenced due to different interactions under study during both the seasons and in pooled data except stalk yield during 2007 and in pooled data (Table 37 and 38). The stalk yield was significantly the highest with 75 mm CPE, whereas, it was significantly the lowest with 100 mm CPE under all the cotton hybrids during the year 2007 and in pooled data owing to better moisture situation under former irrigation and moisture stress under later irrigation schedule. The stalk yield was significantly the highest with Kashinath Bt and it was significantly the lowest with Dhroov Bt under all irrigation schedule during the year 2007 and in pooled data.

Table 37 : Interaction effect between different irrigation levels and cotton hybrids on stalk yield (q ha^{-1}) during 2007

Cotton Hybrids	Irrigation levels		
	50 mm CPE	**75 mm CPE**	100 mm CPE
Dhroov Bt.	98.45	108.07	103.39
Dhroov Non-Bt.	102.93	113.88	107.71
Kashinath Bt.	127.46	131.78	118.98
Nathbaba Non Bt.	108.17	111.21	105.70
	SE	CD at 5%	
C at same level of A	1.17	3.38	
A at same level of C	1.20	3.60	

Table 38: Interaction effect between different irrigation levels and cotton hybrids on stalk yield q ha^{-1} (Pooled mean)

Cotton Hybrids	Irrigation levels		
	50 mm CPE	**75 mm CPE**	**100 mm CPE**
Dhroov Bt.	102.40	112.71	100.70
Dhroov Non-Bt.	106.91	118.85	107.26
Kashinath Bt.	131.79	139.75	123.58
Nathbaba Non Bt.	112.28	114.58	109.17
	SE $\pm$	CD at 5%	
C at same level of A	1.59	4.65	
A at same level of A	1.45	4.35	

4.4 Quality studies

4.4.1 Ginning percentage

Data regarding mean ginning percentage as influenced by various treatments at different pickings are presented in Table 39.

It is to be seen from Table 39 that the ginning percentage was observed to be more in second picking during both the years of investigation and mean. The mean ginning percentage was 35.85 and 36.30 per cent during 2007 and 2008, respectively.

Effect of irrigation levels

The ginning percentage of cotton was not affected significantly due to different irrigation levels at different picking during 2007. However, irrigation scheduled at 75 mm CPE was found to be significantly superior over rest of the irrigation schedules in all the pickings and average ginning percentage during the year 2008. This might be ascribed to increase in weight of seed cotton. Further, it was noticed that significantly the lowest ginning percentage was observed under 100 mm CPE irrigation. Sagarka *et al*. (2002) found that irrigation applied at 0.8 CPE recorded significantly higher lint index than other irrigation levels, however, other quality parameters did not differ due to irrigation levels. Whereas, Subbaramamma and Ratnakumari (2006) found that moisture makes or breaks fibre quality.

Effect of water saving practices

Water saving practices did not show any significant effect on ginning percentage of seed cotton at different pickings and during both the years of experimentation. The findings were in conformity with the results of Ghadge (2003) However, Gaikwad (1985) observed that ginning percentage was decreased under alternate furrow irrigation.

Effect of cotton hybrids

Kashinath Bt produced significantly the lowest ginning percentage at all pickings and in mean values over rest of the cotton hybrids and these cotton hybrids were at par with them self at all pickings and mean values during both the seasons. However, during second season, Dhroov Bt produced significantly the highest ginning percentage over rest of the cotton hybrids except at third and fourth picking, It was on par with Dhroov non Bt. These fluctuating results might be due to seasonal variations. During first season rainfall was more than second season. However, Srinivasulu *et al.* (2006) also found variation in ginning percentage among different cotton hybrids.

Interaction effects

The interaction effects between different factors were found to be non significant at all pickings and in mean values of ginning percentage during both the seasons of study.

4.4.2 2.5 per cent span length

Data pertaining to mean 2.5 per cent span length as influenced by different treatments are presented in Table 40. The mean 2.5 per cent span length was 32.39 and 31.45 mm during 2007 and 2008, respectively.

Effect of irrigation levels

Irrigation levels did not show any significant effect on 2.5 per cent span length during both the years of experimentation. Similar results were obtained by Srinivasareddy and Thimmegowda (1997) and Sagarka *et al.* (2002). However, Subbaramamma and Ratnakumari (2006) reviewed that moisture makes or breaks fibre quality.

Effect of water saving practices

Both the water saving practices did not show any significant effect on 2.5 per cent span length during both the years owing to equal availability of moisture in either of the water saving practices during both the years of investigation. The results are in conformity with the findings of Ghadge (2003).

Effect of cotton hybrids

Dhroov non Bt significantly produced the lowest 2.5 per cent span length than rest of the cotton hybrids and was found to be at par with Dhroov Bt. However, Kashinath Bt was significantly superior over other cotton hybrids followed by Nathbaba non Bt during both the years of study owing to genetical characteristics of cotton hybrids. These findings were in conformity to the results of Nehra *et al.* (2004) and Jeughale *et al.* (2005).

Effect of interactions

The interaction effects between the different factors were found to be non significant. This indicates that all cotton hybrids under the study had given similar response to irrigation levels and water saving practices. Similar results were observed by Srinivasareddy and Thimmegowda (1997).

4.4.3 Elongation per cent

Data presented in Table 40 revealed that mean elongation percentage was 6.01 and 5.85 per cent during 2007 and 2008, respectively.

Effect of irrigation levels

Elongation per cent was not significantly influenced due to different irrigation levels during both the years of investigation. Similar results were observed by Sagarka *et al.* (2002). However, Pettigrew (2004) found that increase in irrigation water, increased the fibre elongation by 6 per cent.

Water saving practices

No significant differences were observed in both the water saving practices on fibre elongation per cent during both the years of investigation owing to equal distribution of soil moisture under both the water saving practices. Ghadge *et al.* (2005) also reported that irrigation techniques did not influence the quality parameters of cotton. The results were confirmed by Thukkaiyannan *et al.* (2005).

Effect of cotton hybrids

The elongation percentage was not significantly influenced under different cotton Bt and non Bt hybrids during both the years of experimentation. Srinivasulu *et al.* (2006) reported that neither the elongation ratio of the fibre nor the strength was influenced by the cotton hybrids. These results are in conformity with the findings of Patil *et al.* (2008[b]).

Effect of interaction

The fibre elongation was not differed significantly due to interactions between irrigation levels, water saving practices and cotton hybrids during both the years of experimentation.

4.4.4 Fibre strength

Mean fibre strength was 22.83 and 22.58 g tex^{-1} during 2007 and 2008 respectively (Table 40).

Effect of irrigation levels

It would be seen from Table 40 that the fibre strength was not influenced significantly due to irrigation levels during both the years of experimentation. The results corroborate the findings of Abraham *et al.* (1980) and Constable and Hodgson (1990).

Effect of water saving practices

The fibre strength was not significantly influenced by water saving practices during both the years. This might be due to better distribution of assimilates from source to sink and comparatively less into vegetative parts. This is in accordance with findings of Howell *et al.* (1984), Gaikwad (1985) and Singh and Bhan (1993).

Effect of cotton hybrids

The fibre strength of Kashinath Bt from *barbdance* group was significantly superior over rest of the cotton hybrids during both the years. However, Nathbaba non Bt, Dhroov non Bt and Dhroov Bt were found to be statistically at par with each other. The *barbedence* group was superior than *hirsutum* in respect of quality parameters (Bhunia, 2008).

