EFFICACY OF BIOREGULANTS ON GROWTH AND PRODUCTIVITY IN TOMATO (*Lycopersicon esculentum* MILL.)

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"Efficacy of bioregulants on growth and productivity in tomato (*Lycopersicon esculentum* Mill.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
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CERTIFICATE

Certified that this thesis, entitled **"Efficacy of bioregulants on growth and productivity in tomato (*Lycopersicon esculentum* Mill.)"** is a record of research work done independently by **Miss.M. Srividhya** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Miss.M. Srividhya,** a candidate for the degree of **Master of Science in Horticulture** with major in **Olericulture,** agree that this thesis entitled **"Efficacy of bioregulants on growth and productivity in tomato (*Lycopersicon esculentum* Mill.)"** may be submitted by **Miss.M. Srividhya,** in partial fulfilment of the requirement for the degree.

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EXTERNAL EXAMINER

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M. SRIVIDHYA

Dedicated

to my

Achan, Amma & Sathu

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Vegetables are so common in human diet that a meal without a vegetable is supposed to be incomplete in most of the world. Vegetables play an important role in human diet as providers of wide range of nutrients that supply energy, promote growth and sustain the metabolic functions essential for life. Besides the nutritional value of vegetables, increased interest is being given to the functional and therapeutic benefits of vegetables to human health. Among vegetables, tomato (*Lycopersicon esculentum* Mill.) is the most important and remunerative crop in India. It is one among the protective foods, both because of its special nutritive value and also because of its widespread production. In India it is cultivated in about 3.5 lakh hectares with a production of 5.3 million tonnes. It is a rich source of minerals, vitamins and organic acids. Every 100 g of tomato fruit provide 0.6 g of minerals, 320 I.U. vitamin A, 31 mg vitamin C, 0.07 mg thiamine, 0.4 mg nicotinic acid, 23 mg calories, 20-25 mg lycopene, 3-4 per cent total sugars and 4-7 per cent total solids (Choudhury, 1998). Lycopene, an unsaturated carotenoid present within the fruit is important as a natural anti-oxidant which provides protection against broad range of epithelial cancers. Tomato based foods are important source of carotenoids in the human diet.

Keeping in view the increase in demand of vegetables for domestic consumption and enormous scope for export, the production has to be increased manifold and there is a possibility of increasing the productivity by using advanced technologies like the use of bioregulators. It has been widely demonstrated that minute concentrations of plant growth substances have the potential to regulate plant growth and development spanning from seed germination, plant growth, flowering, fruiting, seed formation, senescence and even to longevity of plants. There has been a great deal of interest in the plant growth substances ever since the discovery of auxins by Went in 1928. The discovery of gibberellins as a new class of plant hormones, the isolation and identification of zeatin (a cytokinin from maize), abscissic acid (ABA) and ethylene led to a remarkable development of these plant growth substances. Quite recently aliphatic alcohols, brassinosteroids, phenolics especially salicylates and jasmonates are being accepted as promising novel class of plant bioregulators.

Broadly bioregulators are classified into growth promoters and growth retardants. Purohit (1993) classified bioregulators into, Auxins (IAA, IBA, NAA, 2,4-D, etc.), Gibberellins (GA), Cytokinins (Kinetin, Zeatin), Ethylene (Ethrel), Dormins (Abscissic acid, Phaseic acid) and Synthetic growth retardants (CCC, AMO 1618).

The concept of hormonal regulation of plant growth dates back to nearly a century when Julius Sachs, a German botanist noticed from his experiments that special substances are responsible for the formation and growth of different organs. With this information the scientists discovered that the growth and behaviour of many plants could be controlled by applying small amount of organic chemicals, i.e., bioregulators to plant parts, which impart their effect by modifying plant growth and development through changes in endogenous levels of naturally occurring hormone. This manipulation of physiological effects of crop plants by the use of bioregulators has gained importance as one of the latest technologies to increase the yield of vegetables.

The bioregulator NAA as a foliar spray has been reported to increase the fruit set, fruit retention, fruit number and yield of tomato (Akhtar *et al.*, 1996 and Swaroop *et al.*, 2001). Para chloro phenoxy acetic acid (PCPA) has been reported to increase the fruit set under low or high temperature conditions. It has been reported to increase fruit set and early yield (El-Beltagy *et al.*, 1984), average fruit weight, early and total yield (Arora *et al.*, 1990a), improve fruit quality (Ozguven *et al.*, 1998a).

A synthetic growth retardant, CCC has been reported to regulate growth, induce drought resistance and produce early and high total yield (Ibrahim *et al.*, 1996 and Singh *et al.*, 2001). Seed soaking of 2,4-D has been found to improve TSS, seed yield, leaf 'N' content, number of fruits and yield of tomato (Singh and Singh, 1996 and Swaroop *et al.*, 1998). The effect of 2,4-D has been reported to be similar to that of PCPA.

Though much work has been done on the effect of bioregulators in tomato all over the world, those results are found at variance with different situations and crops. Under Kerala conditions the yield of tomato during summer is

very poor due to the high temperature, resulting in flower fall and reduced fruit set. Preliminary studies conducted in Kerala Agricultural University have shown that bioregulators can alter and influence the quality and yield of tomato. Hence the present study was undertaken with the following objectives.

- To identify an effective bioregulator for increasing the productivity under Kerala conditions
- To study the effect of the bioregulators on growth attributes, yield and quality in tomato
- To assess the influence of bioregulators in tomato during different seasons.

Review of Literature

2. REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular vegetables in the tropic and has attained worldwide importance because of its versatility in use in very many preparations. But production of tomatoes is limited because of unfavourable high temperature during flowering and fruit set. Flower formation is reduced drastically and flowers which are formed are often underdeveloped and fail to reach anthesis and set fruits when temperature exceeds 30°C. This may be due to the reduced levels of growth regulators and the exogenous application of growth regulators have been found beneficial in increasing the flower formation and fruit set in tomato. According to Wittwer (1983), "Tomato is without question the most responsive vegetable crop to plant growth regulators".

2.1 BIOREGULATORS

The genetic makeup, its environment and a number of internal factors like growth substances influence the growth and development of a plant. The growth substances alter the physiological activities of the plant and improve the physiological effects including photosynthetic ability of the plants and increase productivity of crops (Dashora and Jain, 1994;Singh and Arora, 1994).

The dynamic role of plant growth regulators in various physiological and biochemical processes of plant is well known, which enables a rapid change in the phenotype of the plants to achieve desirable results. Synthetic growth regulators produce their effects through changing the endogenous levels of naturally occurring plant hormones resulting in improvement of yield and qualities in desired direction and to the desired extent.

Broadly plant bioregulators are classified into growth promoters and growth retardants based on their effects. Though their actions are quite opposite, yet both the groups have profound effect on growth, yield and quality of vegetable crops (Pandita *et al.*, 1974; Milica *et al.*, 1983-84 and Gabr *et al.*, 1984).

Today, one of the most exciting research areas involves the bioregulation of plant composition. Such bioregulation is the process of controlling

specific metabolic pathways by externally applied synthetic chemicals and growth regulators. The available literature on the effect of different plant growth substances on growth, yield and quality of vegetable crops has been reviewed below.

2.2 STUDIES ON CROPS

2.2.1 Tomato

In an experiment conducted by Mishra and Pradhan (1972) it was observed that flowering in CCC treated tomato plants was 5-6 days earlier when compared to control.

Prasad and Prasad (1977) noticed that in tomato cv. Pusa Ruby, foliar spray of NAA 15 ppm at 20 DAT improved the fruit quality and TSS content.

It was observed by Joseph and Peter (1980) that 2,4-D 5 ppm spray reduced the leaf area in tomato plants.

Reddy and YaraGutaiah (1980) reported that GA and NAA at 200 ppm increased plant height and promoted average number of fruits per plant. They also observed that CCC and ethrel decreased growth.

Flower primordia formation was improved when the tomato seedlings were sprayed with NAA 25 and 50 ppm (Oenofeghara, 1981). IAA more than 125 ppm was found to be toxic.

Bokhari (1982) reported that CCC reduced the length of mainstem and the leaf area. 1000 ppm cycocel increased yield and effect was more accentuated when para chloro phenoxy acetic acid was added at the rate of 50 ppm.

The number of leaves in tomato plants was increased by the application of triacontanol at the rate of 20 ppm when sprayed 30 DAT. This was reported by Gunasekaran (1982).

Chaubey and Chaturvedi (1982) reported that protein content was increased to 4.99 g per 100 g of dry matter in tomato fruits when the seedling roots were treated with NAA 20 ppm one hour before transplanting.

Under moisture stress conditions, tomato seedlings sprayed with CCC produced less number of lateral branches. This was reported by Alagiapillai (1984).

El-Beltagy *et al.* (1984) reported that 4-CPA 25 ppm increased fruit set and early yield of tomato.

Abdallah *et al.* (1986) found that soil application of chloro ethyl phosphonic acid (CEPA) 250 ppm enhanced branching and fruit yield in tomato.

Corella *et al.* (1986) observed a decrease in fruit development period with the application of hydroxymethyl 2 chlor-4-phenoxyacetic acid sodium salt (auxin) at 0.25 per cent.

Bisaria and Rastogi (1988) reported that plants of cv. Pusa Ruby when sprayed with Kinetin 100 ppm resulted in increased plant growth, number of leaves per plant and leaf area. The treatment also increased the fruit yield, juice percentage, TSS, sugar, proteins and ascorbic acid.

Alar (daminozide), when sprayed at 1500 ppm concentration showed an increase in fruit weight and yield in tomato cultivar Chaubattia Red (Dimri *et al.*, 1988).

Mohan and Sinha (1988) reported that GA at 5 ppm increased dry matter, yield and plant ascorbic acid in tomato cultivar Pusa Ruby.

Singer *et al.* (1988) found that CCC 2000 ppm resulted in increased frost resistance in tomato seedlings.

Arora *et al.* (1989) observed that cycocel 500 ppm reduced plant height and the number of days to first fruit set and increased number of fruits and the yield. The treatment also reduced tomato leaf curl virus (TLCV) incidences in tomato var. HS-110.

An increase in plant height was observed when the tomato plants were sprayed with high Gibberellin concentration (50-100 ppm). This was reported by Kanahama *et al.* (1989).

Shukla and Prabhakar (1989) opined that mixtalol at 2-6 ppm gave highest yield (455.8 q ha^{-1}) compared to control (266.9 q ha^{-1}).

Arora *et al.* (1990a) reported that PCPA along with Mo at 25 ppm recorded the highest average fruit set, earliest ripening and the highest early and total yields in both summer and rainy seasons.

Severe fruit malformation on tomato cultivars with multilocular fruits was observed by Hosoki *et al.* (1990) when the plants were treated with TIBA or GA3.

Keithly *et al.* (1990) reported that DCPTA [2-(3,4-dichlorophenoxy) triethyl amine] 10 ppm increased dry weight of leaves, stems, roots and also the harvestable yield in tomato cv. Pixie. This treatment also increased TSS and lycopene content.

Seed treatment with NAA, GA, IAA at 30 ppm has been found to increase yield by 12, 8 and 6 per cent respectively when compared to control (Mozarkar *et al.*, 1991).

Phookan *et al.* (1991) reported an increased plant height upto 30 ppm NAA in tomato. He also observed that NAA 40 ppm as foliar spray, given at flowering stage increased TSS content (5.5°Brix) of fruits (control-4.2°Brix). He also reported that CCC at 1500 ppm resulted in high ascorbic acid content.

Lyngdon and Sanyal (1992) stated that highest percent of fruit set per plant, number of fruits per plant at harvest, fruit weight and yield per plant were obtained with 75 ppm NAA treatment.

El-Asdoudi and Ouf (1993) opined that in tomato the plants were taller when 3 foliar sprays of GA 50 ppm were given at 15 days interval.

The best fruit retention and yield in tomato cv. Pusa Early Dwarf was obtained with NAA (15 ppm and 25 ppm), given as seed presoak and a foliar spray at 30 DAT (Kar *et al.*, 1993).

Baruah *et al.* (1994) reported that 150 ppm PP-333 (Paclobutrazol) recorded maximum fruit set in tomato cv. Pusa Ruby.

Malfa *et al.* (1995) found that when flower clusters and whole plants of tomato cv. Vemar were sprayed with 6.5 ppm NOA (2-Naphthoxy Acetic Acid) + 65 ppm 4-CPA the yield was increased.

Sharma (1995) observed that in tomato cv. Solangola, foliar sprays of triacontanol 7.5 ppm applied at 4, 8 and 12 weeks after transplanting increased height of plants. The treatment also enhanced fruit and seed yield per ha.

Singh (1995) obtained early induction of flowering and an improvement of fruit set by foliar sprays of NAA 5-10 ppm.

Sharma and Tiwari (1995) inferred that 2,4-D as a whole plant spray at the rate of 5 ppm at 35, 40 and 60 DAT increased plant height, earliness and fruit yield but decreased leaf area and plant dry weight

Sanyal *et al.* (1995) concluded that plant growth regulators had profound effects on fruit length, weight and sugar:acid ratio after conducting an experiment to study the effect of PGRs (IAA/NAA/GA_3).

Akhtar *et al.* (1996) reported that NAA 25 ppm recorded highest yield and NAA 100 ppm recorded highest vitamin C in tomato.

Amer *et al.* (1996) observed that ABA (5 ppm) treatments significantly reduced shoot length, increased fruit yield per plant and mean fruit weight per plant, whereas GA3 (25 ppm) treatment increased shoot length and number of fruits per plant, but decreased mean fruit weight and fruit yield per plant.

Ibrahim *et al.* (1996) conducted an experiment to study the response of tomato cv. Roma to CCC (2000 ppm) and inferred that CCC application increased number of fruits per plant and total yield. The treatment was also found to decrease the number of days to flowering and plant height.

Kim and Jeong (1996) observed that fruit puffiness was reduced by single application of 4-CPA or CPPU (Forchlorofenuron) at a concentration of 20 ppm.

Singh and Singh (1996) noticed that 2,4-D at 5 ppm applied as seed soak for 24 hours increased TSS, seed yield and leaf 'N' contents whereas whole plant sprays at 20, 30 and 40 DAT increased fruit acidity and ascorbic acid content.

Singh and Singh (1997-98) also opined that seed soaking with 5 ppm of the 2,4-D gave rise to the highest yields and profitability of tomato cultivation.

An increase in plant height was observed by Tomar and Ramgiry (1997) when seedlings of tomato cultivars Sweet-72, SK-1 and Co-3 were transplanted to the field after soaking their roots in GA3 50 ppm solution for 30 minutes. This treatment also increased number of branches per plant and number of fruits per plant.

Yang *et al.* (1997) studied the effect of foliar application or root application of Taiwan Mides Phatamin (unspecified plant growth regulator) and inferred that the growth regulator increased the yield by 4.2-17.2 per cent and also improved the tomato fruit quality.

Ozguven *et al.* (1998a) reported that 60 ppm of 4-CPA when applied twice recorded the highest yield per plant and best quality fruit in tomato cv. F-144.

Ozguven *et al.* (1998b) found that 30 ppm of 4-CPA recorded the highest yield per plant (3445) in tomato cultivar Galit, under protected cultivation.

Swaroop *et al.* (1998) observed that 2 ppm 2,4-D increased the yield by increasing the number of fruits per plant.

El-Habbasha *et al.* (1999) noticed that GA3, IAA and 4-CPA increased fruit set percentage and total fruit yield in tomato plants.

Kalpana and Saroja (1999) observed that paclobutrazol reduced the plant height in tomato cv. PKM-1. The treatment also increased total and reducing sugar content of the fruits.

Mao *et al.* (1999) reported that Pix (mepiquat) increased the content of chlorophyll and soluble sugars in leaves of tomato plants. The beneficial concentration of mepiquat ranged from 50-150 µg/g.

Growth regulators, IBA and NAA (500 ppm) treated tomato cuttings showed increased number of branches, fruit number and therefore yield (Singh, 1999).

Souza-Machoda *et al.* (1999) found that paclobutrazol 50 ppm as seed priming induced earliness upto 7 to 10 days when compared to control.

Shepherd and Singh (1999) observed that cycocel at 3000 ppm recorded the lowest height, highest spread, number of branches, leaves and increased the yield.

Al-Sahhaf (2000) reported that agriton (mixture of auxins) increased fruit set by 8-10 per cent over control on four tomato cultivars.

Muralidharan *et al.* (2000) reported that foliar sprays of different growth stimulants influenced yield and quality parameters of PKM-1 tomato.

Gupta *et al.* (2001) noticed that NAA 75 ppm + Humaur (micronutrient) recorded maximum TSS content while maximum lycopene content and carotenoid contents were recorded with NAA 75 ppm + Multiplex (micronutrient).

Plant bioregulators, CCC and NAA have been found to improve growth and yield of tomato variety HS-101 under rainfed conditions (Singh *et al.*, 2001).

Swaroop *et al.* (2001) opined that alpha-naphthalene acetic acid increased number of fruits per plant, fruit yield and vitamin-C content in tomato cultivars LE-3704, CC-all-00-36, PPI and Acc.No.340.

Wang *et al.* (2001) conducted an experiment in which *Lycopersicon esculentum* var. *cerasiforme* was treated with 4 plant dwarfing agents (CB 9, PP 333, Pix and CCC) and inferred that all dwarfing agents reduced plant height up to 20-30 cm over control plants.

Gupta *et al.* (2002) reported that 75 ppm NAA along with multiplex, a micronutrient recorded greatest fruit size and yield in tomato.

Rai *et al.* (2002) noticed that IAA at 75 ppm along with multiplex at 2500 ppm (a micronutrient) recorded highest plant height and yield where as NAA at 75 ppm + Multiplex at 2500 ppm gave highest sugar content.

2.2.2 Other Solanaceous crops

Good reduction in flower drop was obtained by Patil and Ballal (1980) in *Capsicum annuum* cv. NP-46-A whose seeds were treated with IAA 40 ppm followed by two subsequent foliar sprays, one at the beginning of flowering and then 20 days after flowering.

Hariharan and Unnikrishnan (1983) opined that by soaking the seeds of *Capsicum annuum* L. in NAA 50 ppm for 4-5 days, the plants reached flowering earlier than untreated control.

Mahmoud (1983a) found that CCC at the rate of 1250 ppm with 5 sprays recorded highest vegetative growth i.e., increased number of leaves, branches, stem thickness and dry weight. Yield was also increased by 122 per cent over control. The treatment also increased fruit weight, TSS and protein but reduced acidity in chilli.

In an experiment to study the effect of some growth substances in sweet pepper it was observed by Mahmoud (1983b) that seedling root immersed in a solution of cycocel at 1000 (or) 2000 ppm resulted in significant increase in germination percentage. The study also showed that seed soaking and seedling root immersion in ethrel at 400 ppm increased germination percentage.

In a field investigation conducted at Ludhiana by Sekhon and Singh (1985) in potato, it was found that foliar application of 2-chloroethyl trimethyl ammonium chloride (CCC) at 300, 600 and 900 ml ha^{-1} decreased height and CCC at 600 ml ha^{-1} increased total yield.

Umajyothy and Shanmugavelu (1985) reported that in brinjal, two sprays of triacontanol 1 ppm, 2,4-D 10 ppm plus boron 2 ppm applied once at 15 DAT and then at the time of flowering resulted in high protein content.

Maurya and Lal (1987) treated roots of seven weeks old chilli seedlings in aqueous solution of GA 150 ppm and transplanted. The plants showed maximum plant height whereas the seedlings dipped in NAA 50 ppm recorded minimum plant height.

Yanger and Desai (1987) observed that foliar application of NAA at 20 ppm increased flower production in chilli.

Ali (1988) found that pre-planting treatments with mixtalol increased number of leaves, leaf area, LAI, LAD, NAR, height of plants, number of main stems per plant, fresh and dry weight of haulms and roots in potato.

Lou and Kato (1988) noticed a decrease in stem to root ratio on the eggplants grown in pots after a foliar spray of GA 20 ppm.

Usha and Peter (1988) reported that NAA at 15 ppm reduced flower drop in chilli cv. KAU cluster.

Alam and Islam (1989) studied the effect of NAA, IBA, cycocel and 2,4-D on growth, yield and chemical composition of potato under Bangladesh condition and observed that IBA increased shoot extension, weight of haulms, total sugar and starch content.

Arora *et al.* (1989) observed that vipul 10 ppm increased the number of branches in chilli cultivar NP 46-A.

Dod *et al.* (1989) found that fruit yield was significantly increased in capsicum by 2,4,5-T 50 ppm and NAA 100 ppm. The treatments also significantly increased plant height, number of branches, stem diameter and leaf area.

Doddamani and Panchal (1989) studied the effects of growth regulators on growth and yield components of chillies and found that highest plant height, fruit set, fruit yield, number of fruits per plant, fruit length and fruit thickness were obtained with NAA treatment (10 ppm).

Maharana *et al.* (1990) reported that tuber yield was highest with GA (50 ppm) followed by 10 ppm 2,4-D in potato-tomato graft (Pusa Ruby grafted on Kufri Chandramukhi).

Rajamani *et al.* (1990) concluded that triacontanol at 1.25 ppm given at 20, 40, 60 and 80 DAT would enhance the yield of chilli.

In irrigated field trials conducted by Rao *et al.* (1990) chilli cultivars G4 and LCA-235 were given foliar sprays of NAA 20 ppm at flower initiation and at peak flowering stages. In this the number of flower buds shed decreased from 422 m^{-2} in control to 288 m^{-2} in NAA treated plants.