Effect of interaction

Fibre strength was not significantly influenced by different factors during both the years of investigation.

4.4.5 Fibre fineness (Micronaire value)

The data presented in Table 40 revealed that mean fibre fineness (micronaire value) was 3.79 and 3.37 militex, during 2007 and 2008 respectively. This indicate that fibre quality was fine (3.0 to 3.9 militex).

Effect of irrigation levels

The mean fibre fineness was significantly decreased with increasing moisture stress, imposed with irrigation scheduled at 100 mm CPE over rest of the irrigation schedules during 2007. However, it was found to be non significant during 2008. This might be due to water stress under 100 mm CPE irrigation schedule. Differences were observed by Franklin *et al.* (2000) due to irrigation levels in micronaire value but no cause and effect relationship could be identified. However, Sagarka *et al.* (2002) did not find any significant effect due to irrigation regimes on fibre fineness.

Effect of water saving practices

The fibre fineness was not significantly influenced due to water saving practices. Similar results were observed by Ghadge *et al.* (2005) and Patil *et al.* (2008[b]).

Effect of cotton hybrids

Kashinath Bt was significantly superior than other cotton hybrids in respect of fibre fineness value. It could be categorised under fine fibre (3.00 to 3.9 millitex) followed by Nathbaba non Bt during both the years. However, Dhroov Bt and Dhroov non Bt were at par with each other and were found under the average category (4.00 to 4.9 millitex) and fine category (3.00 to 3.9 millitex) during 2007 and 2008, respectively. This might be due to climatatic differences during the seasons. During 2007 rainfall was more (82.24 cm) as compared to 2008 (67.44 cm).

Effect of interaction

The fibre fineness was not significantly influenced by different interaction combinations between the irrigation levels, water saving practices and cotton hybrids during both the seasons.

4.4.6 Uniformity ratio

The data presented in Table 40 reported that the mean uniformity ratio was 48.40 and 46.10 per cent during 2007 and 2008, respectively.

Effect of irrigation levels

The uniformity ratio was not significantly influenced by different irrigation levels during both the years of experimentation. However, seasonal variations in respect of uniformity ratio was noticed, it was 48.40 and 46.10 per cent during 2007 and 2008, respectively. Sethi *et al.* (1995) observed that uniformity ratio was not affected by irrigation levels.

Water saving practices

The water saving practices either alternate furrow or every furrow irrigation did not affect the uniformity ratio during both the years of study. This might be due to better distribution of assimilates from source to sink and comparatively less into vegetative parts. Similar results were obtained by Howell *et al.* (1984) ad Ghadge *et al.* (2005).

Effect of cotton hybrids

Uniformity ratio was significantly differed by cotton hybrids during 2007, however, during second year, the uniformity ratio was found to be non significant. It was observed that Dhroov Bt, Dhroov non Bt and Nathbaba non Bt were at par with each other and were found significantly inferior over Kashinath Bt cotton hybrid during first year. This might be due to varietal reflections from different cotton hybrids.

Effect of interaction

The interaction effects were found to be non significant during the period of investigation

4.5 Moisture studies

4.5.1 Profile water depletion

Data pertaining to soil moisture depletion as influenced by irrigation levels, water saving practices and cotton hybrids during both the years of experimentation are presented in Table 41 and 42. The data are not statistically analysed the inferences are made on the basis of mean values. From the data, it could be seen that the mean profile water depleted was 37.94 cm and 51.48 cm during 2007 and 2008 respectively.

Effect of irrigation levels

The maximum water depletion was observed under 50 mm CPE than 75 and 100 mm CPE irrigation during both the years of experimentation owing to high frequency under former irrigation schedule. The moisture depletion was high under high frequency irrigation and it was decreased with the decreased irrigation frequency due to availability of adequate moisture under high frequency irrigation. These findings are supported by Verma *et al.* (1991), Singh and Bhan (1993) and Saig and Verma (1994).

Effect of water saving practices

The total water depleted was more under every furrow irrigation during both the years of experimentation and it was decreased under alternate furrow irrigation. This might be due to more water availability under every furrow irrigation (Ghadge, 2003) and (Shelke and Giri, 2003).

Effect of cotton hybrids

Kashinath Bt depleted the highest amount of moisture from soil over other cotton hybrids during both the years of investigation. In order of sequence the second highest was Dhroov Bt followed by Dhroov non Bt and Nathbaba non Bt.

Further, it was noticed that Bt cotton hybrids depleted the higher amount of water than non Bt cotton hybrids during both the years of study. This might be due to maximum production of biomass and yield under the Kashinath Bt and Dhroov Bt.

4.5.2 Water requirement of crop (Total water applied)

The water balance studies were precisely carried out in respect of water expenses and recharge of the profile either by precipitation or irrigation. The relevant data are given in Table 41, 42 and graphically depicted in Fig. 15.

The total depth of water applied as per treatment throughout the crop growth period was considered as the irrigation requirement of the crop during both the years of investigation.

Effect of irrigation levels

The maximum irrigation water was required under 50 mm CPE irrigation followed by 75 mm and 100 mm CPE owing to water was applied more frequency under 50 mm CPE. Similar results were reported by Saigs and Verma (1994). Further it was noticed that irrigation scheduled at 75 mm CPE recorded the highest water saving over 50 mm CPE to the tune of 22.93 and 20.92 per cent during 2007 and 2008, respectively, because number of irrigation required less 7 and 9 during corresponding years under former irrigation schedule.

Effect of water saving practices

The water requirement was higher under every furrow irrigation as compared to alternate furrow irrigation. This might be due to application of irrigation alternatively in alternate furrow.

Further, it was noticed that use of alternate furrow irrigation recorded the highest water saving to the extent of 20.68 and 25.58 per cent during 2007 and 2008, respectively. These findings are similar to these reported by Horse 2007 and Patil *et al.* 2008[a].

Effect of cotton hybrids

An equal amount of irrigation was applied to Dhroov Bt, Dhroov non Bt, Kashinath Bt and Nathbaba non Bt during the course of investigation as per treatments of irrigation scheduling and water saving practices.

4.5.3 Consumptive use of water

The total and mean daily consumptive use of water were worked out for both the seasons and are presented in Table 41 and 42 and graphically depicted in Fig. 15.

Effect of irrigation levels

The total consumptive use and daily consumptive use of water was the highest under 50 mm CPE followed by 75 mm and 100 mm CPE level. This might be due to high frequency of irrigation under 50 mm CPE irrigation. Similar trend was observed in daily consumptive use of water in respect of irrigation levels during both the years of investigation. Verma *et al.* (1991) also reported that consumptive use of moisture by crops increased with the frequency of irrigation. The results corroborate the findings of Verma and Deo (1992).

Effect of water saving practices

There was an increase in the total consumptive use of water when irrigation was applied to each furrow. The minimum consumptive use was observed in alternate furrow irrigation during both the seasons. The availability of water was more under every furrow irrigation tended to increase the consumptive use of water (Ghadge, 2003). Singh and Bhan (1993) also supported similar findings.