Doddamani and Panchal (1991) reported that maximum height was obtained when cytozyme (contains hydrolysed protein complex, auxins and cytokinins and activated micronutrients in biological media) was sprayed at 35 and 70 DAT in chilli. This treatment also recorded highest fruit set.

Ramanandan *et al.* (1991) found that triacontanol (5 ppm) alone or with 80 kg K_2O ha^{-1} resulted in higher number of long styled flowers, highest percent fruit set in long and medium styled flowers and the highest yield in brinjal.

Lyngdon and Sanyal (1992) reported that 75 ppm NAA recorded highest number of fruits per plant, fruit weight and yield per plant. GA3, kinetin and ethrel treatments also improved fruit set, retention and yield in chilli.

Sharma *et al.* (1992) observed significant increase in yield with whole plant sprays of 50 ppm NAA or seed treatment with 10 ppm GA3 in brinjal cv. Pusa Purple Long. Plants sprayed with 300 ppm GA3 flowered earlier and recorded the highest number of fruits and yield per plant.

Singh *et al.* (1992) noticed that yield of red ripe fruits of hot chillies can be increased with the application of Ethrel (500 ppm).

Desai *et al.* (1993) inferred that fruit yield and capsaicin yield of chilli crop can be enhanced by the foliar sprays of plants with GA (10 ppm) and CCC (200 ppm).

El-Asdoudi (1993a) studied the effect of gibberellin on flowering and fruiting in *Capsicum annuum* cv. California Wonder plants and found that the maximum fruit set of 61.2 to 63.3 per cent was observed in plants sprayed with GA3 15 ppm.

El-Asdoudi (1993b) observed a marked reduction in sucrose content in the fruits, which were given foliar spray of GA3 at 15 and 30 ppm concentration.

Krishnamohan *et al.* (1993) obtained a Leaf Area Index (LAI) value of 0.36 at 45 DAT in chilli sprayed with IAA 25 ppm at flowering.

Singh *et al.* (1993) reported that in chilli cultivars Pant C-1, Pusa Jwala and NP-46-A, foliar sprays of 40 ppm NAA applied during 40 and 60 DAT improved the plant height and also resulted in maximum percentage of fruit set. The treatment also resulted in greater increase in leaf area.

El-Asdoudi and Ouf (1994) showed that GA at a concentration of 10 ppm decreased the number of days to first sprouting in potato.

Singh and Lal (1994) observed that 1 ppm 2,4-D increased fruit yield by 52.5 per cent over control.

Singh and Lal (1995) noticed a good fruit set in chilli cv. Patnagar with NAA 20 ppm given as foliar spray.

Belakbir *et al.* (1996) found a decrease in soluble carbohydrate concentration and an increase in concentration of glucose, fructose and sucrose in pepper fruits when foliar sprays of GA3 were given at flowering stage and further at 30 and 60 days after flowering.

In studies with potatoes, onions, okras and garlic, mepiquat chloride at 150 ppm resulted in highest yields in potatoes (Gasti *et al.*, 1997).

Belakbir *et al.* (1998) reported that in chillies, GA3 sprays given during flower initiation stage followed by successive applications at 30 days interval increased the soluble solid content in fruits.

Application of IAA to the potato stolons as lanolin paste was found to enhance the photosynthetic rate. This was reported by Puzina *et al.* (1998).

In an experiment to study the influence of growth regulators (5 or 10 ppm cytokinin or 10 or 20 ppm NAA) on fruit length or volume in green chilli cultivars, it was observed by Revanappa *et al.* (1998a) that growth regulators had no significant effect on these characters.

Revanappa *et al.* (1998b) and Revanappa and Nalawadi (1998) observed that 20 ppm NAA produced highest yield in chilli cv. Nagavi and also recorded the highest growth parameters.

Barai and Sarkar (1999) found that IAA, NAA and GA3 showed encouraging effects on the retention of flower, fruit setting and increase of fruit weight in chilli cultivars.

Sharma *et al.* (1999) studied the effect of NAA 10 ppm on bell pepper and inferred that NAA (2 sprays) reduced flower drop, improved fruit set and fruit size.

Thakur *et al.* (1999) reported that growth regulator treatment at 10 per cent methanol, 5 ppm paclobutrazol or 5 ppm mixtalol (triacontanol) enhanced yield potential and fruit quality in bell pepper. Mixtalol gave the highest fruit yield.

Bama *et al.* (2000) studied the effect of mepiquat chloride on total dry matter production, yield and nutrient uptake in potato and concluded that mepiquat chloride increased DMP, improved nutrient uptake and yield when sprayed at a concentration of 1250 ml ha^{-1}.

Singh and Mukherjee (2000) reported that NAA 75 ppm recorded highest yield in chilli cv. RCH-1. The treatment increased percentage fruit set, fruit weight, dry yield and yield per ha and also reduced fruit drop.

Thakur *et al.* (2000) noticed that plant growth regulators like paclobutrazol and triacontanol (20 ppm I spray and 50 ppm II spray) effectively regulated the vital physiological and biochemical processes which enabled the chilli plants to cope with water stress condition.

Deka and Borgohain (2001) reported that there was no significant effect on growth and yield in potato with the use of growth retarding chemicals like ethrel, CCC or MH. But as for as suppression of sprouting is considered MH at 2500 ppm was found to be most effective followed by CCC.

In an experiment to study the influence of GA and IAA on growth, yield and fruit qualities in brinjal, it was inferred by Sorte *et al.* (2001) that 200 ppm GA showed maximum plant growth in respect of height, branches, spread and more fruits per plant.

Muralidharan *et al.* (2002) observed that foliar spray of 0.1 per cent vipul EC at 300 ml ha^{-1} at 25, 45 and 65 DAT maximized the dry pod yield of chillies, improved quality attributes (capsaicin, TSS and ascorbic acid content) and enhanced the uptake of major nutrients.

Patel *et al.* (2002a) reported that 10 ppm NAA spray at flower initiation stage proved quite effective in increasing plant height and plant spread in chilli cv. California Wonder. NAA at 10 ppm treatment resulted in highest yield.

2.2.3 Other crops

In an experiment conducted by Suryanarayana and Rao (1981) it was observed that CCC reduced number of fruits per plant in okra.

Singh and Kumar (1988) opined that 150 mg l^{-1} ethrel gave early harvest in okra followed by 75 mg l^{-1} NAA. 2,4-D was found to be ineffective.

El-Abd *et al.* (1989) reported that plants treated with different levels of PGRs (IAA, NAA, kinetin and GA3) generally showed a significant increase in their growth and yield characters in broad bean.

Arora *et al.* (1990b) observed that NAA at 25 ppm as seed and foliar treatment stimulated plant growth, whereas CCC at 1000 ppm as seed and foliar treatment increased the number of shoots and leaves per plant. They also observed that cycocel at 50 ppm as foliar spray alone gave the earliest flowering.

Kandagal *et al.* (1990) reported that growth regulators viz., TIBA and NAA each at 50 ppm increased number of pods per plant, seed yield per plant and number of seeds per pod in mungbean.

In an experiment to study the growth and fruiting pattern of bhindi cv. Clemson Spineless as affected by Alar and Ethephon, it was inferred by Marsh *et al.* (1990) that both growth regulators depressed shoot growth and leaf production. Total fruit yield was not significantly affected by the treatments.

Rathore *et al.* (1990) reported that CCC 2000 ppm increased germination and seed yield in cluster bean cv. Pusa Sadabahar.

Subbiah *et al.* (1990) observed that planofix at 40 ppm as foliar application twice, first at flower initiation and second 15 days thereafter increased grain yield of cowpea cv. Co-3.

Bisen *et al.* (1991) found that planofix at a concentration of 50 ppm applied as seed soak for 24 hours recorded the greatest plant growth and highest green pod yield in garden pea cv. G.C. 322.

Pandita *et al.* (1991) noticed that vipul at 1.25 ppm when sprayed twice recorded highest plant height. This treatment also recorded maximum number of fruits in okra.

It was found that CCC at 1000 ppm as foliar spray resulted in highest pod number, pod weight and yield in okra (Patel and Singh, 1991).

Saha and Gupta (1998) reported that plant growth retardants viz., triazoles and CCC when applied as soil drench improved growth, photosynthetic activity and yield of mungbean under salinity.

Singh and Kumar (1998) observed that GA3 at 45 ppm increased plant height by 8.97 per cent, advanced flowering by 3.33 days and increased pod yield by 30 per cent in okra cv. Pusa Sawani.

Singh *et al.* (1999a) found that foliar spray of growth regulators like GA and NAA improved vegetative growth, fruit character and ultimate seed yield per plant in okra.

Singh *et al.* (1999b) noticed that 150 ppm GA3 and 20 ppm NAA applied by seed soaking increased seed yield by 64.4 and 55.9 per cent respectively, in okra cv. Pusa Sawani. 150 ppm GA3 recorded highest seed weight per pod and seed yield per hectare.

Foliar spray of paclobutrazol resulted in increased yield of 12 per cent over control in pigeon pea (Sontakey *et al.*, 1999).

Tagade *et al.* (1999) opined that 100 ppm IAA and 25 ppm kinetin were found to be most effective in increasing growth and seed yield of soybean.

Reddy *et al.* (2000) observed that foliar application of NAA 20 ppm along with KNO_3 0.5 per cent significantly increased dry matter production, seed yield and harvest index compared to control in pigeon pea. The treatment also increased the number of pods per plants.

Rao and Varadarajan (2001) found that seed treatment of black gram with etheral under moisture stress conditions improved germination, total dry weight and LAI.

Patel *et al.* (2002b) reported that CCC produced short statured plants of okra with thicker stem and more number of nodes, leaves and branches. In contrast GA3 produced elongated plants with thin stem with less number of nodes, branches and leaves. An early flowering was observed in the treated plants.

A field experiment conducted with five levels of phosphorus sources and three levels of cycocel revealed that CCC spray reduced plant height, increased number of branches per plant, nodules per plant and other yield attributing parameters in green gram (Garai and Datta, 2003)

In an experiment carried out by Senthil *et al.* 2003 to see the response of foliar spray of bioregulators (Brassinosteriod, Salicylic acid, NAA, IAA and Kinetin) on physiological parameters it was observed that all the treatments significantly increased chlorophyll, soluble proein content and peroxidase activity over the control. Among the treatments salicylic acid 60 ppm was found to be more effective.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2002-2003 with the objective to study the effect of different bioregulators in influencing the growth, yield attributes, yield and quality in tomato.

3.1 MATERIALS

The field experiments were laid out in the research farm of Department of Olericulture, located at an altitude of 22.25 m above MSL at 10° 32'N latitude and 76° 16' E longitude. This region enjoys a warm humid tropical climate. The site has a well drained laterite loam soil. Data on maximum and minimum temperature, rainfall and relative humidity during the entire cropping period were collected from Meteorological Observatory of college of Horticulture, Vellanikkara and are presented in weekly averages and weekly totals (Appendix Ia and Appendix Ib)

3.1.1 Seasons of Experimentation

The crop was raised during two cropping seasons viz., Rabi and Summer.

Table.1 Periods of cropping during experimentation

S.No.	Cropping season	Cropping period
1	Rabi	Aug. 2002-Dec.2002
2	Summer	Jan. 2003-July 2003

3.1.2 Variety

The bacterial wilt resistant variety, Sakthi, developed by Kerala Agricultural University was selected for the study (Plate 1).

3.1.3 Bioregulants

Four bioregulants viz., Para chloro phenoxy acetic acid (PCPA), Naphthalene acetic acid (NAA), Cycocel (CCC) and 2,4-dichlorophenoxy acetic

acid (2,4-D) were used at different concentrations, constituting different treatments.

The chemical name and formula of the various bioregulants used in the experiment are furnished in the table (Table 2).

3.2 METHODS

3.2.1 Layout and Experimental Design

The experiment was laid out in Randomised Block Design (RBD) with two replications. There were thirty plants in a plot with three rows of ten plants each. Spacing adopted was 60 x 60 cm. The layout of the experiment is given in Fig.1a and Fig. 1b.

The manurial and fertilizer doses were based on the POP recommendation (KAU, 2001) for tomato. As per this the FYM and NPK were applied at the rate of 20-25 tonnes and 75:40:25 kg $N:P_2O_5:K_2O$ ha^{-1} respectively.

3.2.2 Treatments

Four bioregulants each at three concentrations constituted different treatments (Table.3). The bioregulators were applied at three stages starting with 15, 30 and 45 days after transplanting (DAT).

Table.3 Treatments

Treatment	Bioregulants	Concentration (ppm)
T1	PCPA	25
T2	PCPA	50
T3	PCPA	75
T4	NAA	10
T5	NAA	20
T6	NAA	30
T7	CCC	25
T8	CCC	50
T9	CCC	75
T10	2,4-D	0.5
T11	2,4-D	1.0
T12	2,4-D	2.0
T13	Water Spray	-
T14	Control (No Spray)	-

Table 2. Chemical name and formula of the various bioregulants used in the experiment.

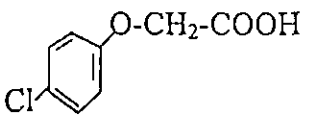
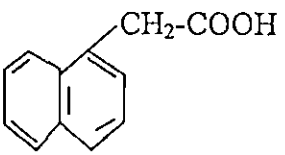
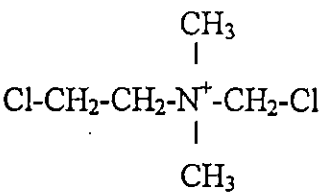
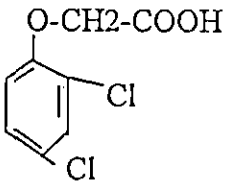
Common name	Chemical name	Chemical structure
PCPA	Para chloro phenoxy acetic acid	
NAA	Naphthalene acetic acid	
CCC	2-chloroethyl trimethyl ammonium chloride	
2,4-D	2,4-dichloro phenoxy acetic acid	

Fig 1a.Layout for rabi season

R_1T_7	R_1T_8	R_1T_1	R_1T_9	R_1T_{10}
R_1T_4	R_1T_3	R_1T_{13}	R_1T_5	R_1T_6
	R_1T_{12}	R_1T_2	R_1T_{11}	R_1T_4
R_1T_{11}	R_2T_7	R_2T_2	R_2T_{10}	R_2T_4
R_2T_3	R_2T_{12}	R_2T_9	R_2T_5	R_2T_1
	R_2T_{13}	R_2T_8	R_2T_6	R_2T_{14}

Fig. 1b. Layout for summer season

R_1T_{12}	R_1T_2	R_1T_6	R_1T_8	R_1T_4	R_1T_1	R_1T_3
R_1T_{11}	R_1T_9	R_1T_{14}	R_1T_{13}	R_1T_{10}	R_1T_5	R_1T_7
R_2T_5	R_2T_9	R_2T_6	R_2T_{13}	R_2T_7	R_2T_3	R_2T_{10}
R_2T_{11}	R_2T_8	R_2T_{14}	R_2T_{12}	R_2T_1	R_2T_4	R_2T_2

Plate 1. Sakthi

3.2.3 Application of Bioregulants

The spray solutions at desired concentrations were prepared considering the purity of the formulations. All the bioregulants used in the study were 99 per cent pure.

Water soluble bioregulant (CCC) was dissolved in distilled water and water insoluble bioregulants (PCPA, NAA and 2,4-D) were first dissolved in 70 per cent absolute alcohol (ethanol) and then mixed with required quantity of distilled water. Spraying was done using a hand sprayer.

3.3 FIELD EXPERIMENT

3.3.1 Nursery

Seeds were sown in raised beds. Sowing was done on 18th July, 2002 and 5th January, 2003 for Rabi and Summer season respectively.

3.3.2 Land Preparation and Planting

The experimental area was ploughed twice, weeds were removed and the land was levelled before layout. Ridges were taken at 60 cm apart and 30 days old seedlings were transplanted in furrows at a spacing of 60 cm.

3.3.3 After Cultivation

The crops were hand weeded regularly to keep the field free of weeds. Light earthing up was done along with top dressing of fertilisers. During summer irrigation was given at alternate days whereas during rabi need based irrigation was given. Staking was given.

3.3.4 Plant Protection

Plant protection chemicals were applied as and when required.

3.3.5 Harvesting

Fruits were harvested at turning stage.

3.4 BIOMETRICAL OBSERVATIONS

For taking observations ten plants per plot were tagged and the following observations were recorded.

3.4.1 Vegetative Characters

a. Plant height (cm)

Plant height at 60 DAT was recorded in ten plants per plot and the average was taken. Measurement was taken from the base of the stem to the growing tip of the plants.

b. Number of branches

Number of branches in ten plants per plot was counted at 60 DAT and the average was taken.

3.4.2 Growth Parameters

a. Relative Growth Rate (RGR)

Relative growth rate is the basic component of growth analysis and is calculated using the concept of compound interest law in growth proposed by Blackman (1919).

Relative growth rate was determined by measuring plant dry weight periodically during growth period and was represented as g g^{-1} day^{-1}. Total dry weight of three plants at 15,30 and 45 DAT was recorded in each treatment. (At a time three plants were taken from each plot). RGR was calculated using the formula given below.

$$RGR = \frac{ln\, W_2 - ln\, W_1}{t_2 - t_1}$$

W_1 and W_2 are plant dry weights at time t_1 and t_2 respectively. *ln* is the natural logarithm.

c. Net Assimilation Rate (NAR)

Net assimilation rate was determined by measuring plant dry weight and leaf area periodically during growth and was represented as g cm^{-2} day^{-1}. It

was calculated using the formula proposed by Gregory *et al.* (1917), which was modified by Williams (1946).

$$NAR = \frac{(W_2 - W_1)(ln\, A_2 - ln\, A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

W_1 and W_2 are plant dry weights at time t_1 and t_2 respectively. A_1 and A_2 are leaf area at times t_1 and t_2 respectively. *ln* is the natural logarithm.

d. Leaf Area Index (LAI)

Leaf area index was calculated by dividing the area of leaves with ground area over which it is growing (Watson, 1947).

$$LAI = \frac{A}{L}$$

A is total leaf area and L is the ground area.

e. Crop Growth Rate (CGR)

Crop growth rate was determined by measuring the plant dry weights of a particular ground at regular interval of time divided by land area. It is reported as g m^{-2} day^{-1}. It was calculated using the formula given below (Watson, 1958).

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

W_1 and W_2 are plant dry weights at times t_1 and t_2 respectively and P is the spacing (m^2).

f. Leaf Area Duration (LAD)

Leaf area duration is the measure of the persistence of the assimilatory surface. It was calculated by using the following formula (Watson, 1947) and represented as days.

$$LAD = \frac{(A_1 + A_2)(t_2 - t_1)}{2}$$

A_1 and A_2 are LAI at time t_1 and t_2 respectively.

3.4.3 Earliness

a. Days to first flower

The number of days taken from transplanting to opening of the first flower in each plot was recorded.

b. Days to first harvest

The number of days taken from transplanting to first harvest of the fruits in each plot was recorded.

3.4.4 Yield and yield attributes

a. Percentage of fruit set

Ten trusses were tagged randomly from each plot and percentage fruit set was worked out in both seasons.

$$\text{Percentage of fruit set} = \frac{\text{Number of fruits set}}{\text{Total number of flowers in a truss}} \times 100$$

b. Number of fruits per plant

Total number of fruits from ten plants per plot at each harvest was counted and their average was calculated to get the number of fruits per plant. This was then summed up to get number of fruits per plant.

c. Number of fruits per plot (7.2 m^2)

Number of fruits from each plot at each harvest was counted and added to get the total number of fruits per plot.

d. Average fruit weight (g)

Total weight of the fruits from ten plants per plot at second and third harvest was divided by the total number of fruits to get the average fruit weight.

e. Fruit volume (cm^3)

Volume of five average sized fruits per plot at second and third harvest was recorded using water displacement method by immersing them in one litre measuring jar. Their average was calculated to get the volume of fruit.

f. Fruit yield per plant (kg)

Weight of fruits from ten plants per plot was recorded after each harvest and the average was calculated from the total to get fruit yield per plant.

g. Fruit yield per plot (kg/7.2 m^2)

Weight of the fruits from each plot after each harvest was recorded and added to get the total yield per plot.

h. Percentage of cracked fruits

The number of cracked fruits in the total fruits was counted and expressed in percentage.

i. Number of seeds per fruit

Number of seeds from five fruits per plot was counted and their average was calculated to get the number of seeds per fruit.

j. Percentage of extrovert / introvert stigma

Number of flowers with introvert / extrovert stigma was counted from five trusses of five plants per plot and was expressed in percentage.

k. Locules per fruit

Locules per fruit were counted from the cross-sections of five fruits.

l. Malformations on plant and fruit

Counts were taken for vegetative and reproductive malformations.

3.4.5 Biochemical characters

a. Total soluble solids (TSS)

Total soluble solids was measured using a pocket refractometer and was expressed in degree brix.

b. Ascorbic acid content

Ascorbic acid content of fruits at turning stage was estimated by titration with 2,6-dichlorophenol indophenol dye (Sadasivam and Manickam, 1991). The value was expressed as mg per 100 g fruit.

3.5 OBSERVATIONS ON PEST AND DISEASES

Observations on the incidence of major pest and diseases viz., bacterial wilt, *Cercospora* leaf spot and spotted wilt were recorded.