The mean maximum daily consumptive use of 0.49 and 0.55 cm per day was noticed in alternate and every furrow irrigation, respectively during 2007, corresponding figures during 2008 were 0.50 and 0.55 mm per day. Consumptive use of water per day was higher under every furrow irrigation than alternate furrow (Gaikwad, 1985).

Effect of cotton hybrids

The total consumptive use of water was numerically higher under Kashinath Bt and Dhroov Bt than non Bt cotton hybrids Nathbaba and Dhroov during both the years of experimentation.

The higher consumptive use of water by Bt cotton hybrids might be due to higher biomass and seed cotton production during the course of investigation. Kashinath Bt produced maximum biomass and Dhroov Bt produced the highest seed cotton yield. Daily consumptive use of water was also higher under Kashinath Bt and Dhroov Bt as compared to non Bt cotton hybrids.

4.5.3 Water use efficiency

The relevant data pertaining to mean seed cotton yield, evapo-transpiration (ET) and water use efficiency are presented in Table 43 and graphically shown in Fig. 16.

The mean water use efficiency was 3.11 and 3.58 kg $ha^{-1}mm^{-1}$ during 2007 and 2008, respectively.

Effect of irrigation levels

The maximum water use efficiency was observed under irrigation schedule of 75 mm CPE than rest of the irrigation levels during both the seasons owing to high seed cotton yield. The lowest water use efficiency was found under 50 mm CPE due to low yield and moderate water use efficiency was recorded by 100 mm CPE. However, the yield was reduced due to moisture stress. Water use efficiency decreased as frequency of irrigation increased (Verma *et al.*, 1991 and Verma and Deo, 1992). Tennakoon and Milroy (2003) reported that an average consumptive use efficiency across all the regions and seasons was 2.5 kg $ha^{-1}mm^{-1}$ with large variability across the regions.

Effect of water saving practices

The high water use efficiency was observed under alternate furrow irrigation than every furrow without reduction in the yield during both the years of study. Bhunia (2007) reported that the highest water use efficiency was found with application of irrigation in alternate furrow in rotation. The results are in conformity with the findings of Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

The maximum water use efficiency was recorded by Dhroov Bt and the minimum by Kashinath Bt during both the years of experimentation. The second highest in order of sequence was Dhroov non Bt followed by Nathbaba non Bt. The consumptive use of water was higher under Kashinath Bt and Dhroov Bt, but the yield was very low in Kashinath Bt and hence it's water use efficiency was very low, during both the years. The seed cotton yield of Dhroov Bt was more leading to higher water use efficiency.

4.6 Cotton *parawilt*

The cotton *parawilt* incidence are presented in Table 44 and 45 and graphically depicted in Fig. 17 and 18.

From the data and figure it could be seen that the *parawilt* was noticed at 56 days after planting and it was gradually increased up to 112 DAP and again decreased at 126 DAP and at last it was increased. The mean *parawilt* values were 3.86 to 8.14 from 56 to 140 DAP, respectively during first year. Whereas, it was 4.18 to 6.41 from corresponding DAP during 2008. During this year, the *parawilt* values were fluctuating; it might be due to rainfall and temperature effect (Hebbar and Mayee, 2004).

Effect of irrigation levels

The mean *parawilt* arcsin values were significantly more under 50 mm CPE irrigation level than 100 amd 75 mm CPE irrigation levels at all growth stages of crop during first year of study. The well distributed rainfall of 852.4 mm was eceived during this year as against rainfall of 674.4 mm in second year creating excess moisture situation thereby increased *parawilt* incidence. Hebbar and Mayee (2004) and Hebbar (2005) reported that imposition of water-logging condition under bright sunlight and high temperature elicited wilt symptoms in plants with large canopy and heavy boll load. Significantly the lowest *parawilt* values were observed under irrigation schedule of 75 mm CPE owing to adequate moisture in the root zone of the crop throughout the growth period.

Irrigation scheduled at 100 mm CPE significantly increased incidence of *parawilt* as compared to rest of the irrigation schedules during second of experimentation owing to moisture stress after rains during crop growth period. The prolonged drought followed by rain or irrigation led to attack of cotton by *parawilt* syndrome (Chauhan *et al.*1989). The incidence of *parawilt* was significantly more with irrigation schedule of 50 mm CPE than irrigation schedule of 75 mm CPE during second year of experimentation owing to excess moisture situation.

From this findings it was noticed that either deficit or excess moisture was responsible for *parawilt* incidence in the present study.

Effect of water saving practices

The water saving practices did not influence cotton *parawilt* at all growth stages during both the seasons. But every furrow irrigation had given higher values of *parawilt* during first year owing to more irrigation water than alternate furrow and well distributed excess rainfall during this year. Alternate furrow irrigation during second year increased *parawilt* values because of moisture stress due to less rainfall followed by irrigation might have increased *parawilt* incidence.

Effect of cotton hybrids

The *parawilt* was not observed on Kashinath Bt throughout the growth period during both the years of experimentation as it belongs to *hirsutum x barbedance* group. Bhale (1984) also reported that the *barbendence* cultivars were free from *parawilt* syndrome. The attack of *parawilt* was significantly less in Nathbaba non Bt during both years of investigation.

Further, it was noticed that Dhroov Bt though out yielded but was susceptible to *parawilt* disorder due to water-logging conditions because of high rainfall during first season and water stress in second season.

However, the incidence of *parawilt* was significantly less on Dhroov non Bt. This showed that Dhroov Bt cotton was highly susceptible to cotton *parawilt* than non Bt cotton hybrids particularly *hirsutum* cultivars. The survery carried out by state Department of Agriculture, Government of Maharashtra in Amaravati, Yeotmal and Nanded Districts on Bt and non Bt cotton hybrids reported that more *parawilt* was observed under Bt cotton than non Bt cotton (Anonymous, 2003).

Effect of interaction

From the Table 46 to 52 and it was reported that the *parawilt* values were significantly the highest with 50 mm CPE irrigation and significantly the lowest with 75 mm CPE irrigation under Dhroov Bt at all growth stages of cotton except at 70 DAP during first year. However, during second year the interaction was found to be non significant at all growth stages except at 56 DAP. At this stage parawilt value was the highest under 50 mm CPE followed by 100 mm CPE irrigation.

Table 46: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arcsin per cent) at 56 DAP during 2007

Irrigation levels	Dhroov Bt.	Dhroov Non-Bt.	Kashinath Bt.	Nathbaba non-Bt.
50 mm CPE	12.57 (4.32)	9.54 (2.98)	0.00 (0.00)	2.97 (0.98)
75 mm CPE	2.97 (0.98)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
100 mm CPE	10.85 (3.92)	7.43 (2.40)	0.00 (0.00)	0.00 (0.00)
	SE ±	CD at 5%0.80		
A at same level of C	0.80	2.30		
C at same level of A	0.90	2.71		

** Figures in parenthesis are per cent parawilt*

Table 47: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arcsin per cent) at 84 DAP during 2007

Irrigation levels	Dhroov Bt.	Dhroov Non-Bt.	Kashinath Bt.	Nathbaba non-Bt.
50 mm CPE	11.94 (4.74)	10.16 (3.45)	0.00 (0.00)	4.46 (1.51)
75 mm CPE	8.07 (2.78)	2.97 ()0.98	0.00 (0.00)	0.00 (0.00)