The percentage of disease incidence was calculated using the following formula.

$$\text{Per cent of disease incidence} = \frac{\text{No. of plants affected by the disease}}{\text{Total no. of plants}} \times 100$$

3.6 STATISTICAL ANALYSIS

Data were analysed as per MSTATC package. To determine the influence of bioregulators on each character pooled analysis over seasons was also carried out.

3.7 ESTIMATION OF NET RETURNS DUE TO APPLICATION OF BIOREGULATORS

The yield data from different treatments was transformed to monetary values based on current market price of tomato (Rs.8/kg). Gross returns due to the application bioregulators was worked out separately for each treatment taking into consideration the cost of inputs and cost of application (Appendix II).

Results

4. RESULTS

The experiment was conducted during two seasons viz., Rabi and Summer. The data were analysed statistically. The results are presented in Tables 4 to 26. On statistical analysis of the data, the treatments showed significant variation for all the nineteen characters except for days to first flower and days to first harvest during rabi season and for locule number per fruit in the summer season. The details are presented below.

4.1 VEGETATIVE CHARACTERS

4.1.1 Height of the plant at 60 DAT

The character was found to vary significantly among treatments during both the seasons (Table 4).

During rabi, plants treated with T_5 produced taller plants with 57.15 cm followed by the treatment T_4 (54.20 cm). The shortest plant was obtained from the plot that received treatment T_9 that recorded a height of 38.65 cm. Control plants recorded a height of 47.80 cm (Fig. 2).

During summer season, the tallest plant was obtained from the plants under treatment T_4 with 43.15 cm and this was on par with T_5 (42.05 cm). It was followed by T_6 that recorded 41.10 cm. The shortest plant was obtained from the treatment T_9 with 36.00 cm and was on par with T_{10} (36.65 cm). Control plants recorded a height of 38.85 cm.

When the seasonal effect was studied it was observed that plants were taller during rabi season (46.14 cm) than summer (39.30 cm).

In general plants treated with NAA produced taller plants whereas those treated with CCC produced shorter plants. The pooled analysis of data showed that the treatment NAA 20 ppm recorded the maximum plant height of 48.10 cm and the plant height was minimum (37.33 cm) in T_9 (CCC 75 ppm)

Table 4. Height of the plant (cm) at 60 DAT as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	42.40 (-11.29)	38.25 (-1.54)	40.33
T_2 - PCPA 50 ppm	45.45 (-4.91)	40.65 (4.63)	43.05
T_3 - PCPA 75 ppm	47.55 (-0.52)	40.90 (5.27)	44.33
T_4 - NAA 10 ppm	54.20 (13.38)	43.15 (11.06)	46.53
T_5 - NAA 20 ppm	57.15 (19.56)	42.05 (8.23)	48.10
T_6 - NAA 30 ppm	49.30 (3.13)	41.10 (5.79)	45.10
T_7 - CCC 25 ppm	46.85 (-1.98)	38.55 (-0.77)	42.70
T_8 - CCC 50 ppm	44.90 (-6.07)	37.60 (-3.21)	41.25
T_9 - CCC 75 ppm	38.65 (-19.14)	36.00 (-7.33)	37.33
T_{10} - 2,4-D 0.5 ppm	43.05 (-9.93)	36.65 (-5.66)	39.85
T_{11} - 2,4-D 1.0 ppm	42.75 (-10.56)	38.25 (-1.54)	40.50
T_{12} - 2,4-D 2.0 ppm	42.20 (-11.71)	39.10 (0.64)	40.65
T_{13} - Water spray	43.70 (-8.57)	39.05 (0.51)	42.88
T_{14} - No spray (control)	47.80	38.85	45.48
Mean	46.14	39.30	
CD (0.05%)	1.21	1.32	9.63

Values in parentheses is the percentage increase/decrease over control.

4.1.2 Number of branches

The bioregulator treatments significantly influenced the number of branches and the treatments were found to vary significantly among themselves during both the seasons (Table 5).

The maximum number of branches was recorded for plants under treatment T_9 (7.90) in rabi, followed by T_7 (7.75) which was comparable with T_8. The lowest number of branches was recorded for the plants under treatment T_{12} (4.95). The treatments T_{10}, T_{13}, T_{11}, T_2 and T_{14} were on par with T_{12}. The number of branches recorded by control plants was 5.35 (Fig. 3).

The plants that were treated with T_9 recorded the highest number of branches (5.55) during summer. This was statistically on par with T_7 and T_8. The lowest number of branches was recorded by the treatment T_{11} (4.20). The treatments T_{12}, T_{13}, T_1, T_2, T_{14} and T_4 were comparable with T_{11}.

When the seasons were compared it was observed that more number of branches were recorded during rabi season (6.08) than summer (4.69).

In general, the plants treated with CCC recorded significantly higher number of branches whereas 2,4-D decreased the same during both the seasons. On pooled analysis of data it was observed that plants treated with CCC 75 ppm (T_9) produced more number of branches (6.73) while 2,4-D 2 ppm (T_{12}) recorded the minimum number of branches (4.60).

4.2 GROWTH PARAMETERS

4.2.1 Relative growth rate

Relative growth rate was calculated at 15-30 DAT and 30-45 DAT and the character varied significantly for the two stages among treatments during both seasons (Table 6).

During rabi, at 15-30 DAT, the treatments T_6, T_7, T_8 and T_9 recorded a higher RGR of 0.020 g g^{-1} day^{-1}. The treatments T_4 and T_5 were on par with the

Table 5. Number of branches at 60 DAT as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	5.80 (8.41)	4.30 (-3.37)	5.05
T_2 - PCPA 50 ppm	5.40 (0.93)	4.40 (-1.12)	4.90
T_3 - PCPA 75 ppm	5.45 (1.87)	4.75 (6.74)	5.10
T_4 - NAA 10 ppm	7.15 (33.64)	4.50 (1.12)	5.83
T_5 - NAA 20 ppm	6.75 (26.17)	4.80 (7.86)	5.78
T_6 - NAA 30 ppm	6.15 (14.95)	4.90 (10.11)	5.53
T_7 - CCC 25 ppm	7.75 (44.86)	5.25 (17.98)	6.50
T_8 - CCC 50 ppm	7.35 (37.38)	5.35 (20.22)	6.35
T_9 - CCC 75 ppm	7.90 (47.66)	5.55 (24.72)	6.73
T_{10} - 2,4-D 0.5 ppm	5.00 (-6.54)	4.75 (6.74)	4.88
T_{11} - 2,4-D 1.0 ppm	5.10 (-4.67)	4.20 (-5.62)	4.65
T_{12} - 2,4-D 2.0 ppm	4.95 (-7.48)	4.25 (-4.49)	4.60
T_{13} - Water spray	5.05 (-5.61)	4.25 (-4.49)	4.65
T_{14} - No spray (control)	5.35	4.45	4.90
Mean	6.08	4.69	
CD (0.05%)	0.47	0.36	1.58

Values in parentheses is the percentage increase/decrease over control.

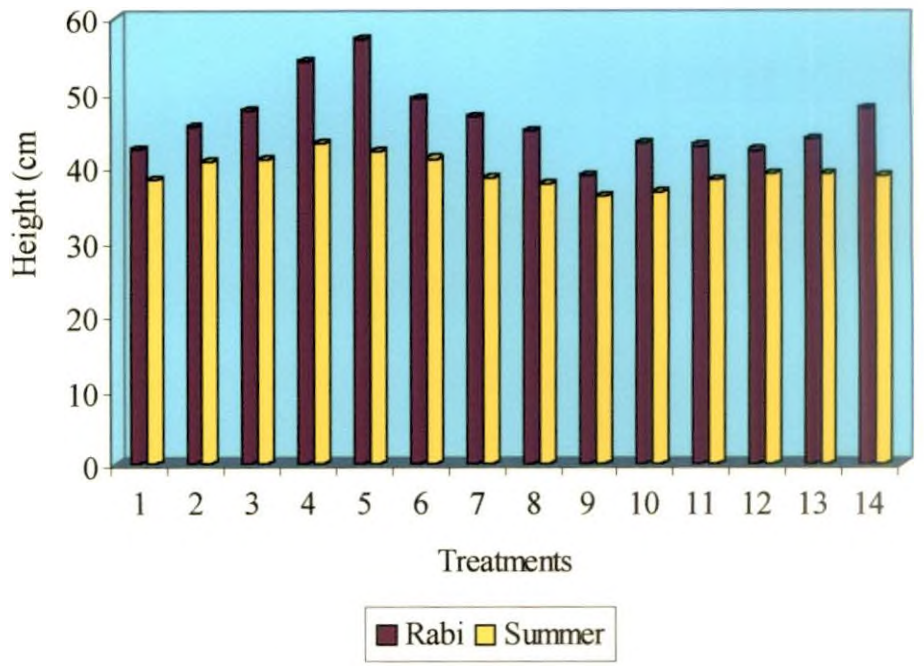


Fig. 2. Height of the plant as influenced by bioregulators

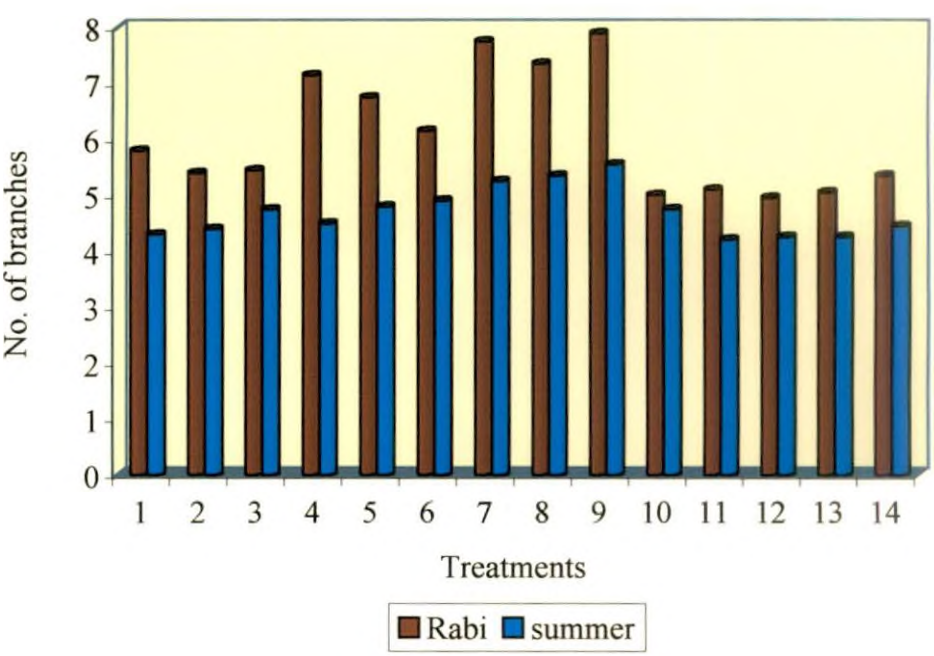


Fig. 3. Number of branches as infiuenced by bioregulators

above treatments with a RGR of 0.019 g g^{-1} day^{-1}. The treatment T_{12} recorded the lowest RGR (0.009 g g^{-1} day^{-1}). Control plants recorded 0.017 g g^{-1} day^{-1} (Fig. 4).

In the second stage, i.e., 30-45 DAT the treatments T_5, T_8 and T_9 recorded the highest RGR (0.026 g g^{-1} day^{-1}), which was on par with T_4, T_6 and T_7 (0.025 g g^{-1} day^{-1}). The treatment T_3 recorded the lowest RGR (0.018 g g^{-1} day^{-1}). Control plants recorded 0.023 g g^{-1} day^{-1}.

During summer, at 15-30 DAT, the plants under treatments T_8 recorded the highest RGR (0.023 g g^{-1} day^{-1}). The treatments T_4, T_5, T_7 and T_9 (0.022 g g^{-1} day^{-1}) were on par with T_8. The treatment T_1 recorded the lowest RGR of 0.009 g g^{-1} day^{-1}. Control plants recorded 0.015 g g^{-1} day^{-1} (Fig. 5).

In the second stage i.e., 30-45 DAT the treatments T_7 and T_8 recorded the highest RGR of 0.024 g g^{-1} day^{-1} while the plants under the treatment T_1 recorded the lowest RGR (0.012 g g^{-1} day^{-1}). Control recorded 0.017 g g^{-1} day^{-1}.

On studying the seasonal effect it was observed that rabi recorded a RGR of 0.017 and 0.023 g g^{-1} day^{-1} at 15-30 and 30-45 DAT respectively while summer recorded 0.018 and 0.020 g g^{-1} day^{-1} at 15-30 and 30-45 DAT respectively. Pooled analysis of data revealed that NAA, CCC and 2,4-D at lower concentration were effective in influencing the RGR during the first stage whereas the treatments did not influence the character during the second stage.

4.2.2 Net Assimilation Rate

Net assimilation rate was calculated at 15-30 DAT and 30-45 DAT and the character varied significantly for both the stages among treatments during both seasons (Table 7).

During rabi, at 15-30 DAT, the treatment T_9 recorded the highest NAR of 0.100 g g^{-1} day^{-1}. The treatment T_7 (0.093 g cm^{-2} day^{-1}) was on par with T_9 followed by the treatments T_8, T_5 and T_2. The treatment T_{12} recorded the lowest NAR (0.050 g cm^{-2} day^{-1}). Control recorded 0.070 g cm^{-2} day^{-1}.

Table 6. Relative growth rate (RGR g g^{-1} day^{-1}) as influenced by bioregulators

Treatments	Seasons				Mean	
	Rabi		Summer		15-30 DAT	30-45 DAT
	15-30 DAT	30-45 DAT	15-30 DAT	30-45 DAT		
T_1 - PCPA 25 ppm	0.016 (-5.88)	0.019 (-17.39)	0.009 (-40.00)	0.012 (-29.41)	0.01	0.02
T_2 - PCPA 50 ppm	0.016 (-5.88)	0.020 (-13.04)	0.012 (-20.00)	0.013 (-23.53)	0.01	0.02
T_3 - PCPA 75 ppm	0.014 (-17.64)	0.018 (-21.74)	0.013 (-13.33)	0.014 (-17.65)	0.01	0.02
T_4 - NAA 10 ppm	0.019 (11.76)	0.025 (8.69)	0.022 (46.67)	0.023 (35.29)	0.02	0.02
T_5 - NAA 20 ppm	0.019 (11.76)	0.026 (13.04)	0.022 (46.67)	0.023 (35.29)	0.02	0.02
T_6 - NAA 30 ppm	0.020 (17.64)	0.025 (8.69)	0.020 (33.33)	0.022 (29.41)	0.02	0.02
T_7 - CCC 25 ppm	0.020 (17.64)	0.025 (8.69)	0.022 (46.67)	0.024 (41.18)	0.02	0.02
T_8 - CCC 50 ppm	0.020 (17.64)	0.026 (13.04)	0.023 (53.33)	0.024 (41.18)	0.02	0.02
T_9 - CCC 75 ppm	0.020 (17.64)	0.026 (13.04)	0.022 (46.67)	0.023 (35.29)	0.02	0.03
T_{10} - 2,4-D 0.5 ppm	0.015 (-11.76)	0.020 (-13.04)	0.020 (33.33)	0.021 (23.53)	0.02	0.02
T_{11} - 2,4-D 1.0 ppm	0.010 (-41.18)	0.020 (-13.04)	0.019 (26.67)	0.020 (17.65)	0.01	0.02
T_{12} - 2,4-D 2.0 ppm	0.009 (-47.06)	0.020 (-13.04)	0.016 (6.67)	0.019 (11.76)	0.01	0.02
T_{13} - Water spray	0.016 (-5.88)	0.023 (0.00)	0.017 (13.33)	0.018 (5.88)	0.02	0.02
T_{14} - No spray (control)	0.017	0.023	0.015	0.017	0.02	0.02
Mean	0.017	0.023	0.018	0.020		
CD (0.05%)	0.0009	0.0012	0.0009	0.0003	0.0084	0.0037

Values in parentheses is the percentage increase/decrease over control.

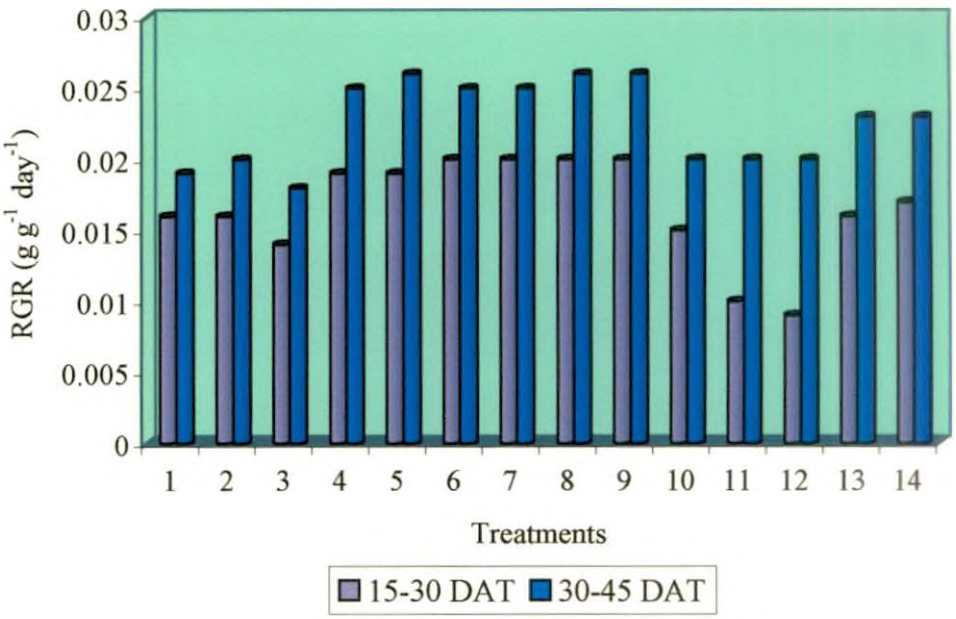


Fig. 4. RGR as influenced by bioregulators during Rabi

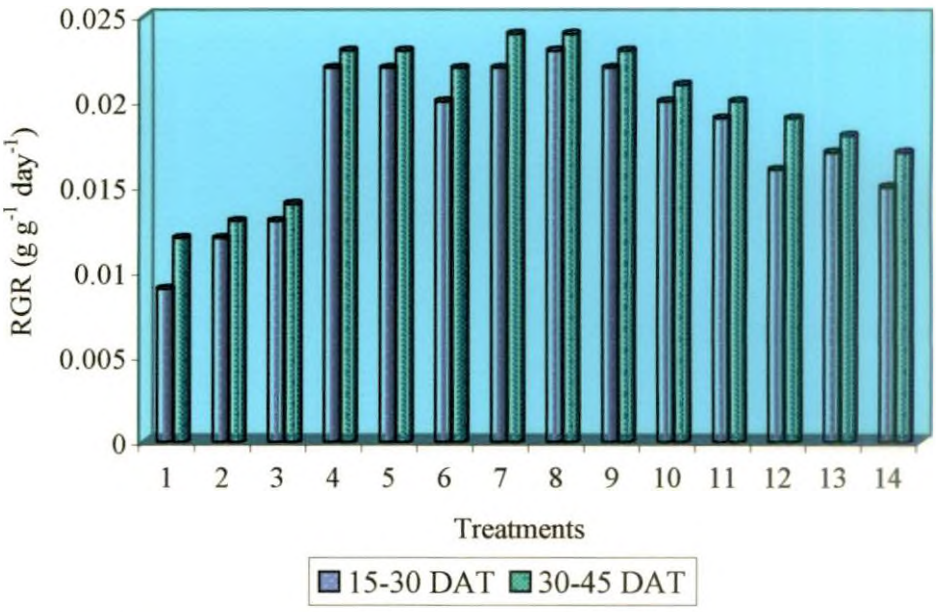


Fig. 5. RGR as influenced by bioregulators during Summer

At 30-45 DAT, the treatment T_9 recorded the highest NAR (0.138 g cm^{-2} day^{-1}) while T_1 recorded the lowest NAR (0.092 g cm^{-2} day^{-1}). Control recorded NAR of 0.100 g cm^{-2} day^{-1} (Fig. 6).

During summer, at 15-30 DAT, T_8 recorded the highest NAR of 0.084 g cm^{-2} day^{-1}, which was on par with the treatments T_4, T_5 and T_9. Lowest NAR was recorded by the treatment T_1 (0.036 g cm^{-2} day^{-1}). Control recorded NAR of 0.054 g cm^{-2} day^{-1}.

At 30-45 DAT the treatment T_4 recorded the highest NAR of 0.095 g cm^{-2} day^{-1}. The treatments T_8, T_5, T_7 and T_9 were on par with T_4.The lowest NAR was recorded by the treatment T_1 (0.042 g cm^{-2} day^{-1}). Control plants recorded 0.063 g cm^{-2} day^{-1} (Fig. 7).

On comparing both seasons rabi recorded 0.077 and 0.109 g cm^{-2} day^{-1} at 15-30 and 30-45 DAT respectively, while summer recorded 0.070 and 0.080 g cm^{-2} day^{-1} at 15-30 and 30-45 DAT respectively. Pooled analysis of data showed that the plants treated with CCC recorded a higher NAR in both the stages while PCPA 25 ppm recorded the minimum NAR during both the stages.