100 mm CPE	10.87 (3.78)	7.42 (2.38)	0.00 (0.00)	7.46 (2.42)
	SE +	CD at 5%0.95		
A at same level of C	0.95	2.73		
C at same level of A	0.86	2.64		

** Figures in parenthesis are percent parawilt*

Table 48: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arc sin per cent) at 98 DAP during 2007

Irrigation levels	Dhroov Bt.	Dhroov Non-Bt.	Kashinath Bt.	Nathbaba non-Bt.
50 mm CPE	13.47 (4.92)	11.27 (3.99)	0.00 (0.00)	10.18 (3.74)
75 mm CPE	9.56 (3.48)	2.97 (0.97)	0.00 (0.00)	0.00 (0.00)
100 mm CPE	11.45 (4.10)	8.91 (3.28)	0.00 (0.00)	7.46 (2.32)
	SE +	CD at 5%		
A at same level of C	0.81	2.31		
C at same level of A	0.93	3.60		

Figures in parenthesis are percent parawilt

Table 49: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arc sin per cent) at 112 DAP during 2007

Irrigation levels	Dhroov Bt.	Dhroov Non-Bt.	Kashinath Bt.	Nathbaba non-Bt.
50 mm CPE	13.89 (4.98)	10.63 (3.76)	0.00 (0.00)	8.50 (3.17)
75 mm CPE	10.83 (3.94)	8.91 (3.28)	0.00 (0.00)	0.00 (0.00)
100 mm CPE	11.45 (4.10)	8.91 (3.28)	0.00 (0.00)	5.97 (2.11)

	SE ±	CD at 5%
A at same level of C	0.95	2.73
C at same level of A	0.80	2.41

** Figures in parenthesis are percent parawilt*

Table 50: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arcsin per cent) at 126 DAP during 2007

Irrigation levels	Dhroov Bt.	Dhroov Non-Bt.	Kashinath Bt.	Nathbaba non-Bt.
50 mm CPE	13.89 (4.98)	9.53 (3.46)	0.00 (0.00)	8.91 (3.28)
75 mm CPE	11.48 (4.13)	7.43 (2.21)	0.00 (0.00)	0.00 (0.00)
100 mm CPE	10.83 (3.92)	7.43 (2.21)	0.00 (0.00)	5.97 (2.11)
	SE ±	CD at 5%		
A at same level of C	1.02	2.94		
C at same level of A	0.95	2.85		

** Figures in parenthesis are percent parawilt.*

Table 51: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arc sin per cent) at 140 DAP during 2007

Cotton Hybrids	Irrigation levels		
	50 mm CPE	**75 mm CPE**	**100 mm CPE**
Dhroov Bt.	16.37 (5.36)	12.14 (4.13)	11.41 (4.12)
Dhroov Non-Bt.	10.79 (3.27)	9.57 (3.36)	9.56 (3.46)
Kashinath Bt.	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Nathbaba Non Bt.	10.81 (2.98)	7.46 (2.27)	9.62 (3.98)
C at same level of A	SE ±	CD at 5% 0.72	

A at same level of C	0.72 0.70	2.08 2.12

** Figures in parenthesis are percent parawilt.*

Table 52: Interaction effect between different irrigation levels and cotton hybrids on cotton *parawilt* (Arc sin per cent) at 56 DAP during 2008

Cotton Hybrids	Irrigation levels		
	50 mm CPE	75 mm CPE	100 mm CPE
Dhroov Bt.	14.33 (5.94)	8.91 (3.78)	10.85 (3.98)
Dhroov Non-Bt.	2.97 (0.87)	0.00 (0.00)	5.94 (2.02)
Kashinath Bt.	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Nathbaba Non Bt.	0.00 (0.00)	2.13 (0.74)	5.08 (1.98)
	SE ±	CD at 5%	
C at same level of A	1.30	3.76	
A at same level of C	1.32	3.81	

** Figures in parenthesis are percent parawilt.*

This indicates that during both the seasons, Dhroov Bt was suffered from *parawilt* syndrome because of excess moisture and moisture deficit during the years. Similar results were observed by Shastry *et al*. (1995).

4.7 Nutrient balance

The data pertaining to balance sheet of available nutrients as influenced by different treatments during two years of experimentation are presented in Table 53, 54 and 55 in respect of nitrogen, phosphorus and potassium balance, respectively.

4.7.1 Nitrogen balance

The data from Table 53 revealed that the initial soil available N was 216.38 kg ha^{-1} while 264.98 kg ha^{-1} N was removed by the crop during two years and hence, net soil N balance was deficit (-20.82 kg ha^{-1}).

Effect of irrigation levels

The available soil N showed a deficit balance after two years of experimentation and magnitude of decrease from the initial level was -23.94 and -20.88 kg ha^{-1} with 75 mm and 50 mm CPE irrigation level, respectively as compared to 100 mm CPE irrigation. The calculated loss was the highest (-17.46 kg ha^{-1}) with 75 mm CPE irrigation and minimum (-90.48 kg ha^{-1}) with 100 mm CPE irrigation. This indicate that application of irrigation at 75 mm CPE replenished the high amount of nitrogen from soil and converted into the higher economic yields. However, the application of 100 mm CPE irrigation water was not sufficient for growth, therefore, there was less uptake and removal of nitrogen from the soil.

Effect of water saving practices

Water saving practices did not show considerable variation in residual soil fertility, however, every furrow irrigation removed more nutrients than alternate furrow irrigation practice owing to sufficient soil moisture available under every furrow irrigation.

Effect of cotton hybrids

The available ‘N’ balance after two years was deficit and the magnitude of decrease was less with non Bt cotton hybrids and it was more with Bt cotton hybrids. The calculated gain of available ‘N’ was decreased with Bt cotton hybrids, Kashinath Bt and Dhroov Bt.

4.7.2 Phosphorus balance

Data from Table 54 reveal that the initial available soil ‘P’ was 22.80 kg ha^{-1} and actually removed by the crop during two years was 53.54 kg ha^{-1}. The net soil ‘P’ after two years was 4.34 kg ha^{-1}.

Effect of irrigation levels

The balance of available phosphorus after two years in plough layer was less (1.40 kg ha^{-1}) with 75 mm CPE irrigation level owing to more uptake of ‘P’ due to optimum moisture content in soil. It was more (6.60 kg ha^{-1}) with 100 mm CPE irrigation which was insufficient to crop tends to decrease the uptake of phosphorous. The calculated loss of available ‘P’ was more with 75 mm CPE irrigation level than 50 mm and 100 mm CPE apparently due to more uptake of available ‘P’ by former irrigation schedule.

Effect of water saving practices

The balance of available 'P' was less with alternate furrow irrigation (2.98 kg ha^{-1}) and magnitude of decrease was more with every furrow irrigation practice (5.70 kg ha^{-1}) owing to optimum moisture availability under every furrow irrigation. The calculated loss was more negative with every furrow irrigation.

Effect of cotton hybrids

The balance of available 'P' after two years was negative with Kashinath Bt and it was positive with Dhroov Bt, Dhroov non Bt and Nathbaba non Bt. The calculated loss of 'P' was more with Kashinath Bt than rest of the cotton hybrids apparently due to more uptake of available 'P by former cotton hybrid.