4.2.3 Leaf Area Index

Leaf area index was recorded at 3 stages viz., 15, 30 and 45 DAT and a significant difference was observed among treatments for all the three stages during both the seasons (Table 8).

In rabi, at 15 DAT, plants under treatment T_7 recorded a higher LAI of 3.84 which was on par with most of the treatments. The treatment T_{12} recorded the lowest LAI (3.51). Control plants recorded a LAI of 3.67 (Fig. 8).

In the second stage (30 DAT), the plants under treatment T_6 recorded a higher LAI (6.52), which was on par with T_4, T_5, T_8 and T_7. The treatment T_{12} recorded the lowest LAI of 4.58. Control plants recorded 6.20.

At 45 DAT, higher LAI was recorded from plants under treatment T_6 (9.11), on par with T_5 (8.82). Lower LAI was recorded for the treatment T_3 (5.17). Control recorded 7.37.

Table 7. Net assimilation rate (NAR g cm^{-2} day^{-1}) as influenced by bioregulators

Treatments	Seasons				Mean	
	Rabi		Summer		15-30 DAT	30-45 DAT
	15-30 DAT	30-45 DAT	15-30 DAT	15-30 DAT		
T_1 - PCPA 25 ppm	0.070 (0.00)	0.092 (-8.00)	0.036 (-33.33)	0.042 (-33.33)	0.05	0.07
T_2 - PCPA 50 ppm	0.083 (18.57)	0.115 (15.00)	0.050 (-7.40)	0.053 (-15.87)	0.07	0.08
T_3 - PCPA 75 ppm	0.076 (8.57)	0.110 (10.00)	0.057 (5.55)	0.063 (0.00)	0.07	0.09
T_4 - NAA 10 ppm	0.080 (14.28)	0.108 (8.00)	0.083 (53.70)	0.095 (50.79)	0.08	0.10
T_5 - NAA 20 ppm	0.088 (25.71)	0.108 (8.00)	0.082 (51.85)	0.093 (47.61)	0.09	0.10
T_6 - NAA 30 ppm	0.068 (-2.85)	0.105 (5.00)	0.077 (42.59)	0.089 (41.26)	0.07	0.10
T_7 - CCC 25 ppm	0.093 (32.85)	0.120 (20.00)	0.080 (48.14)	0.093 (47.61)	0.09	0.11
T_8 - CCC 50 ppm	0.090 (28.57)	0.123 (23.00)	0.084 (55.56)	0.094 (49.21)	0.09	0.11
T_9 - CCC 75 ppm	0.100 (42.85)	0.138 (38.00)	0.082 (51.85)	0.093 (47.62)	0.09	0.12
T_{10} - 2,4-D 0.5 ppm	0.073 (42.85)	0.111 (11.00)	0.076 (40.74)	0.089 (41.27)	0.08	0.10
T_{11} - 2,4-D 1.0 ppm	0.056 (-20.00)	0.105 (5.00)	0.078 (44.44)	0.089 (41.27)	0.07	0.10
T_{12} - 2,4-D 2.0 ppm	0.050 (-28.57)	0.103 (3.00)	0.070 (29.63)	0.087 (38.09)	0.06	0.10
T_{13} - Water spray	0.081 (15.71)	0.098 (-2.00)	0.064 (18.51)	0.071 (12.70)	0.07	0.08
T_{14} - No spray (control)	0.070	0.100	0.054	0.063	0.06	0.08
Mean	0.077	0.109	0.070	0.080		
CD (0.05%)	0.0085	0.0085	0.0018	0.0030	0.026	0.022

Values in parentheses is the percentage increase/decrease over control.

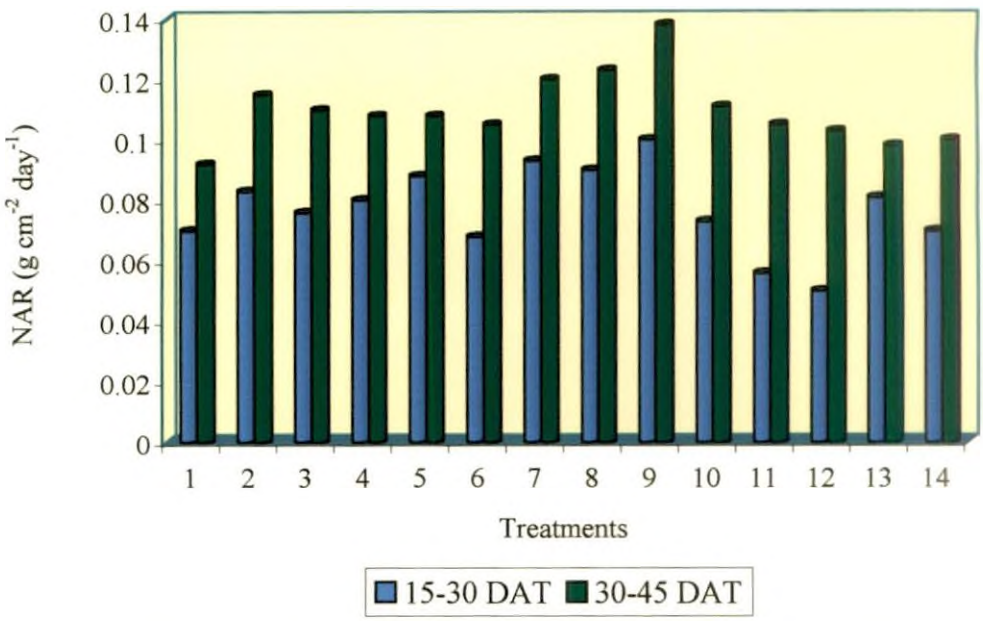


Fig. 6. NAR as influenced by bioregulators during Rabi

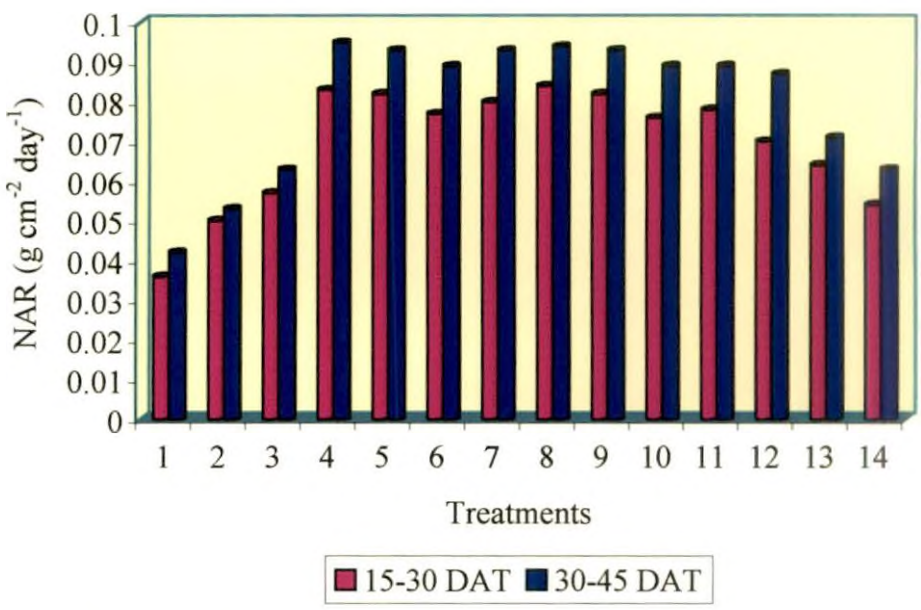


Fig. 7. NAR as influenced by bioregulators during Summer

During summer, at 15 DAT, the treatments T_4 and T_9 recorded the highest LAI of 3.85, while T_1 recorded the least LAI (3.41). Control plants recorded 3.65 (Fig. 9).

At 30 DAT, the highest LAI was recorded for treatment T_8 (6.28) followed by T_7 (6.08) and T_9 (6.04). The lowest LAI was recorded for the treatment T_3 with 3.96. Control (T_{14}) plants recorded 5.12.

At 45 DAT, the plants under treatment T_8 recorded the highest LAI of 6.58 followed by T_9 (6.45) and T_7 (6.40), whereas T_3 recorded the least LAI of 5.05. Control plants recorded 5.73.

When both the seasons were compared rabi recorded LAI of 3.70, 5.66 and 6.86 at 15, 30 and 45 DAT respectively while summer recorded 3.67, 5.11 and 5.82 at 15, 30 and 45 DAT respectively. Pooled analysis of data showed that the LAI during the first stage was not influenced by the bioregulators. The plants treated with CCC 50 ppm recorded the maximum LAI during the second stage (6.24) while NAA 30 ppm recorded the maximum LAI during the third stage (7.64). The plants treated with PCPA and 2,4-D recorded a comparatively lower LAI during both the stages.

4.2.4 Crop growth rate

Crop growth rate was recorded at two stages, 15-30 DAT and 30-45 DAT. The character varied significantly among treatments for the two stages in both the seasons (Table 9).

At 15-30 DAT the plants under treatment T_9 recorded a higher CGR of 0.47 g m^{-2} day^{-1} during rabi. The treatments T_8 and T_7 (both 0.46 g m^{-2} day^{-1}) were on par with T_9. This was followed by T_5 and T_6 (0.46 and 0.45 g m^{-2} day^{-1} respectively). Plants under treatment T_{12} recorded the lowest CGR of 0.21 g m^{-2} day^{-1} (Fig. 10).

At 30-45 DAT the treatment T_6 recorded a higher CGR of 0.87 g m^{-2} day^{-1} .The treatments T_5 and T_9 were on par with T_6 with 0.86 and 0.85 g m^{-2} day^{-1} respectively. The treatment T_2 recorded the lowest CGR (0.56 g m^{-2} day^{-1}). Control

Table 8. Leaf area index (LAI) as influenced by bioregulators

Treatments	Seasons						Mean		
	Rabi			Summer			15 DAT	30 DAT	45 DAT
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT			
T_1 - PCPA 25 ppm	3.53 (-3.81)	5.60 (-9.67)	5.90 (-19.95)	3.40 (-6.84)	4.43 (-13.48)	5.77 (0.70)	3.47	5.01	5.83
T_2 - PCPA 50 ppm	3.58 (-2.45)	4.76 (-23.22)	5.46 (-25.92)	3.49 (-4.38)	4.02 (-21.48)	5.08 (-11.34)	3.53	4.39	5.27
T_3 - PCPA 75 ppm	3.65 (-0.54)	4.59 (-25.97)	5.17 (-29.85)	3.53 (-3.29)	3.96 (-22.65)	5.05 (-11.87)	3.59	4.27	5.11
T_4 - NAA 10 ppm	3.83 (4.36)	6.50 (4.84)	8.70 (18.04)	3.85 (5.48)	5.48 (7.03)	6.04 (5.41)	3.84	5.99	7.37
T_5 - NAA 20 ppm	3.79 (3.27)	6.47 (4.35)	8.82 (19.67)	3.75 (2.74)	5.51 (7.61)	6.20 (8.20)	3.77	5.99	7.51
T_6 - NAA 30 ppm	3.80 (3.54)	6.52 (5.16)	9.11 (23.60)	3.80 (4.11)	5.82 (13.67)	6.18 (7.85)	3.80	6.17	7.64
T_7 - CCC 25 ppm	3.84 (4.63)	6.08 (-1.93)	7.19 (-2.44)	3.82 (4.66)	6.08 (18.75)	6.40 (11.69)	3.83	6.08	6.79
T_8 - CCC 50 ppm	3.78 (2.99)	6.21 (0.16)	6.72 (-8.82)	3.78 (3.56)	6.28 (22.65)	6.58 (14.83)	3.78	6.24	6.65
T_9 - CCC 75 ppm	3.81 (3.81)	5.97 (-3.71)	6.80 (-7.73)	3.85 (5.48)	6.04 (17.97)	6.45 (12.56)	3.83	6.00	6.61
T_{10} - 2,4-D 0.5 ppm	3.78 (2.99)	4.89 (-21.13)	5.77 (-21.71)	3.80 (4.11)	4.89 (-4.49)	5.72 (-0.17)	3.79	4.89	5.74
T_{11} - 2,4-D 1.0 ppm	3.56 (-2.99)	4.85 (-21.77)	5.72 (-22.39)	3.56 (-2.47)	4.69 (-8.39)	5.62 (-1.91)	3.56	4.77	5.67
T_{12} - 2,4-D 2.0 ppm	3.51 (-4.35)	4.58 (-26.13)	5.67 (-23.07)	3.49 (-4.38)	4.31 (-15.82)	5.46 (-4.71)	3.50	4.44	5.56
T_{13} - Water spray	3.65 (-0.54)	6.08 (-1.94)	7.70 (4.47)	3.63 (-0.55)	4.90 (-4.29)	5.25 (-8.38)	3.64	5.49	6.47
T_{14} - No spray (control)	3.67	6.20	7.37	3.65	5.12	5.73	3.66	5.66	6.56
Mean	3.70	5.66	6.86	3.67	5.11	5.82			
CD (0.05%)	0.184	0.314	0.316	0.060	0.056	0.061		0.71	1.67

Values in parentheses is the percentage increase/decrease over control.

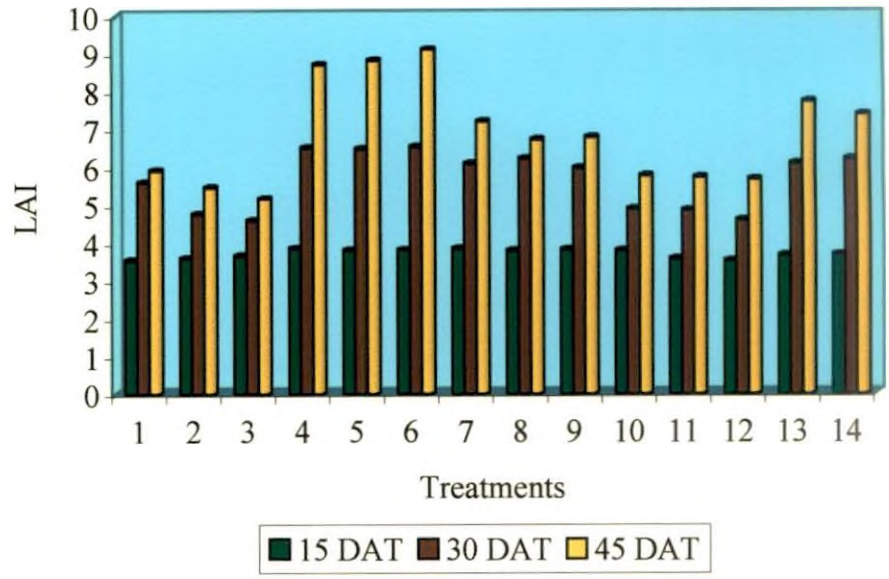


Fig. 8. LAI as influenced by bioregulators during Rabi

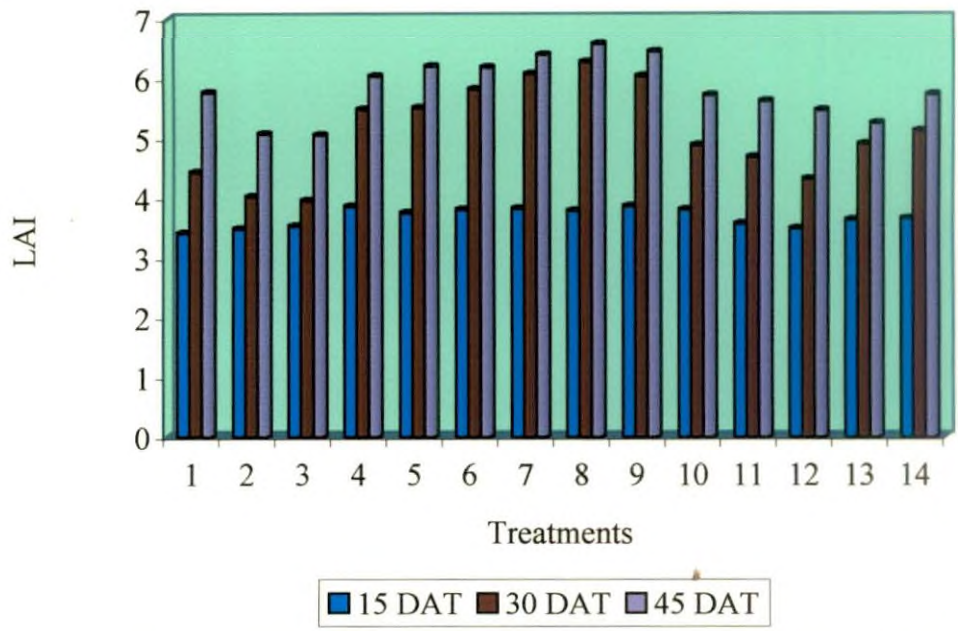


Fig. 9. LAI as influenced by bioregulators during Summer

plants recorded a CGR of 0.37 and 0.71 g m^{-2} day^{-1} at 15-30 DAT and 30-45 DAT respectively.

In summer, at 15-30 DAT, plants under treatment T_8 and T_9 recorded a higher CGR of 0.41 g m^{-2} day^{-1}.

At 30-45 DAT T_8 recorded a higher CGR of 0.61 g m^{-2} day^{-1}, which was on par with T_7 (0.60 g m^{-2} day^{-1}). During both the stages T_1 recorded the lowest CGR of 0.14 g m^{-2} day^{-1} at15-30 DAT and 0.22 g m^{-2} day^{-1} at 30-45 DAT. Control plants recorded a CGR of 0.24 and 0.34 g m^{-2} day^{-1} at 15-30 DAT and 30-45 DAT respectively (Fig. 11).

When the seasonal effect was studied rabi recorded a higher CGR of 0.37 and 0.71 g m^{-2} day^{-1} at 15-30 and 30-45 DAT while summer recorded a CGR of 0.31 and 0.45 g m^{-2} day^{-1} at 15-30 and 30-45 DAT respectively. Pooled analysis of data revealed that the plants treated with CCC recorded the maximum CGR during both the stages. The plants treated with NAA recorded a CGR comparable with CCC treatments. The plants treated with PCPA and 2,4-D recorded a minimum CGR.

4.2.5 Leaf Area Duration

Leaf area duration was calculated at two stages viz., 15-30 DAT and 30-45 DAT. A significant variation among treatment was noticed for the two stages during both seasons (Table 10).

During rabi, at 15-30 DAT, T_4 recorded the highest leaf area duration of 77.45 days. The treatments T_6, T_5, T_8 and T_7 were on par with T_4.The lowest LAD was recorded for the treatment T_{12} with 60.67 days. Control plants recorded 74.00 days (Fig. 12).

At 30-45 DAT the plants under treatment T_6 recorded the highest LAD (117.20 days), which was on par with T_5 and T_4. The lowest LAD (73.15 days) was observed in plants under treatment T_3. Control plants recorded LAD of 101.69 days.

Table 9. Crop growth rate (CGR g m^{-2} day^{-1}) as influenced by bioregulators

Treatments	Seasons				Mean	
	Rabi		Summer		15-30 DAT	30-45 DAT
	15-30 DAT	30-45 DAT	15-30 DAT	30-45 DAT		
T_1 - PCPA 25 ppm	0.35 (-5.40)	0.57 (-19.71)	0.14 (-41.67)	0.22 (-35.29)	0.25	0.39
T_2 - PCPA 50 ppm	0.34 (-8.11)	0.56 (-21.13)	0.19 (-20.83)	0.23 (-32.35)	0.26	0.40
T_3 - PCPA 75 ppm	0.32 (-13.51)	0.58 (-18.31)	0.22 (-8.33)	0.29 (-14.71)	0.27	0.43
T_4 - NAA 10 ppm	0.43 (16.22)	0.79 (11.27)	0.38 (58.33)	0.55 (61.76)	0.41	0.67
T_5 - NAA 20 ppm	0.46 (24.32)	0.86 (21.13)	0.38 (58.33)	0.55 (61.76)	0.42	0.71
T_6 - NAA 30 ppm	0.45 (21.62)	0.87 (22.54)	0.37 (54.17)	0.55 (61.76)	0.41	0.71
T_7 - CCC 25 ppm	0.46 (24.32)	0.82 (15.49)	0.38 (58.33)	0.60 (76.47)	0.42	0.71
T_8 - CCC 50 ppm	0.46 (24.32)	0.85 (19.71)	0.41 (70.83)	0.61 (79.41)	0.44	0.73
T_9 - CCC 75 ppm	0.47 (27.03)	0.85 (19.71)	0.41 (70.83)	0.59 (73.52)	0.44	0.72
T_{10} - 2,4-D 0.5 ppm	0.33 (-10.81)	0.58 (-18.31)	0.32 (33.33)	0.47 (38.23)	0.32	0.53
T_{11} - 2,4-D 1.0 ppm	0.23 (-37.84)	0.62 (-12.68)	0.32 (33.33)	0.45 (32.35)	0.21	0.53
T_{12} - 2,4-D 2.0 ppm	0.21 (-43.24)	0.58 (-18.31)	0.27 (12.5)	0.43 (26.47)	0.24	0.50
T_{13} - Water spray	0.36 (-2.70)	0.68 (-4.23)	0.28 (16.67)	0.39 (14.71)	0.32	0.53
T_{14} - No spray (control)	0.37	0.71	0.24	0.34	0.30	0.53
Mean	0.37	0.71	0.31	0.45		
CD (0.05%)	0.011	0.019	0.014	0.011	0.159	0.599

Values in parentheses is the percentage increase/decrease over control.

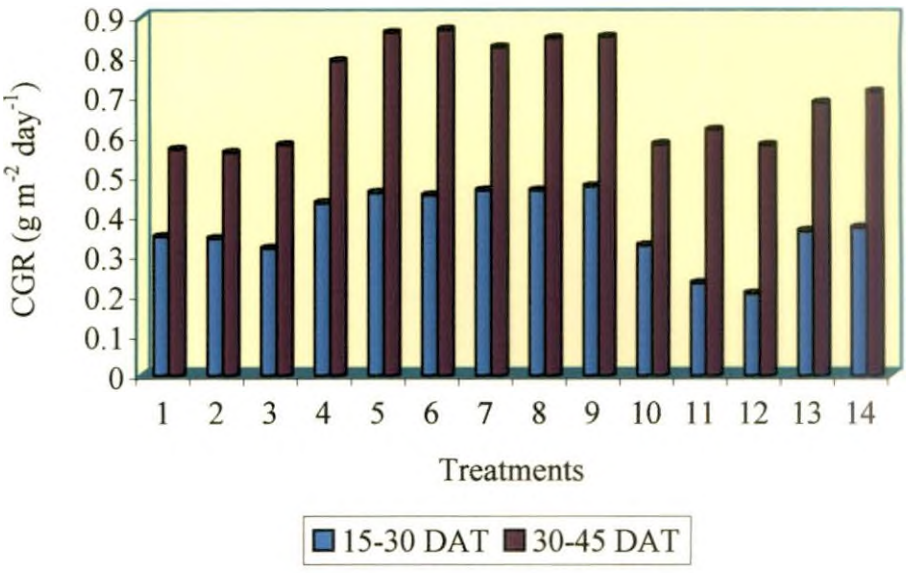


Fig. 10. CGR as influenced by the bioregulators during Rabi

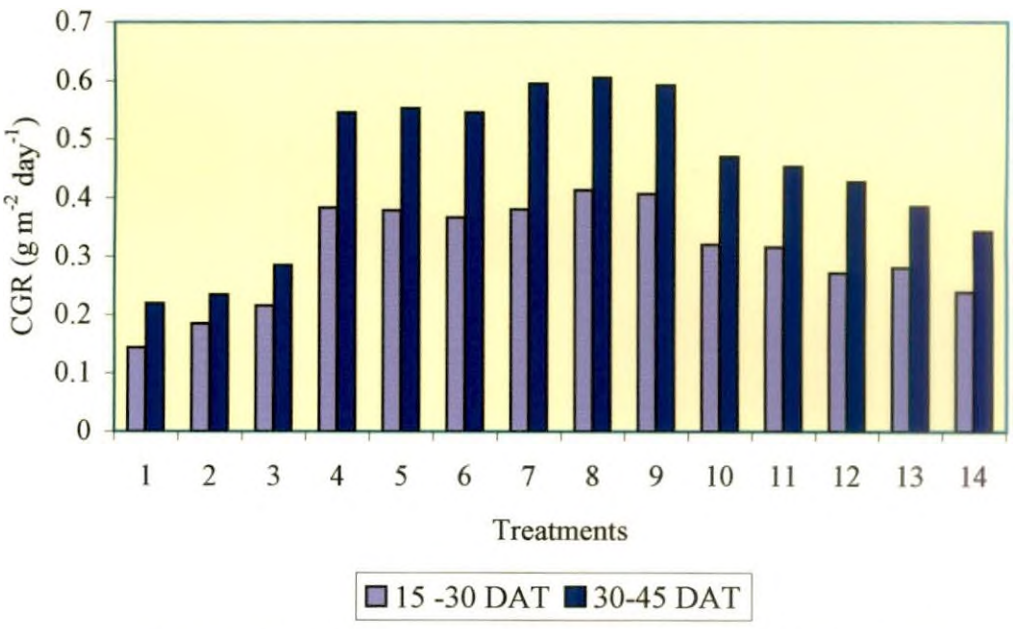


Fig. 11. CGR as influenced by bioregulators during Summer

During summer, at 15-30 DAT, the plants under treatment T_8 recorded the highest LAD (75.40 days) whereas the treatment T_3 recorded the lowest LAD of 56.15 days. Control plants recorded LAD of 65.77 days.

At 30-45 DAT also the treatment T_8 recorded the highest LAD of 96.64 days and the treatment T_3 recorded the lowest LAD (67.58 days). Control plants recorded LAD of 81.38 days (Fig. 13).

On comparing both the seasons LAD during rabi was high with 70.20 and 94.12 days at 15-30 and 30-45 DAT respectively while summer recorded 65.85 and 82.14 days at 15-30 and 30-45 DAT respectively. Pooled analysis of data showed that the plants treated with CCC and NAA recorded a higher LAD values between 73 and 75 days during the first stage while NAA treated plants recorded a higher LAD values during the second stage with values between 100 and 103 days.

4.3 EARLINESS

4.3.1 Days to first flower

There was no significant difference among the treatments for this character in rabi whereas the character varied significantly among treatments during summer (Table 11).

Though the difference was not significant during rabi the plants under treatment T_5 flowered earlier (31.00 days) followed by T_4 and T_6 whereas the treatment T_7 took more number of days (35.50 days) to flower followed by T_{14} and T_{13}.

In summer, the number of days taken for flowering was lowest for T_2 (33.50 days) and was highest for T_{13} and T_{14} (43.00 days). The treatments T_1 and T_3 were on par with T_2 (Fig. 14).

Seasonal variation was observed for days to first flower opening. During rabi the plants flowered earlier (33.32 days) than summer (40.64 days).

Table 10. Leaf area duration (LAD days) as influenced by bioregulators

Treatments	Seasons				Mean	
	Rabi		Summer		15-30 DAT	30-45 DAT
	15-30 DAT	30-45 DAT	15-30 DAT	30-45 DAT		
T_1 - PCPA 25 ppm	68.44 (-7.51)	86.24 (-15.19)	58.83 (-10.55)	76.47 (-6.03)	63.63	81.35
T_2 - PCPA 50 ppm	62.53 (-15.50)	76.61 (-24.66)	56.28 (-14.43)	68.19 (-16.21)	59.41	72.40
T_3 - PCPA 75 ppm	61.93 (-16.31)	73.15 (-28.07)	56.15 (-14.63)	67.58 (-16.96)	59.04	70.36
T_4 - NAA 10 ppm	77.45 (4.66)	113.98 (12.09)	69.98 (6.40)	86.38 (6.14)	73.71	100.18
T_5 - NAA 20 ppm	76.93 (3.96)	114.60 (12.69)	69.32 (5.40)	87.82 (7.91)	73.12	101.21
T_6 - NAA 30 ppm	77.39 (4.58)	117.20 (15.25)	72.49 (10.21)	90.34 (11.01)	74.94	103.77
T_7 - CCC 25 ppm	74.38 (0.51)	99.47 (-2.18)	74.20 (12.82)	93.53 (14.92)	74.29	96.49
T_8 - CCC 50 ppm	74.88 (1.19)	99.91 (-1.75)	75.40 (14.64)	96.64 (18.75)	75.14	96.63
T_9 - CCC 75 ppm	73.28 (-0.97)	95.49 (-6.10)	74.14 (12.73)	93.58 (14.99)	73.71	94.53
T_{10} - 2,4-D 0.5 ppm	64.96 (-12.21)	79.89 (-21.44)	65.13 (-0.97)	79.54 (-2.26)	65.04	79.71
T_{11} - 2,4-D 1.0 ppm	63.05 (-14.79)	79.22 (-22.10)	61.84 (-5.97)	77.32 (-4.98)	62.45	78.27
T_{12} - 2,4-D 2.0 ppm	60.67 (-18.01)	76.83 (-24.45)	58.42 (-11.17)	73.22 (-1.03)	59.54	75.02
T_{13} - Water spray	72.98 (-1.38)	103.36 (1.64)	63.91 (-2.82)	77.95 (-4.21)	68.44	90.65
T_{14} - No spray (control)	74.00	101.69	65.77	81.38	69.80	91.53
Mean	70.20	94.12	65.85	82.14		
CD (0.05%)	3.12	4.22	0.62	1.73	5.63	15.99

Values in parentheses is the percentage increase/decrease over control.

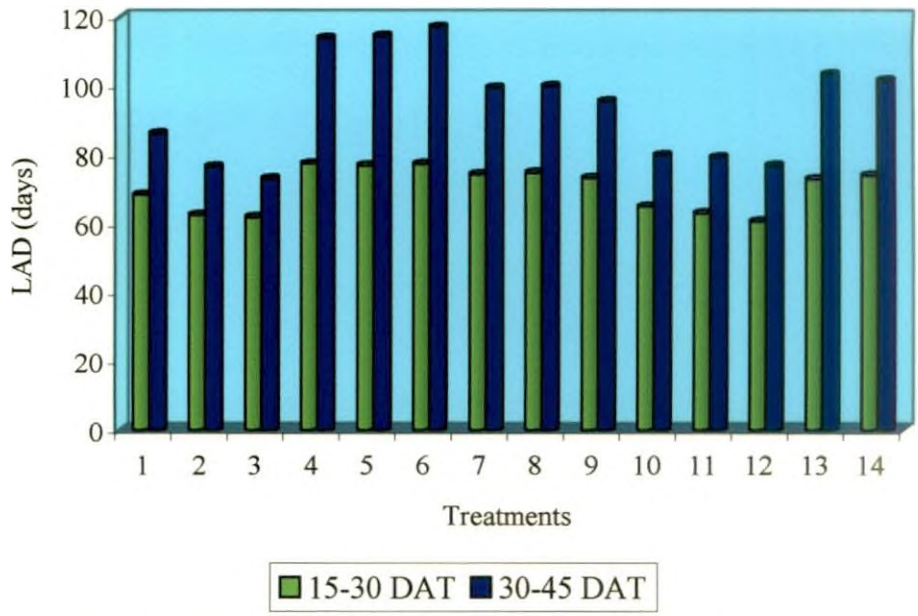


Fig. 12. LAD as influenced by bioregulators during Rabi

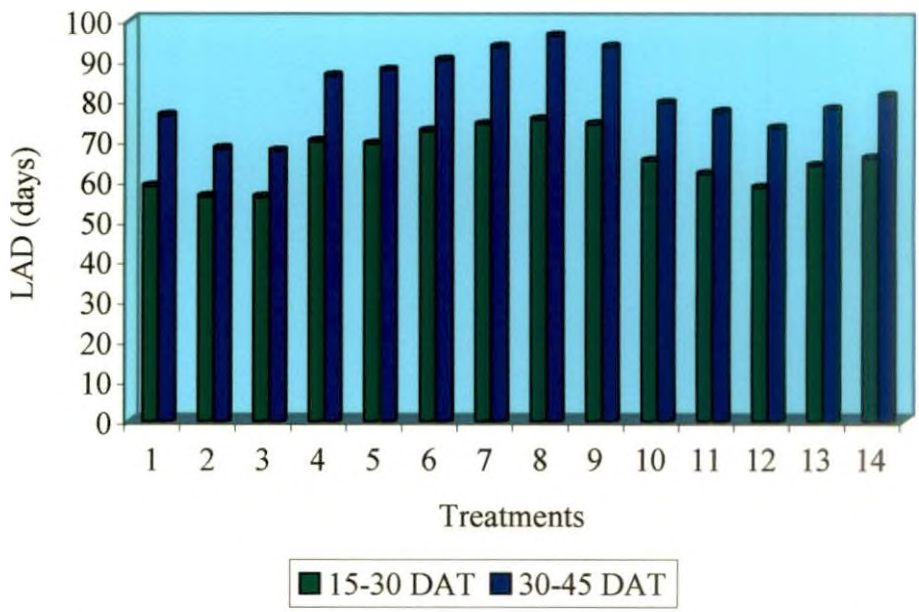


Fig. 13. LAD as influenced by bioregulators during Summer

Table 11. Days to first flower as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	32.50 (-7.14)	38.00 (-11.62)	35.25
T_2 - PCPA 50 ppm	33.50 (-4.28)	33.50 (-22.09)	33.50
T_3 - PCPA 75 ppm	35.00 (0.00)	37.00 (-13.95)	36.00
T_4 - NAA 10 ppm	31.50 (-10.00)	41.50 (-3.48)	36.50
T_5 - NAA 20 ppm	31.00 (-11.42)	42.00 (-2.32)	36.50
T_6 - NAA 30 ppm	32.00 (-5.57)	42.50 (-1.16)	37.25
T_7 - CCC 25 ppm	35.50 (1.42)	40.50 (-5.81)	38.00
T_8 - CCC 50 ppm	34.00 (-2.82)	41.00 (-4.65)	37.50
T_9 - CCC 75 ppm	33.50 (-4.28)	40.50 (-5.81)	37.00
T_{10} - 2,4-D 0.5 ppm	34.00 (-2.82)	42.50 (-1.16)	38.25
T_{11} - 2,4-D 1.0 ppm	32.50 (-7.14)	42.50 (-1.16)	37.50
T_{12} - 2,4-D 2.0 ppm	33.00 (-5.71)	41.50 (-3.48)	37.25
T_{13} - Water spray	33.50 (-4.28)	43.00 (0.00)	30.25
T_{14} - No spray (control)	35.00	43.00	39.00
Mean	33.32	40.64	
CD (0.05%)	NS	1.63	4.72

Values in parentheses is the percentage increase/decrease over control.

In general the plants treated with PCPA flowered earlier followed by NAA, i.e., PCPA and NAA reduced the number of days taken for flowering. Pooled analysis of data revealed that minimum number of days for opening of the first flower was in T_2 (33.50), which received PCPA 50 ppm while it was maximum for the control plants (39.00 days).

4.3.2 Days to first harvest

Days to first harvest did not show significant variation among treatments during rabi, whereas the character varied significantly among treatments during summer (Table 12).

Though the character do not vary significantly during rabi the lowest number of days for first harvest was recorded by the treatment T_4 (57.50).

The plants treated with PCPA 25 ppm (T_1) recorded less number of days for first harvest (70.50) during summer (Fig. 15). This was closely followed by T_2 and T_3. Control plants (T_{14}) recorded more number of days for first harvest (83.50).

When the seasons were compared it was observed that harvest during rabi was earlier (62.25 days) than summer (76.68 days).

During both the seasons NAA and PCPA at lower concentration (10 ppm and 25 ppm respectively) reduced the number of days taken for first harvest. The pooled data analysis showed that PCPA 25 ppm resulted in early yield (65.75 days) whereas control plants took more number of days to first harvest (74.25).

4.4 YIELD AND YIELD ATTRIBUTES

4.4.1 Percentage fruit set

A significant variation was observed among treatments during both the seasons for this character (Table 13).

Maximum percentage of fruit set was observed in plants under treatment T_6, which recorded 93.05 per cent followed by the treatment T_8 (89.20

Table 12. Days to first harvest as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	61.00 (-6.15)	70.50 (-15.56)	65.75
T_2 - PCPA 50 ppm	61.00 (-6.15)	72.50 (-13.17)	66.75
T_3 - PCPA 75 ppm	65.00 (0.00)	73.50 (-11.97)	69.25
T_4 - NAA 10 ppm	57.50 (-11.53)	75.50 (-9.58)	66.50
T_5 - NAA 20 ppm	60.00 (-7.69)	76.50 (-8.38)	68.25
T_6 - NAA 30 ppm	60.00 (-7.69)	77.50 (-7.18)	68.75
T_7 - CCC 25 ppm	65.00 (0.00)	74.00 (-11.37)	69.50
T_8 - CCC 50 ppm	65.00 (0.00)	76.00 (-8.98)	70.50
T_9 - CCC 75 ppm	61.00 (-6.15)	76.50 (-8.38)	68.75
T_{10} - 2,4-D 0.5 ppm	65.00 (0.00)	77.50 (-7.18)	71.25
T_{11} - 2,4-D 1.0 ppm	62.50 (-3.84)	79.50 (-4.79)	71.00
T_{12} - 2,4-D 2.0 ppm	62.50 (-3.84)	78.00 (-6.58)	70.25
T_{13} - Water spray	61.00 (-6.15)	82.50 (-1.19)	71.75
T_{14} - No spray (control)	65.00	83.50	74.25
Mean	62.25	76.68	
CD (0.05%)	NS	1.16	

Values in parentheses is the percentage increase/decrease over control.

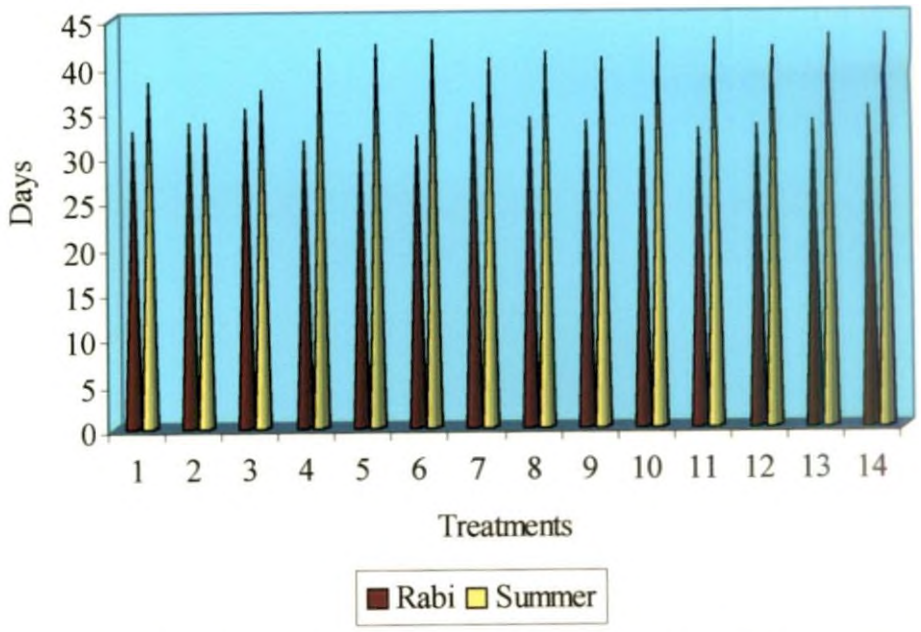


Fig. 14. Days to first flower as influenced by bioregulators

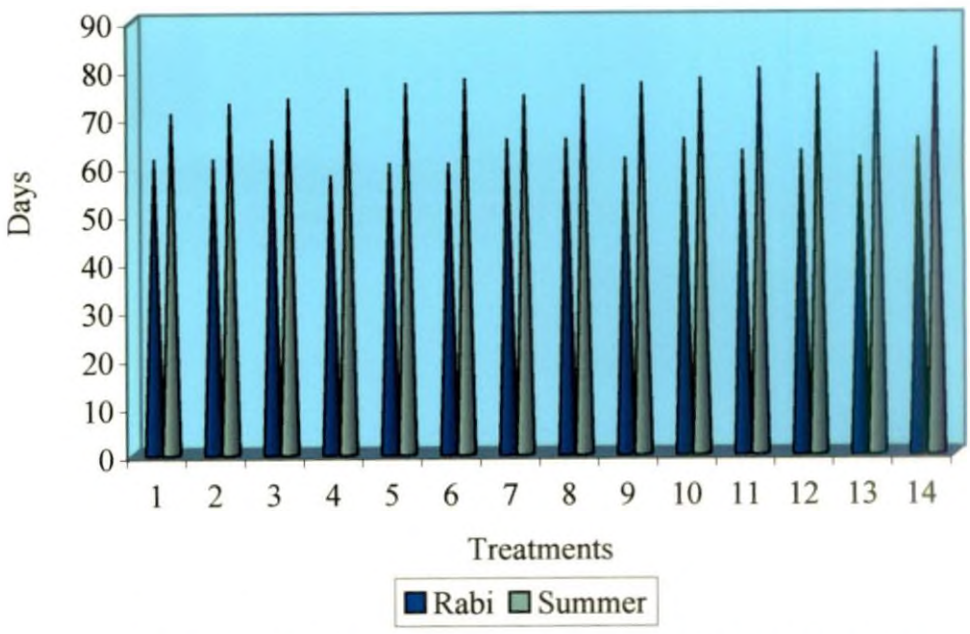


Fig. 15. Days to first harvest as influenced by bioregulators

per cent) during Rabi. Control plants (T_{14}) recorded a minimum fruit set percentage of 70.00. The treatments T_{13} and T_{10} were found to be on par with T_{14}.

In summer, the highest fruit set percentage was recorded in T_9 with 42.00 per cent followed by T_3 (39.00), on par with T_8 (38.50). During this season also control plants (T_{14}) recorded the least fruit set percentage of 11.50.The treatment T_{13} (12.00 per cent) was comparable with T_{14} (Fig. 16).

The per cent fruit set was much higher in rabi (80.36) compared to summer (25.71). During rabi NAA at higher concentration (30 ppm) and in summer CCC at higher concentration (75 ppm) recorded a higher fruit set percentage over other treatments.

In general the plants treated with NAA, CCC and PCPA increased the fruit set percentage while 2,4-D was found to reduce the same. Pooled analysis of data revealed that CCC 75 ppm (T_9) was effective in increasing the fruit set (64.25 per cent) which was 57.67 per cent over control. The treatments CCC 50 ppm and PCPA 75 ppm were also found to be equally effective.