4.7.3 Potassium balance

Data from Table 55, it is observed that the initial available soil 'K' was 330 kg ha^{-1}, uptake by crop was 289.36 kg ha^{-1} and total soil 'K' balance after two years was 328.86 kg ha^{-1}. However, net soil 'K' balance was negative (-1.14 kg ha^{-1}) and calculated gain of 'K' was 113.72 kg ha^{-1}.

Effect of irrigation levels

The available 'K' showed a prominent negative balance with normal irrigation schedule of 75 mm CPE, which could be mainly attributed to the removal of more quantity of 'K' by this irrigation schedule. However, positive 'K' balance was recorded with 100, CPE and it was noticed that the net deficit in soil 'K' relatively low magnitude was recorded even with 50 mm CPE irrigation schedule.

Effect of water saving practices

The net soil ‘K’ balance was negative with every furrow irrigation and it was positive with alternate furrow irrigation. The calculated gain in available ‘K’ was decreased with every furrow irrigation practice.

Effect of cotton hybrids

The available ‘K’ balance was negative and magnitude of reduction was more with Bt cotton hybrids, Kashinath Bt (-7.39 kg ha^{-1}) and Dhroov Bt (-1.99 kg ha^{-1}) than Dhroov non Bt and Nathbaba non Bt. The calculated gain was more with non Bt cotton hybrids than Bt cotton hybrids.

4.8 Economic studies

Data pertaining to gross monetary returns, cost of cultivation, net monetary returns and benefit:cost ratio as influenced by different treatments during both the years of experimentation are presented in Table 56. The mean gross and net monetary returns are graphically shown in Fig. 19.

4.8.1 Gross monetary returns

Perusal of the data presented in Table 56 and graphically in Fig. 19 revealed that the gross monetary returns from cotton crop were Rs. 58419, Rs. 79128 and Rs. 68705 ha^{-1} during 2007 and 2008 seasons and on pooled basis, respectively. Further, it was noticed that the gross monetary returns were maximum during 2008 as compared to 2007, because seed cotton yield was more and selling rates were also higher during second year.

Effect of irrigation levels

The gross monetary returns were significantly the highest under irrigation schedule at 75 mm CPE than 50 and 100 mm CPE irrigation schedules during both the years and pooled data. This might be due to significant increase in yield with former irrigation schedule. When data were pooled for two seasons, the irrigation schedules of 75 mm CPE recorded significantly the highest gross monetary returns over rest of the irrigation schedules. Kaswala *et al.* (2000) recorded the highest gross monetary returns with irrigation applied at 0.7 IW/CPE ratio over 0.5 and 0.3 IW/CPE ratio. The results corroborate with the findings of Verma and Deo (1992).

Effect of water saving practices

Water saving practices did not show any significant influence on gross monetary returns during both the years of experimentation and on pooling over two years. Similar results were observed by Gaikwad (1985) and Ghadge (2003). However, Solaiappan *et al.* (1993) reported that close spacing and alternate furrow irrigation system gave maximum monetary returns under summer irrigated cotton.

Effect of cotton hybrids

Dhroov Bt recorded significantly the highest gross monetary returns over rest of the cotton hybrids. However, the Kashinath Bt recorded the lowest gross monetary returns during both the years of experimentation and in pooled data. Further it was noticed that Dhroov non Bt and Nathbaba non Bt were found to be at par during 2008. However, Dhroov non Bt was second in order of sequence followed by

Nathbaba non Bt during 2007 and on pooling. Dhroov Bt was found to be the highest in gross monetary returns because the seed cotton yield was highest as compared to other cotton hybrids and its counter part also. Similar results in respect of Bt and its non Bt were observed by Barawale *et al.* (2002) and Kumar (2006).

Effect of interactions

The interaction effect between different factors under study on gross monetary returns was found to be non significant during both the years of experimentation and when the data was pooled for two years. This indicates that the cotton hybrids in study was gave equal response to irrigation levels and water saving practices. Patil *et al.* (2004) reported that the interaction effect between irrigation methods and genotypes were non significant.

4.8.2 Cost of cultivation

The data from Table 56 revealed that the cost of cultivation was Rs. 30850 and Rs. 32228 ha^{-1} during 2007 and 2008, respectively and when data was pooled over two years (Rs. 31537 ha^{-1}).

Effect of irrigation levels

The cost of cultivation was significantly higher under 50 mm CPE irrigation than rest of irrigation levels, however, during second year it was on par with 75 mm CPE irrigation because during second year picking cost of seed cotton was increased as seed cotton yield was more under 75 mm CPE irrigation level. When the cost of cultivation data was pooled for two years, the irrigation was applied at

50 mm CPE reported significantly higher cost than other irrigation levels.

Further, it was noticed that application of irrigation at 100 mm CPE required significantly the lowest cost of cultivation over 50 and 75 mm CPE irrigation levels. This might be due to low irrigation requirement and also low picking cost of seed cotton.

Effect of water saving practices

The cost of cultivation was not significantly influenced by either alternate furrow or every furrow irrigation. The results are confirmed with the findings of Gaikwad (1985) and Ghadge (2003).

Effect of cotton hybrids

Kashinath Bt required significantly less cost of cultivation as compared to rest of the cotton hybrids during both the years of experimentation and in pooled data. However, Dhroov Bt was found to be on par with Dhroov non Bt during first year and required significantly higher cost of cultivation during second year and in pooled data. Nathbaba non Bt was at third position in order of sequence regarding cost of cultivation.

Further, it was noticed that Dhroov Bt and Dhroov non Bt did not find much difference in cost of cultivation because the pest incidence was less during both the years of experimentations, and hence required less cost. Sahai and Rahman (2005) reported that non Bt required less cost of cultivation than Bt cotton hybrids.

Effect of interaction

The interaction effect due to different factors under study on cost of cultivation was found to be non significant during both the years of experimentation and in pooled data.

4.8.3 Net monetary returns

From the Table 56, it could be seen that the net monetary returns of cotton was Rs. 27292, Rs. 46897 and Rs. 37095 during 2007, 2008 and in pooled data, respectively.

Effect of irrigation levels

The net monetary returns were significantly the highest with irrigation schedule at 75 mm CPE than 50 mm and 100 mm CPE during both the years and in pooled data. The net monetary returns were higher during second year because seed cotton yield was more under irrigation schedule 75 mm CPE and rate was also high as compared to first year.

Further, it was noticed that the net monetary returns were significantly the lowest under 100 mm CPE irrigation level than other irrigation schedules. This might be due to water stress during crop growth period leading to low yield which leads to less net monetary returns during the period of investigation and when the data was pooled for two years. Kaswala *et al.* (2000) reported that the highest net monetary returns with the irrigation applied at 0.7 IW/CPE ratios as compared to 0.5 and 0.3 IW/CPE ratio. The results corroborate the findings of Verma and Deo (1992) and Singh (2002[b]).

Effect of water saving practices

The effect of water saving practices did not influence significantly the net monetary returns during both the years of investigation and in pooled data, this might be due to non significant effect of water saving practices on seed cotton yield, cost of cultivation and gross monetary returns.

Further, it was noticed that the application of irrigation at every furrow had produced more net monetary returns than alternate furrow irrigation but no significant differences were observed. Similar results were observed by Sivanappan and Chandrasekaran (1984) and Raman *et al.* (1990).