4.4.2 Number of fruits per plant

A significant variation was observed among treatments for the character, number of fruits per plant during both the seasons (Table 14).

In rabi, the plants under the treatment T_{10} recorded higher number of fruits per plant (20.86). The treatments T_{12}, T_{11}, T_6 and T_3 were on par with T_{10}. Control plants recorded lower number of fruits per plant (15.58), which was on par with T_{13} (16.36). The plants treated with 2,4-D produced 30 per cent more fruits than control (Fig. 17).

The maximum number of fruits per plant was recorded for the treatment T_3 with 6.69 fruits per plant during summer. The treatments T_9 and T_8 were found on par with T_3. Minimum number of fruits per plant was recorded in control plants (1.50), which was on par with T_{13} (2.00). During summer the 2,4-D treatments were found to be less effective in increasing the fruit number while PCPA at all concentrations and CCC at higher concentration were found to be more effective for increasing the number of fruits per plant. About 250 to 350 per cent increase in

Table 13. Percentage of fruit set as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	73.60 (5.14)	35.00 (204.35)	54.30
T_2 - PCPA 50 ppm	81.00 (15.71)	30.00 (160.87)	55.50
T_3 - PCPA 75 ppm	87.15 (24.50)	39.00 (239.14)	63.08
T_4 - NAA 10 ppm	86.10 (23.00)	20.00 (73.91)	53.05
T_5 - NAA 20 ppm	80.60 (15.14)	20.00 (73.91)	50.30
T_6 - NAA 30 ppm	93.05 (32.93)	21.50 (86.96)	57.28
T_7 - CCC 25 ppm	86.00 (22.85)	33.00 (186.95)	59.50
T_8 - CCC 50 ppm	89.20 (27.43)	38.50 (234.78)	63.85
T_9 - CCC 75 ppm	86.50 (23.57)	42.00 (265.21)	64.25
T_{10} - 2,4-D 0.5 ppm	72.60 (3.71)	18.50 (60.87)	45.55
T_{11} - 2,4-D 1.0 ppm	75.60 (8.00)	20.00 (73.91)	47.80
T_{12} - 2,4-D 2.0 ppm	73.15 (4.50)	19.00 (65.21)	46.07
T_{13} - Water spray	70.50 (0.71)	12.00 (4.34)	41.25
T_{14} - No spray (control)	70.00	11.50	40.75
Mean	80.36	25.71	
CD (0.05%)	2.60	2.07	17.30

Values in parentheses is the percentage increase/decrease over control.

Table 14. Number of fruits per plant as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	18.21 (16.85)	5.98 (298.33)	12.09
T_2 - PCPA 50 ppm	17.37 (11.46)	5.70 (280.00)	11.53
T_3 - PCPA 75 ppm	19.08 (22.49)	6.69 (346.00)	12.89
T_4 - NAA 10 ppm	18.26 (17.20)	4.01 (167.67)	11.14
T_5 - NAA 20 ppm	18.59 (19.32)	4.30 (186.67)	11.45
T_6 - NAA 30 ppm	19.26 (23.62)	4.18 (178.33)	11.72
T_7 - CCC 25 ppm	18.06 (15.92)	3.78 (152.33)	10.92
T_8 - CCC 50 ppm	18.25 (17.10)	6.05 (303.33)	12.15
T_9 - CCC 75 ppm	18.17 (16.65)	6.20 (313.33)	12.19
T_{10} - 2,4-D 0.5 ppm	20.86 (33.85)	3.46 (130.33)	12.16
T_{11} - 2,4-D 1.0 ppm	20.48 (31.45)	3.29 (119.33)	11.89
T_{12} - 2,4-D 2.0 ppm	20.56 (31.93)	3.66 (144.33)	12.11
T_{13} - Water spray	16.36 (4.97)	2.00 (33.33)	9.18
T_{14} - No spray (control)	15.58	1.50	8.54
Mean	18.51	4.34	
CD (0.05%)	1.83	0.69	2.85

Values in parentheses is the percentage increase/decrease over control.

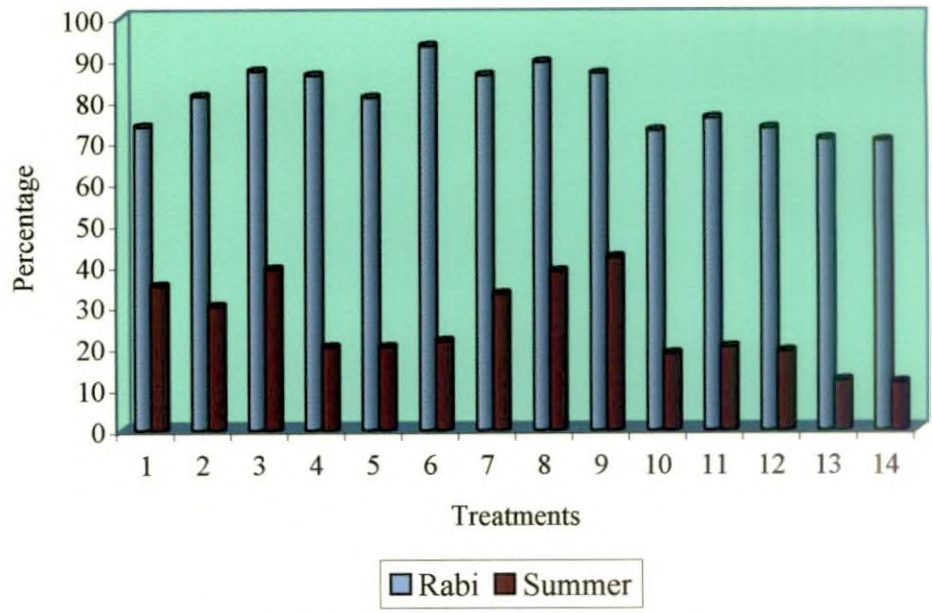


Fig. 16. Percentage fruit set as influenced by bioregulators

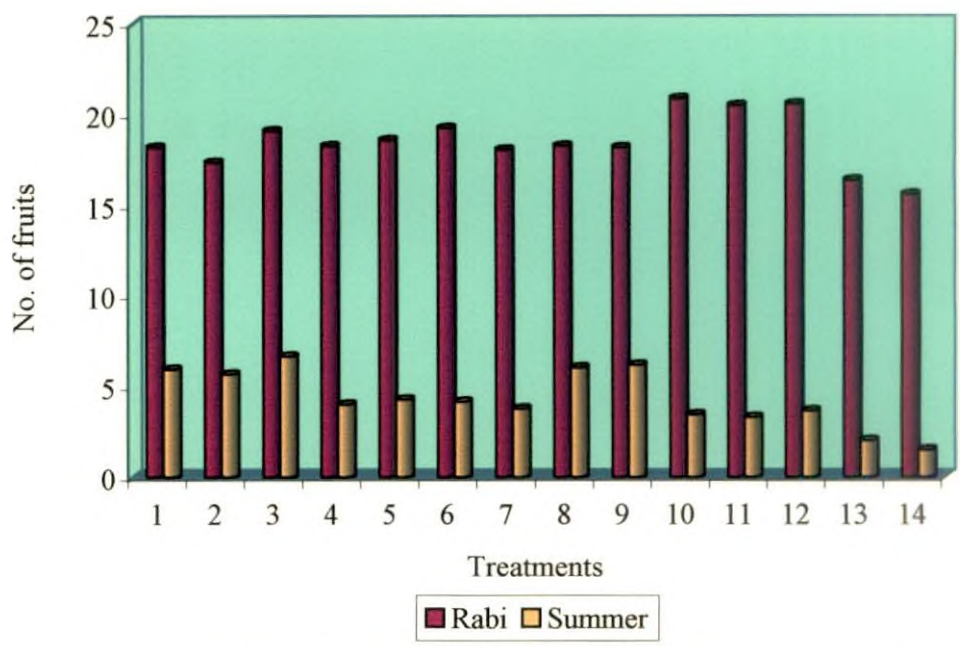


Fig. 17. Number of fruits as influenced by bioregulators

fruit number over control was observed during summer by PCPA and CCC application.

Seasonal variation was also manifested for the number of fruits per plant and it was more during rabi (18.51) than summer (4.34).

Pooled analysis of data revealed that number of fruits per plant was maximum from the plot which received PCPA 75 ppm with 12.89 fruits while control plants recorded a minimum of 8.54 fruits per plant.

4.4.3 Number of fruits per plot (7.2 m^2)

Number of fruits per plot showed a significant variation among the treatments during both the seasons (Table 15).

The plants from the plot that received 2,4-D 0.5 ppm (T_{10}) produced the maximum number of fruits (417.10) in rabi. The treatments T_{12}, T_{11}, T_6 and T_3 were statistically on par with T_{10}.Control plants recorded the minimum number of fruits per plot (311.60), which was comparable with T_{13} (327.10).

In summer, the plants from the plot treated with PCPA 75 ppm (T_3) recorded more number of fruits per plot (133.80). The treatments T_9 and T_8 were comparable with T_3, followed by T_1 and T_2 both being on par. Control plants recorded the least number of fruits per plot with 30.00 fruits. This was on par with T_{13} (40.00).

When the seasonal effect was studied the character showed a significant variation for seasons with rabi recording a relatively high fruit number of 370.10 while summer recorded 86.86 fruits per plot.

4.4.4 Average fruit weight

The character, fruit weight varied significantly among treatments during both the seasons (Table 16).

Fruits with maximum weight were obtained from plants under treatment T_9 with an average fruit weight of 35.35 g during rabi season. The treatment T_8

Table 15. Number of fruits per plot (7.2 m^2) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	364.10 (16.84)	119.50 (298.33)	241.80
T_2 - PCPA 50 ppm	347.30 (11.45)	114.00 (280.00)	230.65
T_3 - PCPA 75 ppm	381.70 (22.49)	133.80 (346.00)	257.75
T_4 - NAA 10 ppm	365.20 (17.20)	80.30 (167.67)	222.75
T_5 - NAA 20 ppm	371.80 (19.31)	86.00 (186.67)	228.90
T_6 - NAA 30 ppm	385.20 (23.62)	83.50 (178.33)	234.35
T_7 - CCC 25 ppm	361.20 (15.91)	75.70 (152.33)	218.45
T_8 - CCC 50 ppm	364.90 (17.10)	121.00 (303.33)	242.95
T_9 - CCC 75 ppm	363.50 (16.66)	124.00 (313.00)	243.75
T_{10} - 2,4-D 0.5 ppm	417.10 (33.86)	69.10 (130.33)	243.10
T_{11} - 2,4-D 1.0 ppm	409.60 (31.45)	65.80 (119.33)	237.70
T_{12} - 2,4-D 2.0 ppm	411.10 (31.93)	73.30 (114.33)	242.20
T_{13} - Water spray	327.10 (4.97)	40.00 (33.33)	183.55
T_{14} - No spray (control)	311.60	30.00	170.80
Mean	370.10	86.86	
CD (0.05%)	36.62	13.90	

Values in parentheses is the percentage increase/decrease over control.

was on par with T_9 (35.07 g). The lowest fruit weight was obtained from plants under treatment T_{12} (26.73 g), which was on par with T_{10} (27.21 g) and T_{11} (27.22 g). Fruits from control plants recorded an average fruit weight of 30.35 g (Fig. 18).

In summer also fruits from plants under treatment T_9 recorded the maximum fruit weight with an average of 32.64 g, which was found to be on par with T_8 (31.94 g). The lowest fruit weight was recorded for the treatment T_{10} (25.63 g), which was on par with T_{12} (25.96 g) and T_{11} (26.99 g). Control plants recorded an average fruit weight of 27.75 g.

On comparing the seasons, there was no much difference as the average fruit weight was 31.14 g and 29.17 g during rabi and summer respectively.

The plants treated with CCC at all concentrations recorded maximum fruit weight whereas plants treated with 2,4-D recorded minimum fruit weight during both the seasons. On pooled analysis of data it was observed that the plants treated with CCC 75 ppm and 50 ppm produced fruits with maximum fruit weight of 33.99 and 33.50 g respectively whereas the plants treated with 2,4-D 2 ppm produced fruits with minimum fruit weight (25.91 g).

4.4.5 Average Fruit volume

The character, fruit volume, varied significantly among the treatments during both the seasons (Table 17).

In the first season, i.e., rabi maximum fruit volume was recorded in plants treated with T_9 (37.15 cm^3). The treatment T_8 (36.70 cm^3) was on par with T_9. The minimum fruit volume was recorded for the treatment T_{12} (28.10 cm^3) which was on par with T_{11} (28.75 cm^3) and T_{10} (28.95 cm^3). Control plants recorded an average fruit volume of 32.20 cm^3 (Fig. 19).

During summer also the treatment T_9 recorded higher fruit volume with an average of 34.00 cm^3, on par with T_8 (33.25 cm^3). The treatment T_{12} recorded the lowest fruit volume of 27.40 cm^3, which was on par with T_{10} (27.95 cm^3) and T_{11} (28.45 cm^3). Fruits from control plants recorded 29.55 cm^3.

Table 16. Average fruit weight (g) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	31.19 (2.77)	29.64 (6.81)	30.42
T_2 - PCPA 50 ppm	32.71 (7.76)	29.56 (6.52)	31.13
T_3 - PCPA 75 ppm	31.49 (3.75)	29.87 (7.62)	30.68
T_4 - NAA 10 ppm	31.23 (2.89)	29.91 (7.78)	30.57
T_5 - NAA 20 ppm	31.72 (4.53)	29.75 (7.20)	30.74
T_6 - NAA 30 ppm	32.36 (6.63)	29.85 (7.56)	31.11
T_7 - CCC 25 ppm	32.60 (7.43)	30.54 (10.03)	31.57
T_8 - CCC 50 ppm	35.07 (15.55)	31.94 (15.08)	33.50
T_9 - CCC 75 ppm	35.35 (16.47)	32.64 (17.60)	33.99
T_{10} - 2,4-D 0.5 ppm	27.21 (-10.34)	25.63 (-7.65)	26.42
T_{11} - 2,4-D 1.0 ppm	27.22 (-10.31)	26.99 (-2.75)	27.10
T_{12} - 2,4-D 2.0 ppm	26.73 (-11.91)	25.96 (-6.45)	25.91
T_{13} - Water spray	30.74 (1.28)	28.42 (2.40)	29.58
T_{14} - No spray (control)	30.35	27.75	29.05
Mean	31.14	29.17	
CD (0.05%)	1.49	1.38	1.99

Values in parentheses is the percentage increase/decrease over control.

Table 17. Average fruit volume (cm^3) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	32.50 (0.93)	31.00 (4.90)	31.75
T_2 - PCPA 50 ppm	34.40 (6.83)	30.75 (4.06)	32.58
T_3 - PCPA 75 ppm	33.35 (3.57)	31.15 (5.41)	32.25
T_4 - NAA 10 ppm	32.95 (2.32)	31.50 (6.59)	32.23
T_5 - NAA 20 ppm	33.00 (2.48)	31.05 (5.07)	32.03
T_6 - NAA 30 ppm	33.15 (2.95)	31.00 (4.90)	32.08
T_7 - CCC 25 ppm	33.90 (5.27)	31.65 (7.10)	32.78
T_8 - CCC 50 ppm	36.70 (13.97)	33.25 (12.52)	34.98
T_9 - CCC 75 ppm	37.15 (15.37)	34.00 (15.05)	35.58
T_{10} - 2,4-D 0.5 ppm	28.95 (-10.09)	27.95 (-5.410	28.45
T_{11} - 2,4-D 1.0 ppm	28.75 (-10.71)	28.45 (-3.72)	28.60
T_{12} - 2,4-D 2.0 ppm	28.10 (-12.73)	27.40 (-7.27)	27.75
T_{13} - Water spray	32.35 (0.46)	30.15 (2.03)	31.25
T_{14} - No spray (control)	32.20	29.55	30.88
Mean	32.67	30.63	
CD (0.05%)	1.40	1.69	2.26

Values in parentheses is the percentage increase/decrease over control.

When the seasonal effect was studied rabi recorded a higher fruit volume of 32.67 cm^3 than summer (30.63 cm^3).

As in the case of fruit weight, the plant treated with CCC recorded higher fruit volume while the plants treated with 2,4-D at all concentrations recorded lower fruit volume. Pooled analysis of data revealed that plants treated with CCC 75 ppm and 50 ppm produced fruits with higher volume of 35.58 and 34.98 cm^3 respectively while 2,4-D ppm (T_{12}) recorded the minimum fruit volume (27.75 cm^3).

4.4.6 Fruit yield per plant

The character was found to vary significantly among treatments during both the seasons (Table 18).

During rabi season, the treatment T_9 recorded the highest yield of 0.63 kg per plant. The treatments T_8, T_7, T_5 and T_3 were on par with T_9. Control (T_{14}) plants recorded the lowest yield of 0.47 kg per plant, which was on par with T_{12}, T_{13}, T_{11} and T_{10} (Fig. 20).

During summer also the treatment T_9 and T_3 recorded the highest fruit yield per plant of 0.20 kg. The treatment T_8 was found to be on par with T_9 and T_3. The lowest fruit yield per plant was obtained with T_{14} (0.04 kg).

On comparing both the seasons it was observed that fruit yield per plant was higher (0.55 kg) during rabi than summer (0.13 kg).

In general treatment with CCC was found to be effective in increasing fruit yield per plant during both rabi and summer seasons. Mean yield per plant over two seasons was maximum in CCC 75 ppm treated plants (0.42 kg) while it was minimum in control plants (0.26 kg).

4.4.7 Fruit yield per plot (kg/7.2 m^2)

The treatments significantly influenced the fruit yield per plot and the character varied significantly among the treatments during both the seasons (Table 19).

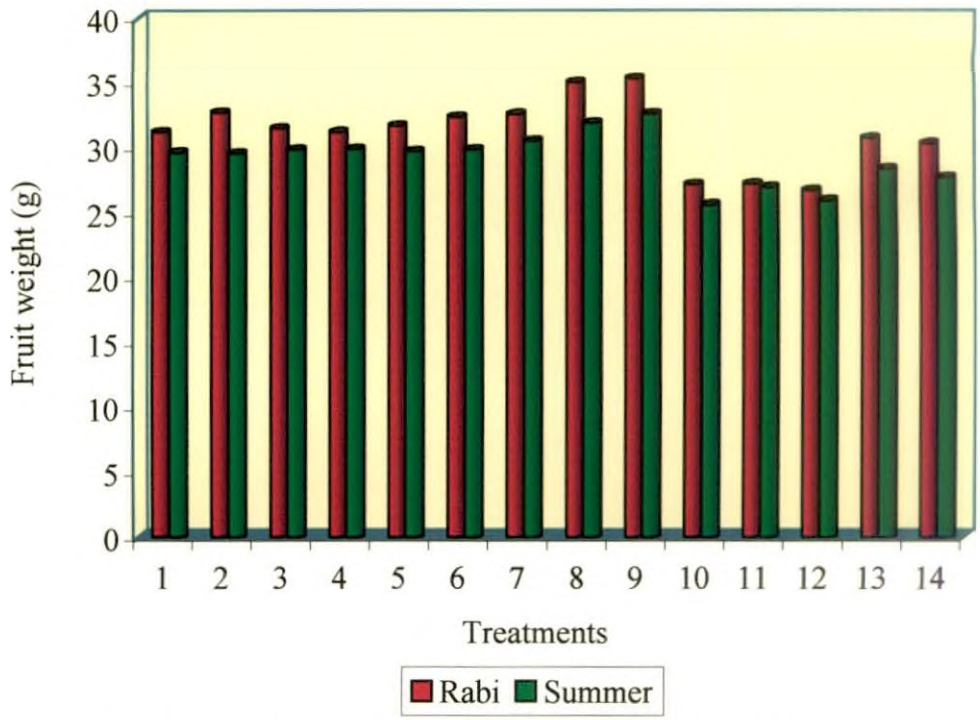


Fig. 18. Average fruit weight as influenced by bioregulators

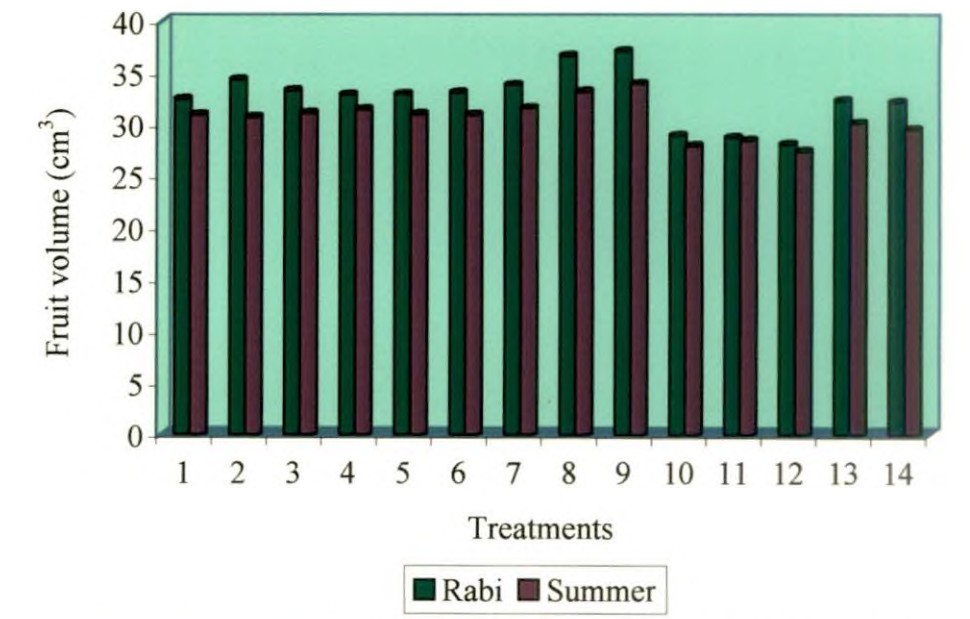


Fig. 19. Average fruit volume as influenced by bioregulators

Table 18. Fruit yield per plant (kg) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	0.56 (18.89)	0.18 (323.80)	0.37
T_2 - PCPA 50 ppm	0.55 (17.62)	0.17 (304.76)	0.36
T_3 - PCPA 75 ppm	0.58 (23.35)	0.20 (373.80)	0.39
T_4 - NAA 10 ppm	0.56 (18.89)	0.12 (185.71)	0.34
T_5 - NAA 20 ppm	0.58 (22.92)	0.13 (204.76)	0.35
T_6 - NAA 30 ppm	0.61 (28.87)	0.13 (197.16)	0.37
T_7 - CCC 25 ppm	0.59 (24.20)	0.12 (173.80)	0.35
T_8 - CCC 50 ppm	0.62 (32.48)	0.19 (359.52)	0.41
T_9 - CCC 75 ppm	0.63 (34.18)	0.20 (383.33)	0.42
T_{10} - 2,4-D 0.5 ppm	0.51 (7.64)	0.09 (111.90)	0.30
T_{11} - 2,4-D 1.0 ppm	0.50 (5.52)	0.09 (111.90)	0.29
T_{12} - 2,4-D 2.0 ppm	0.49 (3.82)	0.10 (128.57)	0.29
T_{13} - Water spray	0.49 (4.24)	0.06 (35.71)	0.27
T_{14} - No spray (control)	0.47	0.04	0.26
Mean	0.55	0.13	
CD (0.05%)	0.05	0.02	

Values in parentheses is the percentage increase/decrease over control.