Effect of cotton hybrids

Dhroov Bt recorded the highest net monetary returns than rest of the cotton hybrids during both the seasons of experimentation and when data were pooled for two years. Similarly, the Kashinath Bt was found to be the lowest in respect of net monetary returns. However, Dhroov non Bt was found to be at par with Nathbaba non Bt during second year of investigation, whereas during first year and in pooled mean Dhroov non Bt was significantly superior over Nathbaba non Bt.

Further, it was noticed that Dhroov Bt was found significantly superior over its non Bt version during the period of investigation and in pooled mean (Anonymous, 2004). The results were confirmed with the findings of Singh *et al.* (2003), Nehra *et al.* (2004) and Garg *et al.* (2004).

Effect of interaction

The interaction effects between different factors under study were found to be non significant during both the years of investigation and on pooling.

4.8.4 Benefit : cost ratio

The data pertaining to benefit : cost ratio are presented in Table 56. It could be seen from table that the benefit: cost ratio was 1.87, 2.44 and 2.15 during 2007, 2008 and pooled mean, respectively.

Effect of irrigation levels

The benefit : cost ratio due to irrigation applied at 75 mm CPE was significantly the highest than those observed in rest of the irrigation treatments during both the years and when data were pooled. Significantly the lowest benefit : cost ratio was recorded with 100 mm CPE irrigation during both the years of experimentation. However, it was found to be on par with 50 mm CPE irrigation schedule, when two years data were pooled.

The highest benefit : cost ratio under 75 mm CPE irrigation might be due to adequate availability of moisture throughout the growth period boosted the seed cotton yield, ultimately increased the monetary returns which could be converted it into higher benefit : cost ratio. Singh (2002[a]) reported the higher benefit : cost ratio (2.44) when sugarcane ratoon was irrigated at 0.9 IW/CPE ratio as compared to 0.6 and 1.2 IW/CPE ratios.

These results show that, it is advisable to schedule irrigation to cotton at 75 mm CPE throughout the crop growth period to obtain maximum benefit : cost ratio.

Effect of water saving practices

There was no significant influence of either of the water saving practices on benefit : cost ratio during both the years of investigation and when the data were pooled for two years.

Alternate furrow irrigation techniques was useful in maintaining the higher moisture regime as in every furrow, which reflected in higher values of yield attributes and finally seed cotton yield and ultimately monetary returns and benefit : cost ratio (Ghadge, 2003).

Effect of cotton hybrids

Dhroov Bt recorded significantly higher benefit : cost ratio. However, Kashinath Bt recorded significantly the lowest benefit : cost ratio over rest of the cotton hybrids. This might be due to maximum gross monetary returns under Dhroov Bt and minimum under Kashinath Bt. The Dhroov non Bt was second in order of sequence followed by Nathbaba non Bt.

Further, it was noticed that Dhroov Bt was significantly superior over its non Bt in respect of benefit : cost ratio. This might be due to higher yield, higher gross monetary returns and less cost of cultivation. These results corroborate with the findings of Reddy *et al.* (2005). Singh *et al.* (2007) and Deosarkar *et al.* (2008).

Effect of interaction

The interaction effects between different factors under study were found to be non significant in respect of the benefit : cost ratio during both the years of investigation and in pooled data.

5. Summary and Conclusions

The field investigation on "Effect of irrigation levels and water saving practices on Bt and non Bt cotton (*Gossypium* spp.) hybrids with special reference to parawilt" was carried out during 2007 and 2008 at AICRP on Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra).

The soil of experimental field was vertisol, clayey in texture, low in available nitrogen (216.38 kg ha^{-1}), medium in available phosphorus (22.8 kg ha^{-1}) and very high in available potassium content (330 kg ha^{-1}) with alkaline in reaction (pH 8.3). The experiment was laid out in split plot design with 24 treatment combinations comprising three irrigation levels on cumulative pan evaporation basis with constant depth of irrigation and two water saving practices were allotted to the main plot and four cotton hybrids were assigned to sub plot replicated thrice.

Four cotton hybrids *viz.* Dhroov Bt, Dhroov non Bt, Kashinath Bt and Nathbaba non Bt were dibbled two seed per hill on the side of 90 cm ridges at a constant distance of 90 cm in between plants on 20 April and 16 April during 2007 and 2008, respectively. The recommended dose of fertilizer used was 10 ton FYM + 100 : 50 : 50 kg N, P_2O_5 and K_2O ha^{-1}, respectively. The full dose of P_2O_5 and K_2O was applied at the time of planting. The nitrogen was applied in three splits in proportion of 20 : 40 : 40 at planting, 30 DAP and 60 DAP. Fluchloralin 45 E.C. @ 850 ml ha^{-1} spray was taken to control the weeds and then presoaking irrigation was applied. All the recommended practices for cotton were followed uniformly except irrigation scheduling which were given as per treatments. Two common irrigations totaling 14.4 cm during both the seasons were given to ensure the better germination and uniform stand of crop. Irrigations were applied with constant depth of 7.2 cm.

In addition to yield data, periodic observations on plant growth in respect of height, number of monopodial, sympodial branches, number of squares, bolls, dry matter accumulation, number of functional leaves leaf area, leaf area index, AGR and RGR were recorded to evaluate the treatment effect. The post harvest observations on number of picked bolls plant^{-1}, seed cotton weight, seed weight and lint weight boll^{-1} were also recorded. The economics, nutrient balance and water economy with relative incidence of cotton *parawilt* were also considered to test the practical acceptability of the irrigation scheduling and water saving practices along with cotton hybrids. The important findings emerged from present investigation are summarised and conclusions drawn are given in this chapter.

5.1 Summary

5.1.1 Effect of irrigation levels

The irrigation scheduled at 75 mm CPE recorded significantly higher values of growth parameters *viz.,* plant height (during second year) and sympodial branches, number of squares, number of bolls, number of functional leaves, leaf area per plant, dry matter accumulation than rest of the irrigation schedules during both the years of investigation. While, plant height during first year and number of monopodial branches during both the years were significantly higher under 50 mm CPE irrigation than rest of the irrigation schedules.

Further, it was observed that the water stress imposed at early growing stages by scheduling irrigation at 100 mm CPE recorded significantly less values of these characters as compared to 50 mm and 75 mm CPE irrigation schedules. However, irrigation scheduled at 50 mm CPE recorded the lower values of these growth parameters as compared to 75 mm CPE irrigation schedule during both the seasons.

Similarly, leaf area index, AGR and RGR values were significantly more under normal irrigation (75 mm CPE). Increasing severity of water deficit (100 mm CPE)at crop growth period significantly decreased the LAI, AGR and RGR values during both the seasons.

Phenological growth stages were significantly curtailed under 100 mm CPE followed by 75 mm CPE irrigation levels than 50 mm

CPE, it required more number of days for first square formation, flowering, boll formation and physiological maturity.

The yield contributing characters such as number of picked bolls $plant^{-1}$, seed weight, number of seeds $boll^{-1}$ and seed cotton weight $plant^{-1}$ were significantly higher under normal irrigation schedule at 75 mm CPE than rest of the irrigation schedules.

The application of irrigation at 100 mm CPE decreased significantly the all yield contributing characters during both the years of experimentation as compared to other irrigation levels.

Irrigation scheduled at 75 mm CPE significantly increased seed cotton yield and stalk yield as compared to other irrigation schedules during both the years and pooled data. Seed cotton yield and stalk yield were significantly the lowest under 100 mm CPE irrigation schedule during both the seasons and pooled data due to moisture stress.