Table 19. Fruit yield/plot (kg /7.2 m^2) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	11.20 (18.89)	3.55 (323.80)	7.38
T_2 - PCPA 50 ppm	11.08 (17.62)	3.39 (304.76)	7.24
T_3 - PCPA 75 ppm	11.63 (23.35)	3.99 (373.80)	7.81
T_4 - NAA 10 ppm	11.20 (18.89)	2.40 (185.71)	6.80
T_5 - NAA 20 ppm	11.59 (22.92)	2.58 (204.76)	7.09
T_6 - NAA 30 ppm	12.13 (28.87)	2.50 (197.61)	7.32
T_7 - CCC 25 ppm	11.70 (24.20)	2.31 (173.80)	7.01
T_8 - CCC 50 ppm	12.47 (32.48)	3.87 (359.52)	8.17
T_9 - CCC 75 ppm	12.64 (34.18)	4.06 (383.33)	8.35
T_{10} - 2,4-D 0.5 ppm	10.14 (7.64)	1.78 (111.90)	5.96
T_{11} - 2,4-D 1.0 ppm	9.93 (5.52)	1.77 (111.90)	5.85
T_{12} - 2,4-D 2.0 ppm	9.78 (3.82)	1.92 (128.57)	5.56
T_{13} - Water spray	9.82 (4.24)	1.34 (35.71)	5.58
T_{14} - No spray (control)	9.42	0.83	5.13
Mean	11.05	7.35	
CD (0.05%)	1.08	0.35	

Values in parentheses is the percentage increase/decrease over control.

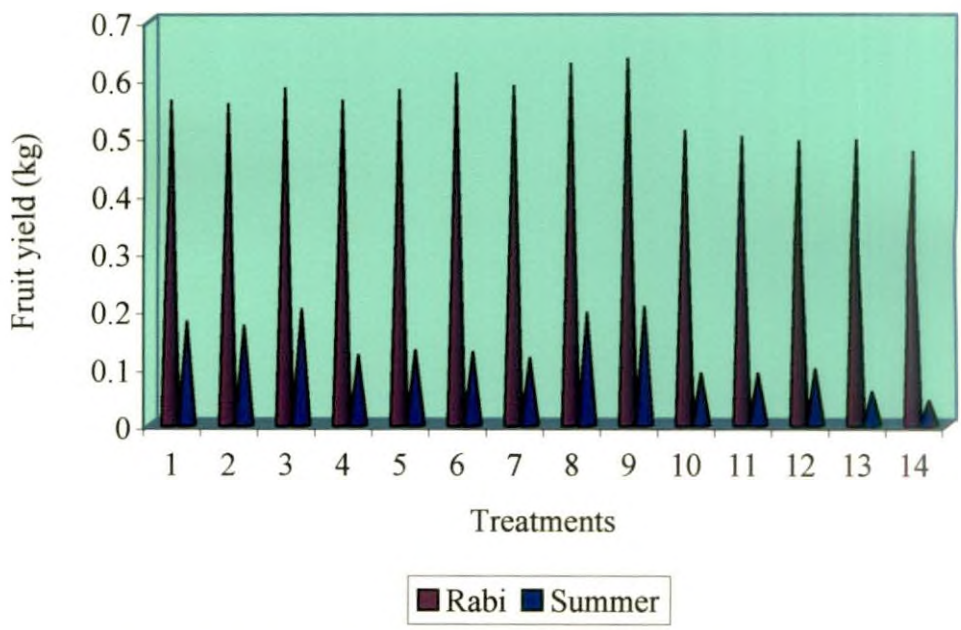


Fig. 20. Fruit yield per plant as influenced by bioregulators

a) Control

b) PCPA 75 ppm

c) NAA 30 ppm

d) CCC 50 ppm

e) CCC 75 ppm

Plate 2. Fruit yield as influenced by bioregulators

In rabi, the plants from the plot that received T_9 (CCC 75 ppm) recorded the maximum fruit yield per plot of 12.64 kg which was on par with T_8, T_6, T_7, T_3 and T_5.Control plants recorded the minimum yield of 9.42 kg per plot which was comparable with T_{12}, T_{13} and T_{11}.

During summer also the plants treated with T_9 recorded the maximum yield of 4.06 kg per plot, which was on par with T_3 and T_8 with 3.99 and 3.87 kg per plot respectively. Control plants recorded the minimum yield of 0.83 kg per plot, which was on par with T_{13} with 1.14 kg per plot.

Seasonal variation was noticed for this character. Rabi recorded a higher plot yield of 11.05 kg while summer recorded 7.35 kg per plot.

4.4.8 Percentage cracking

The percentage of fruits cracked varied significantly among the treatments during both the seasons (Table 20).

During rabi the treatment T_9 recorded the least percentage of cracked fruits 27.00. The treatments T_7, T_1 and T_8 were found to be on par with T_9 while the fruits from control plants recorded the highest percentage of cracked fruits (43.50) that was on par with T_{13}, T_{12} and T_{10} (Fig. 21).

In summer, the lowest percentage of cracked fruits was noticed in plants under treatment T_7 (12.00). The treatments T_5 and T_9 were found to be on par with T_7. The highest percentage of cracked fruits was observed in T_{13} (25.00), which was on par with T_{14} (23.00).

On comparing the two seasons, cracking was lower during summer (18.32) than rabi (34.28).

In general, plants treated with CCC at all concentrations recorded the lowest cracking percentage during both the seasons. Pooled analysis of data revealed that CCC 25 ppm (T_7) was effective in reducing the percentage (19.25). The maximum percentage of cracking was recorded in water sprayed plants (33.50).

Table 20. Percentage of cracked fruits as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	29.00 (-33.33)	20.50 (-10.86)	24.75
T_2 - PCPA 50 ppm	31.50 (-27.58)	17.00 (-26.08)	24.25
T_3 - PCPA 75 ppm	31.00 (-28.73)	20.00 (-13.04)	25.50
T_4 - NAA 10 ppm	33.00 (-24.13)	15.00 (-34.78)	24.00
T_5 - NAA 20 ppm	31.50 (-27.58)	12.50 (-45.65)	22.00
T_6 - NAA 30 ppm	32.00 (-26.43)	20.50 (-10.87)	26.25
T_7 - CCC 25 ppm	27.50 (-36.78)	12.00 (-47.83)	19.75
T_8 - CCC 50 ppm	29.00 (-33.33)	15.00 (-34.78)	22.00
T_9 - CCC 75 ppm	27.00 (-37.93)	13.00 (-43.48)	20.00
T_{10} - 2,4-D 0.5 ppm	41.50 (-4.59)	20.50 (-10.87)	31.00
T_{11} - 2,4-D 1.0 ppm	40.00 (-8.04)	20.50 (-10.87)	30.25
T_{12} - 2,4-D 2.0 ppm	41.50 (-4.59)	22.00 (-4.34)	31.75
T_{13} - Water spray	42.00 (-3.44)	25.00 (8.69)	33.50
T_{14} - No spray (control)	43.50	23.00	33.25
Mean	34.29	18.32	
CD (0.05%)	2.45	1.52	7.99

Values in parentheses is the percentage increase/decrease over control.

4.4.9 Seeds per fruit

The character varied significantly among the treatments during both the seasons (Table 21). Parthenocarpic fruits with only seed remnants were obtained from the plants under treatments T_2, T_3, T_{10}, T_{11} and T_{12} during both the seasons.

During rabi, maximum number of seeds (145.50) was observed in fruits from control plants followed by plants under treatment T_{13} (129.50). The minimum number of seeds was observed in plants under treatment T_6 (56.00).

During summer also fruits from control plant (T_{14}) recorded the highest number of seeds (104.50). This was on par with T_9. Least number of seeds was obtained from fruits treated with T_6 (56.50).

A higher number of seeds were present during rabi (101.17) than during summer (88.00). The treatment with all concentrations of 2,4-D and higher concentrations of PCPA were found to be effective in producing parthenocarpic fruits while NAA and CCC produced fruits with comparatively more number of seeds. The number of seeds was maximum in CCC treated plants when compared to NAA.

4.4.10 Percentage extrovert stigma

In rabi the extrovert stigma was not noticed, whereas the character varied significantly among treatments during summer (Table 22).

In summer, the plants treated with T_9 recorded the least percentage of extrovert stigma (55.00) followed by T_3 (57.50) and T_8 (59.00) which were on par. Maximum percentage of extrovert stigma was recorded in T_{14} (91.00) which was on par with T_{13} (90.50). Plants treated with CCC and PCPA produced only less than 70 per cent extrovert stigma (Fig. 22).

4.4.11 Number of locules per fruit

The character varied significantly among treatments during the rabi season whereas the character was non-significant among treatments during summer season (Table 23).

Introvert stigma

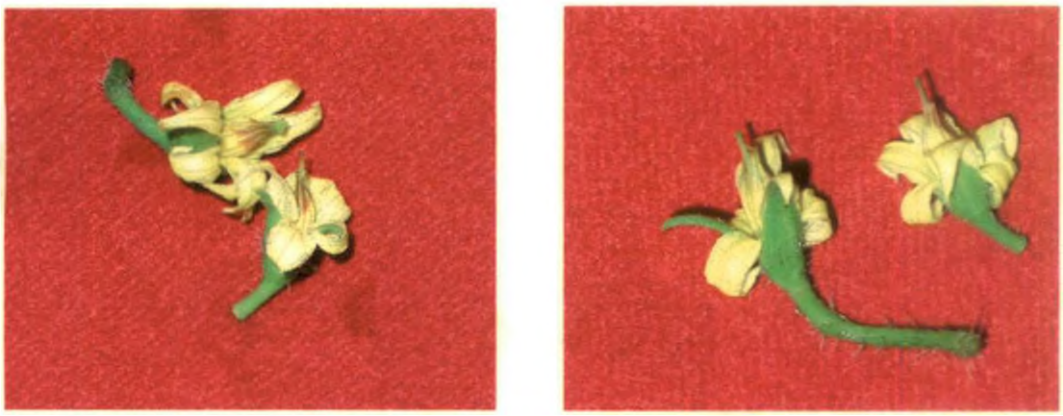


Plate 6. Extrovert stigma during summer

Table 21. Seeds per fruit as influenced by bioregulators

Treatment	Rabi		Summer	
	Seed	Seed remnants	Seed	Seed remnants
T_1 - PCPA 25 ppm	91.00	X	81.50	X
T_2 - PCPA 50 ppm	X	37.00	X	34.00
T_3 - PCPA 75 ppm	X	30.00	X	24.50
T_4 - NAA 10 ppm	83.00	X	83.00	X
T_5 - NAA 20 ppm	81.00	X	77.00	X
T_6 - NAA 30 ppm	56.00	X	56.00	X
T_7 - CCC 25 ppm	106.50	X	91.00	X
T_8 - CCC 50 ppm	105.00	X	94.50	X
T_9 - CCC 75 ppm	113.00	X	104.00	X
T_{10} - 2,4-D 0.5 ppm	X	12.50	X	12.50
T_{11} - 2,4-D 1.0 ppm	X	53.50	X	53.50
T_{12} - 2,4-D 2.0 ppm	X	12.50	X	12.50
T_{13} - Water spray	129.50	X	99.50	X
T_{14} - No spray (control)	145.50	X	104.50	X
Mean	101.17		88.00	
C.D (0.05)	5.64		5.87	

Table 22. Percentage of Extrovert stigma as influenced by bioregulators

Treatments	Seasons	
	Rabi	Summer
T_1 - PCPA 25 ppm	X	61.00 (-32.96)
T_2 - PCPA 50 ppm	X	68.50 (-24.72)
T_3 - PCPA 75 ppm	X	57.50 (-36.81)
T_4 - NAA 10 ppm	X	80.50 (-11.53)
T_5 - NAA 20 ppm	X	78.50 (-13.73)
T_6 - NAA 30 ppm	X	77.00 (-15.38)
T_7 - CCC 25 ppm	X	65.00 (-28.57)
T_8 - CCC 50 ppm	X	59.00 (-35.16)
T_9 - CCC 75 ppm	X	55.00 (-39.56)
T_{10} - 2,4-D 0.5 ppm	X	80.50 (-11.53)
T_{11} - 2,4-D 1.0 ppm	X	78.00 (-14.28)
T_{12} - 2,4-D 2.0 ppm	X	79.00 (-13.18)
T_{13} - Water spray	X	90.50 (-0.54)
T_{14} - No spray (control)	X	91.00
Mean	X	72.93
CD (0.05%)	X	2.16

Values in parentheses is the percentage increase/decrease over control

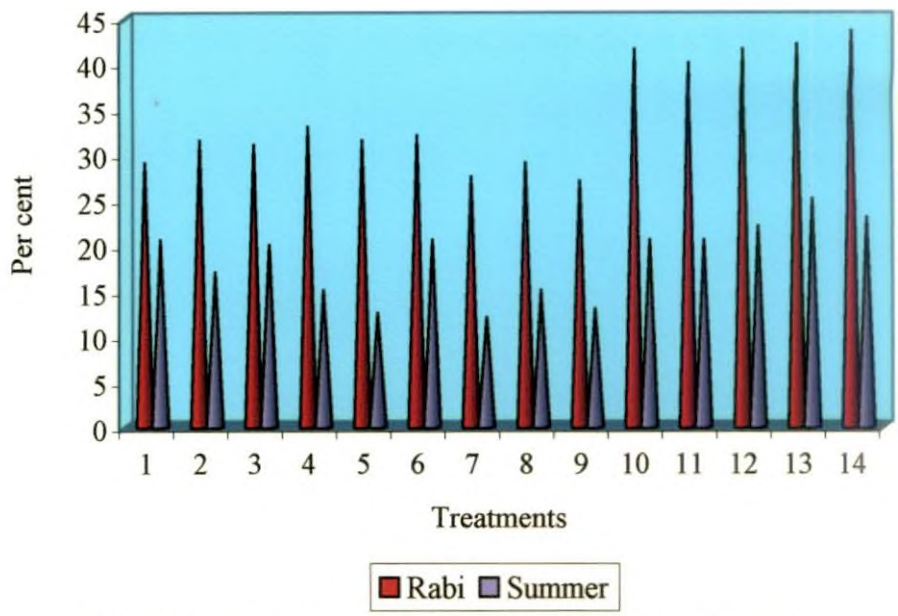


Fig. 21. Percentage cracking as influenced by bioregulators

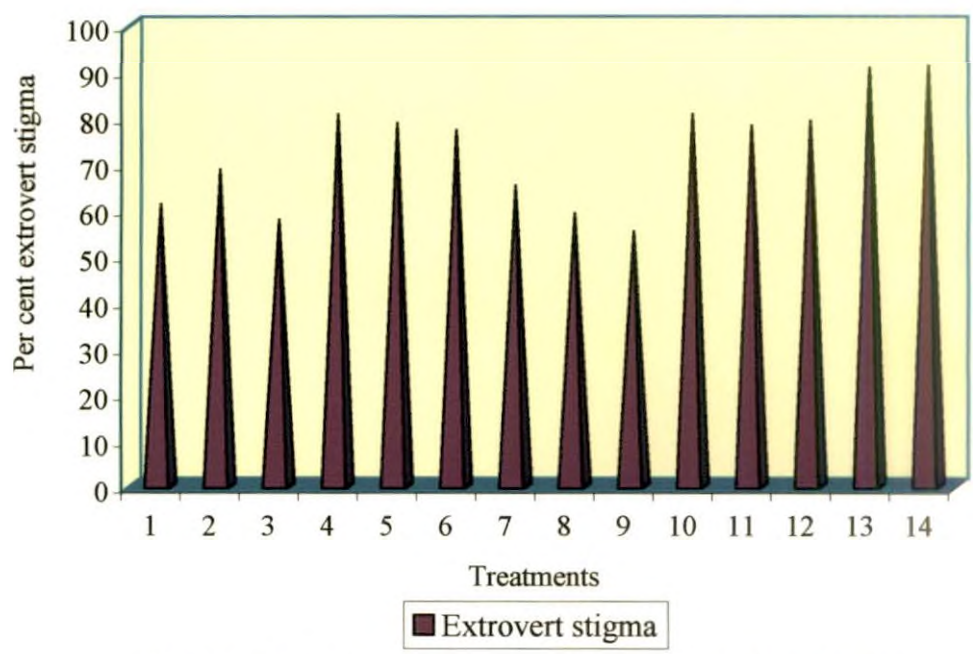


Fig. 22. Percentage of extrovert stigma as influenced by bioregulators

Table 23. Number of locules per fruit as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	2.50	2.50	2.50
T_2 - PCPA 50 ppm	2.50	2.50	2.50
T_3 - PCPA 75 ppm	2.50	2.50	2.50
T_4 - NAA 10 ppm	4.00	3.00	3.50
T_5 - NAA 20 ppm	3.00	3.00	3.00
T_6 - NAA 30 ppm	4.00	2.50	3.25
T_7 - CCC 25 ppm	2.50	2.50	2.50
T_8 - CCC 50 ppm	2.50	2.50	2.50
T_9 - CCC 75 ppm	2.50	2.50	2.50
T_{10} - 2,4-D 0.5 ppm	3.00	3.00	3.50
T_{11} - 2,4-D 1.0 ppm	5.00	3.50	4.25
T_{12} - 2,4-D 2.0 ppm	4.00	2.50	3.25
T_{13} - Water spray	3.50	3.00	3.25
T_{14} - No spray (control)	3.00	3.00	3.00
Mean	3.18	2.75	
CD (0.05%)	1.36	NS	1.27

The treatment T_{11} recorded a higher locule number (5.00) during rabi, which was on par with T_4, T_6 and T_{12}. The lowest locule number (2.50) was observed in treatments T_1, T_2, T_3, T_7, T_8 and T_9 (Fig. 23).

Though the locule number did not vary significantly among the treatments in summer, the highest locule number was recorded by the fruits from plants treated with T_{11} (3.50).

When both the seasons were compared, rabi recorded a higher locule number of 3.18 than summer, which recorded 2.75.Pooled analysis of data showed that 2,4-D 1.0 ppm produced fruits with more number of locules (4.25) whereas PCPA and CCC treated plants produced fruits with comparatively lower number of locules.

4.4.12 Malformations on plant and fruit

Vegetative malformations i.e., leaf abnormalities were observed in plants treated with PCPA whereas reproductive malformations i.e., fruit abnormalities were observed in plants treated with 2,4-D and CCC. In PCPA treated plants the vegetative malformations were observed 3-5 days after the application and continued up to 30-45 days.

All the concentrations of PCPA (25, 50 and 75 ppm) resulted in leaf abnormalities and it was more pronounced at higher concentration (75 ppm). Malformations observed were upward cupping of leaves and thickening of the leaf lamina. The leaf area was less at all the intervals i.e., 15, 30 and 45 DAT when compared to other treatments. About 90-100 per cent of the sprayed plants showed malformations.

Reproductive (fruit) malformations were more pronounced (20-30 percent) in 2,4-D treated plants that produced fruits with tail like out growth while CCC treated plants produced double fruits (2-5 percent).

4.5 BIOCHEMICAL CHARACTERS

4.5.1 Total Soluble Solids

There was a significant variation among the treatments for TSS during both the seasons (Table 24).