The quality parameters *viz.* ginning per cent, 2.5 % span length, elongation per cent, fibre strength, fibre fineness (micronaire value) and uniformity ratio were not affected significantly by irrigation schedules during both the seasons except fibre fineness and ginning percentage, during 2007 and 2008, respectively, where these quality parameters were significantly improved 75 and 50 mm CPE irrigation than 100 mm irrigation schedule.

The *parawilt* incidence was significantly the lowest under 75 mm CPE irrigation level at all the growth stages during both the years of investigation. However, it was significantly the highest under 50 mm and 100 mm CPE irrigation schedule during 2007 and 2008, respectively.

The profile water depleted, total consumptive use, consumptive use per day, total irrigation water applied was maximum under 50 mm CPE irrigation level and these were less under 100 mm CPE. These irrigation parameters were moderate under 75 mm CPE irrigation level. However, the water saving was 22.95 and 20.92 per cent under 75 mm CPE and it was 29.86 and 32.45 per cent under 100 mm CPE over 50 mm CPE irrigation level during 2007 and 2008, respectively but under 100 mm CPE irrigation schedule the yields were reduced during both the years.

The water use efficiency was higher under 75 mm CPE irrigation schedule than rest of the irrigation schedules, which was 3.44 and 4.17 kg $ha^{-1}mm^{-1}$ during 2007 and 2008, respectively.

The nitrogen, phosphorus and potassium balance after two years revealed that the application of irrigation at 75 mm CPE removed the higher amount of nutrients from the soil than rest of the irrigation levels. However, the application of water at 100 mm CPE was not sufficient for growth, therefore there was less nutrient uptake and removal from the soil.

The application of irrigation at 75 mm CPE significantly increased gross Rs. 64281, Rs. 92326 and Rs. 78305 ha^{-1}, net monetary returns Rs. 32620, Rs. 59261 and Rs. 45941 ha^{-1} and benefit cost ratio 2.03, 2.78 and 2.40, during 2007, 2008 and pooled mean, respectively as compared to application of irrigation at 50 and 100 mm CPE.

5.1.2 Effect of water saving practices

The growth attributes, *viz.* plant height, number of functional leaves, leaf area, leaf area index, AGR, RGR, monopodia, sympodia per plant, dry matter accumulation and phenological characters remained unaffected due to water saving practices. However, values are more under every furrow irrigation technique.

More or less the same trend was observed for yield attributing characters during both the years of investigation.

The seed cotton and stalk yields did not influence significantly either by every furrow or alternate furrow irrigation practices during the period of experimentation.

The quality parameters *viz.* ginning percentage, 2.5 % span length, fibre fineness, fibre strength, elongation per cent and uniformity ratio were not affected significantly due to either of the water saving practices during 2007 and 2008.

Statistically the *parawilt* incidence was not affected significantly either by alternate or every furrow irrigation during the course of investigation. However, numerically it was more under every furrow than alternate furrow during 2007 and 2008, respectively.

The profile water depletion, total consumptive use, consumptive use per day and total water applied were found to be more under every furrow irrigation practice than alternate furrow irrigation during both the years of experimentation. However, water saving was higher to the tune of 20.68 and 25.58 % during 2007 and 2008, respectively under alternate furrow irrigation as compared to every furrow irrigation without impairing the yield.

Water saving practices did not show considerable variation in residual soil fertility.

The water use efficiency was higher under alternate furrow than every furrow irrigation practice during both the seasons.

The water saving practices were not significantly influenced the gross, net monetary returns and benefit : cost ratio during both the years of experimentation. However, the economic parameters were found higher under every furrow irrigation practice.

5.1.3 Effect of cotton hybrids

Kashinath Bt recorded significantly more plant height, monopodial branches, number of functional leaves and dry matter production while, Dhroov Bt produced significantly more number of sympodial branches, number of squares and number of bolls plant^{-1} than Kashinath Bt, Dhroov non Bt as well as Nathbaba non Bt at all growth stages during both the years of investigation.

The growth functions *viz.* leaf area, leaf area index, AGR and RGR were found to be significantly higher under Kashinath Bt than rest of the cotton hybrids at all crop growth stages during both the seasons of experimentation. However, the lowest growth functions were observed under Dhroov Bt. Further, it was noticed that Dhroov non Bt and Nathbaba non Bt were significantly on par with each other in respect of leaf area plant^{-1} during both the seasons.

The phenological growth stages *viz.* days required to first square formation, flowering, boll formation and physiological maturity were significantly the lowest under Dhroov Bt. However, they were significantly highest under Kashinath Bt than other cotton hybrids. The Dhroov non Bt and Nathbaba non Bt were at par with these phenological characters expect days to physiological maturity which was significantly more under Nathbaba non Bt.

The yield attributes *viz.*, total number of bolls plant^{-1}, picked bolls plant^{-1}, seed cotton weight boll^{-1}, seed weight boll^{-1}, lint weight boll^{-1} and seed cotton weight plant^{-1} were significantly lower under Kashinath Bt. However, all yield attributing characters were significantly more under Dhroov Bt except seed cotton weight boll^{-1} and seed weight boll^{-1}. They were at par with Dhroov non Bt during the period of investigation.

The seed cotton yield q ha^{-1} was significantly higher under Dhroov Bt while stalk yield q ha^{-1} was significantly higher under Kashinath Bt than rest of the cotton hybrids. However, Dhroov non Bt and Nathbaba non Bt were found at par in respect of seed cotton yield and stalk yield during both the seasons except seed cotton yield during first year, it was significantly higher under Dhroov non Bt.

The quality parameters, such as 2.5 per cent span length, fibre strength and fibre fineness (Micronaire value) were found significantly superior under Kashinath Bt than rest of the cotton hybrids. However, elongation per cent, during both the years, ginning percentage and uniformity ratio during 2007 and 2008, respectively were found to be non significant with cotton hybrids.

Further, it was noticed that the ginning percentage was significantly higher in Dhroov Bt and significantly lower in Kashinath Bt during the year 2008.

The maximum water was depleted from soil profile by Kashinath Bt (43.96 and 56.49 cm) followed by Dhroov Bt (41.00 and 53.98 cm), than Dhroov non Bt (34.39 and 47.57 cm) and Nathbaba non Bt (32.40 and 47.94 cm) during 2007 and 2008, respectively. The total consumptive use and consumptive use per day was also more under former cotton hybrid during both the years of investigation. Dhroov non Bt and Nathbaba non Bt were depleted and consumed near about same quantity of soil moisture during the course. However, water use efficiency was found to be higher i.e. 3.75 and 4.03 kg ha^{-1} mm^{-1} during the year 2007 and 2008, respectively under Dhroov Bt and it was lowest under Kashinath Bt.

The *parawilt* incidence was not observed in Kashinath Bt, however, it was more under Dhroov Bt during both the years. The second highest was Dhroov non Bt in order of sequence followed by Nathbaba non Bt at all growth stages except 56 days onwards during 2008, which was at par with each other.

The genotypes of cotton exhibited the significant variation in the nutrient removal from soil and residual soil fertility. Kashinath Bt removed the higher amount of nutrients from soil resulted less residual soil fertility. It was closely followed by Dhroov Bt. However, Dhroov non Bt and Nathbaba non Bt did not show considerable variation in residual soil fertility at the end of the experiment.

The gross and net monetary returns and benefit : cost ratio were significantly the highest under Dhroov Bt and it was significantly the lowest under Kashinath Bt. Further, it was noticed that Dhroov non Bt was recorded significantly more gross and net monetary returns and benefit : cost ratio than Nathbaba non Bt during 2007, however, it was on par with Nathbaba non Bt in respect net and gross monetary returns during 2008.

Effect of interaction

The interaction between irrigation levels, water saving practices and cotton hybrids were not significant for all growth characters except plant height and dry matter at harvest during 2007, where irrigation applied at 50 mm CPE to Kashinath Bt recorded significantly more plant height than other interaction combinations. However, dry matter production plant^{-1}, was significantly higher when irrigation was applied at 75 mm CPE to Kashinath Bt than other treatment combinations.

The yield attributes were not significantly influenced due interaction between various treatments except number of picked bolls plant^{-1}, where, it was significantly more with Dhroov Bt and non Bt than Kashinath Bt and Nathbaba non Bt under both the water saving practices during 2007. Further, it was noticed that the number of picked bolls plant^{-1} was the highest with 75 mm CPE and significantly the lowest with 100 mm CPE irrigation level under both the water saving practices. The number of picked bolls plant^{-1} was not significantly affected by alternate furrow and every furrow irrigation under all the irrigation levels during 2007.

The interaction effect of treatment combinations were found to be non significant under seed cotton yield, except stalk yield during 2007 and when data were pooled for two years. The stalk yield was significantly the highest with 75 mm CPE irrigation and significantly the lowest under all the Bt and non Bt cotton hybrids. The mean stalk yield and pooled stalk yield was significantly the highest with Kashinath Bt and significantly the lowest with Dhroov Bt under all the irrigation levels.

Interactions between different treatments were found to be non significant for all the quality parameters during both the years of investigation.

The highest *parawilt* values were observed under 50 mm CPE and significantly the lowest under 100 mm CPE in Dhroov Bt at all the growth period except at 70 DAP during 2007. However, *parawilt* value was the highest with 50 mm CPE followed by 100 mm CPE irrigation in Dhroov Bt at 56 DAP during 2008.

The gross and net monetary returns and benefit : cost ratio were not significantly influenced by interaction effects between irrigation levels and cotton hybrids.

5.2 Conclusions

1. Application of irrigation at 75 mm CPE significantly improved the growth, yield attributes, seed cotton yield (29.56 q ha^{-1}), quality parameters, gross monetary (Rs. 78,305/- ha^{-1}), net monetary

returns(Rs. 45,941/- ha^{-1}) and benefit : cost ratio (2.40) than 50 mm and 100 mm CPE irrigation levels. .

2. The growth and yield components, seed cotton and stalk yields and quality parameters were not significantly influenced either by alternate furrow or every furrow irrigation.

3. Dhroov Bt significantly improved the yield attributes, seed cotton yield (31.46 q ha^{-1}), gross (Rs. 71,818/- ha^{-1}) and net monetary returns (Rs. 48,646/- ha^{-1}) and benefit : cost ratio (2.48) than Dhroov non Bt, Kashinath Bt and Nathbaba non Bt. However, the Kashinath Bt was found significantly superior in respect of quality parameters except ginning percentage, which was higher under Dhroov Bt.

4. The highest WUE was observed with 75 mm CPE (3.81 $kgha^{-1}mm^{-1}$) irrigation where as it was the lowest with 50 mm CPE (2.95 $kgha^{-1}mm^{-1}$). However, consumptive use and consumptive use day^{-1} was higher under 50 mm CPE. The alternate furrow irrigation recorded the highest WUE (3.47 $kgha^{-1}mm^{-1}$) and water saving (23.13 per cent) without any loss of yield over every furrow irrigation.

   Dhroov Bt exhibited higher WUE (3.89 $kgha^{-1}mm^{-1}$) as compared to Dhroov non Bt (3.76 $kgha^{-1}mm^{-1}$), Kashinath Bt (2.44 $kgha^{-1}mm^{-1}$) and Nathbaba non Bt (3.31 $Kgha^{-1}mm$).

5. The *parawilt* incidence was significantly lower with 75 mm CPE than 50 mm and 100 mm CPE during both the years. The *parawilt* incidence was not observed in Kashinath Bt during both the years of experimentation. However, Dhroov Bt was found susceptible to *parawilt* under water logging and water stress conditions.

Thus it can be concluded that the application of irrigation at 75 mm CPE with constant depth (7.2 cm) in alternate furrow to Dhroov Bt cotton is better practice to increase the seed cotton yield.

Water is the scare commodity, it should be used judiciously to Bt cotton which requires more water than non Bt. It is necessary to carryout more research on Bt cotton hybrids in relation to water, *parawilt* and environmental factors.

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*** Original not seen**

APPENDIX – I

Details of the prices used for calculation of economics

Sr. No.	Particulars	2007-08	2008-09
1.	Labour charge (Rs. head^{-1})	72.00	72.00
2.	Ploughing (Rs. ha^{-1})	1750.00	1750.00
3.	Discing (Rs. ha^{-1})	500.00	500.00
4.	Harrowing (Rs. ha^{-1})	500.00	500.00
5.	Opening of ridges and furrow	500.00	500.00
6.	Cost of seed material Rs. packet^{-1} (450 g)		
	i. Bt cotton hybrids	750.00	750.00
	ii. Non Bt cotton hybrids	350.00	350.00
7.	Cost of compost/fertilizers		
	i. Compost (ton^{-1})	620.00	625.00
	ii. Urea Rs. bag^{-1} (50 kg)	249.00	290.00
	iii. Single super phosphate Rs. bag^{-1} (50 kg)	196.00	210.00
	iv. Muriate of potash Rs. bag^{-1} (50 kg)	228.00	220.00
	v. DAP Rs. bag^{-1} (50 kg)	460.00	485.00
8.	Irrigation charges	250.00	250.00
9.	Cost of weedicide, insecticides and fungicides		
	i. Phorate 10 G. (Rs/kg)	65.00	65.00
	ii. Diamethoate 30 EC (Rs. lit^{-1})	260.00	260.00
	iii. Acefate 75 WP (Rs. kg^{-1})	610.00	610.00
	iv. Endosulfan 35 EC (Rs. lit^{-1})	255.00	260.00
	v. Metasystax (Rs. lit^{-1})	290.00	294.00
	vi. Cypermethrin 2.5 EC (Rs. lit^{-1})	555.00	560.00
	vii. Trizophos 40 EC (Rs. lit^{-1})	410.00	410.00
	viii. Confidor Rs. 250 ml^{-1}	560.00	560.00
	ix. Spindosad 45 EC (Rs. 250 ml^{-1})	2750.00	2750.00
	x. Blue copper (Rs. kg^{-1})	150.00	150.00
	xi. Sulphur 80 WP (Rs. kg^{-1})	162.00	165.00
	xii. Fluchloraline (Rs. lit^{-1})	300.00	325.00
10.	Market prices		
	i. Seed cotton (Rs. q^{-1})	2161.00	2650.00
	ii. Stalk (Rs. q^{-1})	50.00	50.00

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