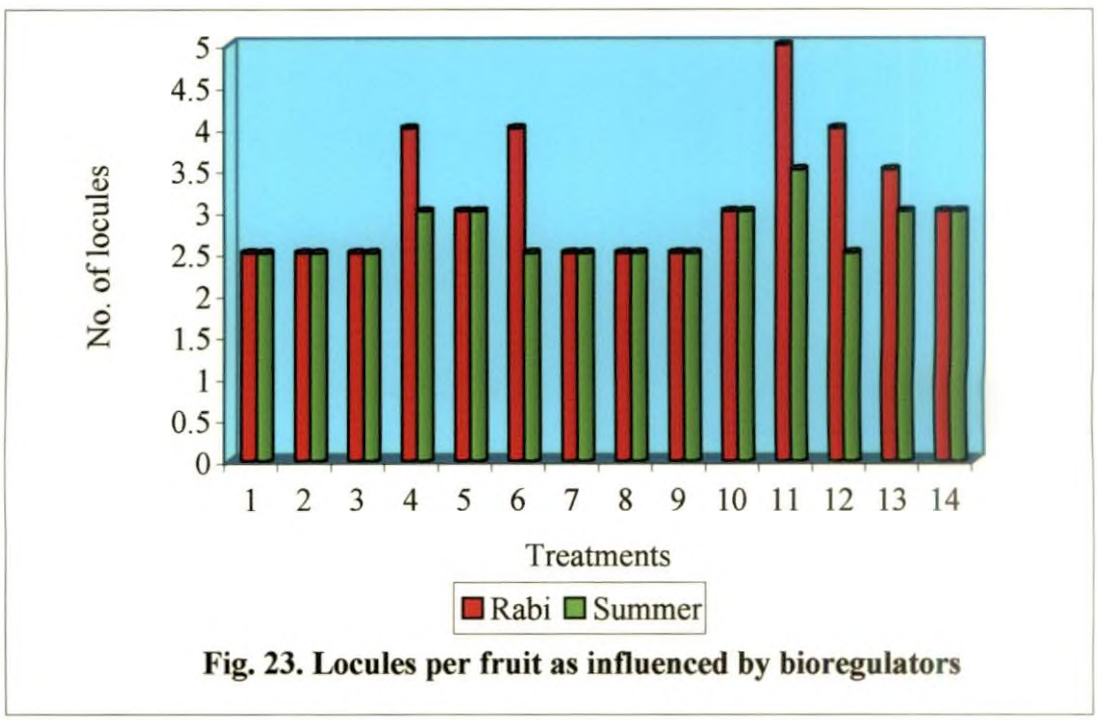
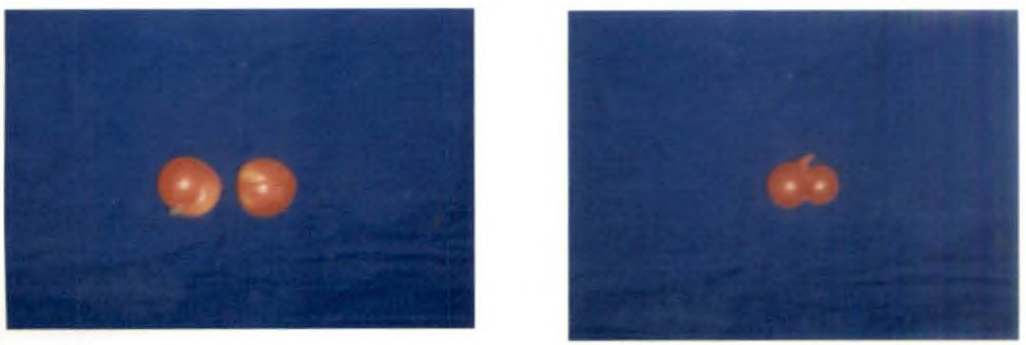
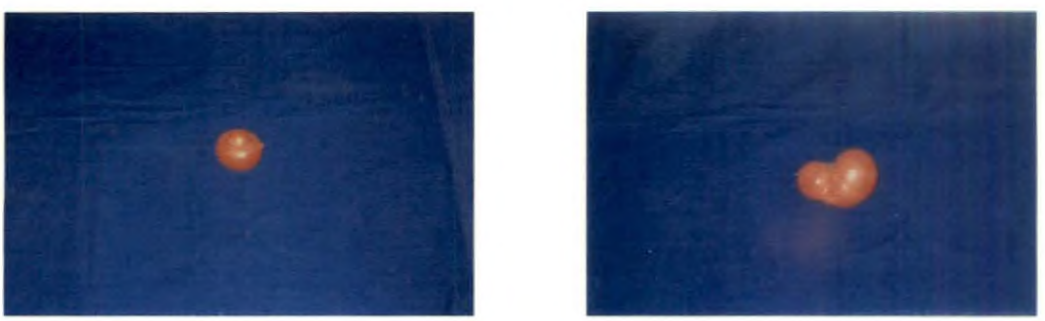


Fig. 23. Locules per fruit as influenced by bioregulators



a) 2,4-D 2 ppm



b) CCC 50 and 75 ppm

Plate 3. Fruit malformations caused by bioregulators

Table 24. Total soluble solids (TSS °Brix) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	6.20 (12.72)	5.10 (-3.77)	5.65
T_2 - PCPA 50 ppm	6.70 (21.81)	5.10 (-3.77)	5.90
T_3 - PCPA 75 ppm	5.80 (5.45)	5.30 (0.00)	5.55
T_4 - NAA 10 ppm	5.10 (-7.27)	4.60 (-13.20)	4.85
T_5 - NAA 20 ppm	5.00 (-9.09)	5.00 (-5.60)	5.00
T_6 - NAA 30 ppm	5.30 (-3.63)	4.60 (-13.20)	4.95
T_7 - CCC 25 ppm	5.40 (-1.81)	4.90 (-7.54)	5.15
T_8 - CCC 50 ppm	5.20 (-5.45)	4.30 (-18.86)	4.75
T_9 - CCC 75 ppm	4.20 (-23.63)	4.20 (-20.75)	4.20
T_{10} - 2,4-D 0.5 ppm	4.20 (-23.63)	4.50 (-15.09)	4.35
T_{11} - 2,4-D 1.0 ppm	5.40 (-1.81)	5.20 (-1.88)	5.30
T_{12} - 2,4-D 2.0 ppm	5.20 (-5.45)	5.00 (-5.66)	5.10
T_{13} - Water spray	5.10 (-7.27)	5.10 (-3.77)	5.10
T_{14} - No spray (control)	5.50	5.30	5.40
Mean	5.30	4.87	
CD (0.05%)	0.51	0.27	0.74

Values in parentheses is the percentage increase/decrease over control.

During rabi, the highest TSS content (6.70°brix) was observed in fruits obtained from the plants under treatment T_2. The treatment T_1 was found to be on par with T_2. The lowest TSS content (4.20°brix) was recorded in fruits obtained from plants under with T_9 and T_{10}. Fruits from control plants recorded a TSS content of 5.50°brix (Fig. 24).

During summer, the highest TSS content was observed in fruits from plants under treatments T_3 and T_{14} (5.30° brix). The treatments T_{11}, T_2, T_1 and T_{13} were on par with the above two treatments. The lowest TSS content was recorded by fruits obtained from treatment T_9 (4.20° brix).

On comparing both the seasons, rabi recorded a higher TSS content of 5.30° brix than summer that recorded 4.87° brix. Pooled analysis of data showed that PCPA 50 ppm recorded the maximum TSS content (5.90° brix) whereas it was minimum for T_9 (CCC 75 ppm) treated plants (4.20° brix).

4.5.2 Ascorbic acid content

A significant difference was noticed among treatments during both seasons for this character (Table 25).

During rabi, maximum ascorbic acid content of 46.00 mg per 100 g of fruit was obtained from the treatment T_9. The treatments T_{14}, T_{13} and T_8 were on par with T_9.The plants under treatment T_{12} recorded the lowest ascorbic acid content (31.50 mg per 100 g).

During summer, fruits from control (T_{14}) plants recorded a higher ascorbic acid content of 41.00 mg per 100 g of fruit, which was on par with T_{13}. Minimum ascorbic acid content was obtained from plants under the treatments T_{11} and T_{12} both recording 32.50 mg per 100 g of fruit (Fig. 25).

When seasonal effect was studied it was observed that rabi recorded a slightly higher ascorbic acid content of 37.64 mg per 100 g of fruit than summer which recorded 35.34 mg per 100 g of fruit.

Pooled analysis of data over two seasons revealed that control plants recorded a higher ascorbic acid content of 42.80 mg per 100 g fruit whereas it was

Table 25. Ascorbic acid content (mg/100 g fruit) as influenced by bioregulators

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 - PCPA 25 ppm	37.85 (-15.13)	36.30 (-11.46)	37.08
T_2 - PCPA 50 ppm	37.60 (-15.69)	35.90 (-12.43)	36.75
T_3 - PCPA 75 ppm	37.50 (-15.91)	36.60 (-10.73)	37.05
T_4 - NAA 10 ppm	33.35 (-25.22)	35.50 (-13.41)	34.43
T_5 - NAA 20 ppm	37.35 (-16.25)	33.00 (-19.51)	35.18
T_6 - NAA 30 ppm	36.05 (-19.17)	33.00 (-19.51)	34.53
T_7 - CCC 25 ppm	33.85 (-24.10)	35.00 (-14.63)	34.43
T_8 - CCC 50 ppm	42.40 (-4.93)	34.50 (-15.85)	38.45
T_9 - CCC 75 ppm	46.00 (3.13)	33.50 (-18.29)	39.75
T_{10} - 2,4-D 0.5 ppm	33.50 (-24.88)	35.00 (-14.63)	34.25
T_{11} - 2,4-D 1.0 ppm	32.85 (-26.34)	32.50 (-20.73)	32.68
T_{12} - 2,4-D 2.0 ppm	31.50 (-29.37)	32.50 (-20.73)	32.00
T_{13} - Water spray	42.60 (-4.48)	40.50 (-1.21)	41.55
T_{14} - No spray (control)	44.60	41.00	42.80
Mean	37.64	35.34	
CD (0.05%)	2.93	2.35	8.18

Values in parentheses is the percentage increase/decrease over control.

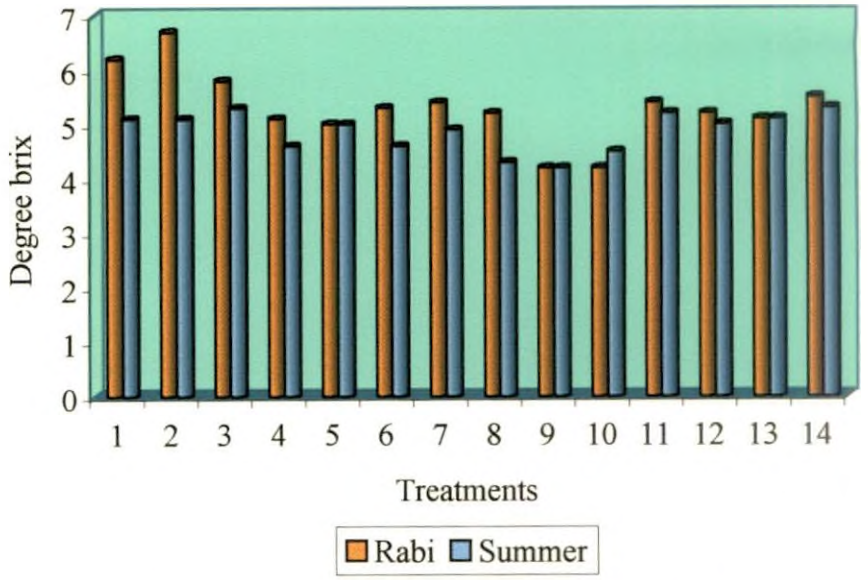


Fig. 24. TSS as influenced by bioregulators

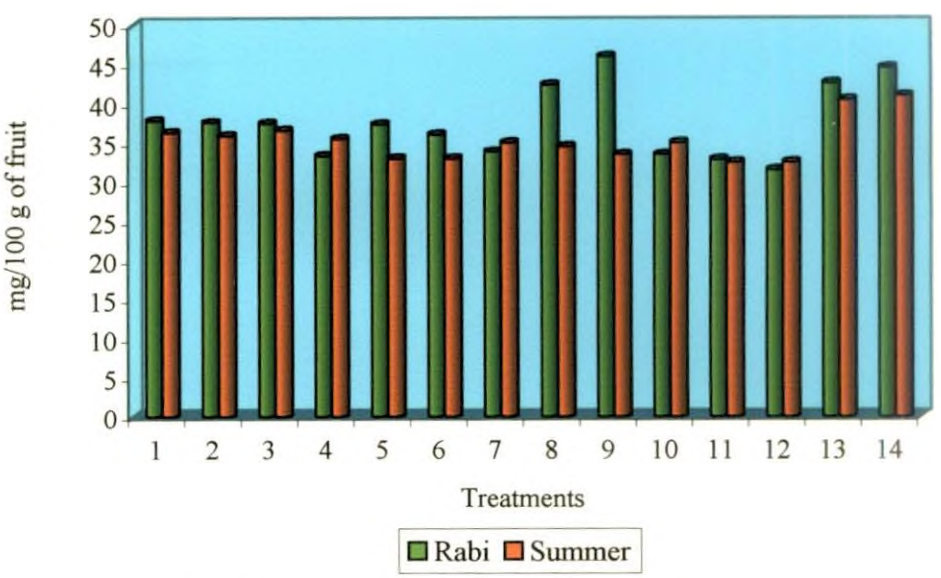


Fig. 25. Ascorbic acid as influenced by bioregulators

Table 26. Percentage incidence of *Cercospora* leaf spot as influenced by bioregulators

Treatments	Seasons	
	Rabi	Summer
T_1 - PCPA 25 ppm	9.52	X
T_2 - PCPA 50 ppm	9.09	X
T_3 - PCPA 75 ppm	10.00	X
T_4 - NAA 10 ppm	30.00	X
T_5 - NAA 20 ppm	22.22	X
T_6 - NAA 30 ppm	33.33	X
T_7 - CCC 25 ppm	14.28	X
T_8 - CCC 50 ppm	10.00	X
T_9 - CCC 75 ppm	13.63	X
T_{10} - 2,4-D 0.5 ppm	20.00	X
T_{11} - 2,4-D 1.0 ppm	16.67	X
T_{12} - 2,4-D 2.0 ppm	18.68	X
T_{13} - Water spray	31.81	X
T_{14} - No spray (control)	40.00	X

minimum for the treatment T_{12} (2,4-D 2.0 ppm) which recorded 32.00 mg per 100 g of fruit.

4.6 INCIDENCE OF PEST AND DISEASE

No major insect pest was noticed in the crop during the entire cropping period. However, fruit borer attack was noticed during the early stage, which was immediately controlled. Nevertheless, diseases like bacterial wilt, spotted wilt, leaf curl and *Cercospora* leaf spot affected the rabi crop. All the diseases were promptly controlled at the early stages except the *Cercospora* leaf spot. Its incidence was very high and the disease was uncontrollable at the later stages of the crop.

The percentage incidence of *Cercospora* leaf spot was calculated during both the seasons (Table 26). The incidence was negligible during summer whereas it was more pronounced during rabi. Minimum incidence was noticed in plants treated with PCPA and CCC whereas it was maximum in NAA treated plants and control plants. The percentage incidence was between 9 and 10 in PCPA treated plants while it was between 10 and 15 in CCC treated plants. The plants in the control plot recorded the highest percentage incidence of 40.00. Among the bioregulators NAA recorded a higher per cent incidence of 33.33. All the NAA treated and the water sprayed plants recorded more than 30 per cent disease incidence.

Discussion

5. DISCUSSION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important commercial vegetables. It is the world's largest grown vegetable crop after potato and sweet potato, but tops in canned vegetables. A rich source of minerals, vitamins and organic acids, tomato production is nutritionally as well as economically quite promising. Its production in Kerala is limited because of high incidence of bacterial wilt and high temperature during summer resulting in flower abscission and reduced fruit set, which in turn is reflected on the poor crop stand and yield of the plant.

The growth and development of a plant is influenced by the genetic makeup, its environment and number of internal factors mainly growth substances. The growth substances alter the physiological activities of the plant and improve the physiological effects including photosynthetic ability of the plants and productive potential of crops.

Exogenous application of bioregulators has been found useful in improving yield and quality by altering the endogenous growth substances. The application of bioregulators was found as an effective tool in improving the growth and productivity in many vegetable crops like tomato, chilli, okra, cucurbits, etc. (Verma and Choudhary, 1980 and Thakur and Arora, 1986).

In the present investigation, the effect of four bioregulators viz., PCPA, NAA, CCC and 2,4-D in influencing the growth and productivity during rabi and summer in tomato was studied. The different treatments were compared with water spray and unsprayed control. The results obtained are discussed below.

5.1 VEGETATIVE CHARACTERS

The effect of bioregulators on vegetative characters like height of the plant and number of branches were more pronounced during rabi than summer.

In both the seasons plants treated with NAA produced taller plants. In rabi the plants treated with NAA 20 ppm (T_5) produced the tallest plants (57.15 cm) closely followed by plants treated with NAA 10 ppm (T_4) which

recorded a height of 54.20 cm. During summer the plants treated with NAA 10 ppm (T_4) produced taller plants with 43.15 cm, closely followed by NAA 20 ppm (T_5) with 42.05 cm.

A significant increase in plant height observed on applying NAA is in consonance with the findings of Singh and Upadhyay (1967) and Resmi (2001). The increase in plant height due to NAA may be due to the initiation of cell division and cell elongation through continued synthesis of RNA and protein. Also the exogenous application of auxin causes pH changes in terms of H^+ extrusion and H^+ inturn leads to wall loosening causing cell elongation (Dhanalakshmi *et al.*, 1996). The increase in height may also be due to apical dominance, i.e., suppression of lateral buds perhaps by keeping ABA high and cytos low.

The application of NAA might have increased the growth of plants due to the stimulation of root growth and increased metabolic activity causing increased uptake of nutrients from the soil. This is in accordance with the findings of Chippa and Lal (1988) in soybean. Elongation of main axis is also due to the osmotic uptake of water under the influence of growth regulators, which maintain a swelling force against softening of cell wall.

The reduction in height was observed in plants treated with CCC. The effect was more as the concentration increased. The shortest plants were obtained by treating with 75 ppm CCC (T_9) during both the seasons. The treatment produced plants with a height of 38.65 cm and 36.00 cm during rabi and summer respectively.

The reduction in height of the plants by CCC may be due to the fact that CCC acts as a growth retardant. The reduction in height can also result from the reduction in the growth of auxillary buds that might have changed the distribution pattern of assimilates. This is in consonance with the reports of Choudhary *et al.* (1976) in potato and Phookan *et al.* (1991) in tomato.

Kuraishi and Muir (1963) inferred that the restriction of plant height by growth retardant was mainly due to the reduction in diffusible auxin level in plant tissue. It has also been well documented that tertiary ammonium compounds

like CCC produced reduction in height without any malformation by reducing cell elongation and by lowering the rate of cell division (Rademacher, 1991). Briston and Simmonds (1968) suggested that in CCC treated plants, the functional form of gibberellic acid disappears and an increase in bound form is noticed, which may be the possible reason for the retardation of growth.

The plants treated with CCC at all concentrations produced more number of branches in both the seasons compared to other treatments. The plants treated with CCC 75 ppm (T_9) produced 7.90 and 5.55 branches during rabi and summer respectively.

More number of secondary branches by the foliar application of CCC was in accordance with the findings of Williams and Malhotra (1983) and Resmi (2001) while the report of Kumar (1984) was contradictory. Since CCC is a growth retardant its anti-gibberellic action will naturally reduce the elongation of the main axis and hence resulted in more auxillary branches.

The change in branching habit by CCC treatment may possibly be due to stimulation of breaking up of apical dominance thereby changing the auxin balance which is the controlling factor (Rademacher, 1991). Hinson and Hanson (1962) have also reported that certain amount of control on apical dominance could invariably result in accelerated development of auxillary buds into new branches.

Treatment with NAA at lower concentration (10 ppm) has also been observed to increase the number of branches. Similar results were obtained by Singh and Kumar (1988) and Tagade *et al.* (1999), which was attributed to the beneficial effects of NAA on cell division and cell elongation.

Application of 2,4-D and PCPA at all concentrations reduced the plant height and number of branches during both the seasons. This was in contradiction with the reports of Choudhary and Singh (1960), Adlekha and Verma (1964) who reported that 2,4-D increased the plant height and the number of branches. Application of PCPA has led to the malformation of leaves and branches. The malformations noticed were upward cupping of leaves and thickening of the lamina.

The reduction in plant height and number of branches due to the application of 2,4-D may be due to its herbicidal action. Though primarily a weedicide, 2,4-D has found wide application for the regulation of various growth responses when used in low concentration. Kuraishi and Muir (1963) inferred that the restriction in plant height was mainly due to reduction in diffusible auxin level in the plant tissues. Reduction in plant height was primarily due to decreased photosynthetic area caused by retardation of cell division and cell elongation mostly at the sub apical meristem brought about by its application.

The beneficial effect of growth regulators in influencing plant height and spread could be attributed to the increased rate of photosynthetic products entering the system resulting in cell elongation and rapid cell division at the growing portion as suggested by Randhawa and Singh (1970).

5.2 GROWTH PARAMETERS

Growth parameters like RGR, NAR, LAI, CGR and LAD were calculated and analysed statistically. Variation in growth parameters was noticed due to the influence of bioregulators. The growth parameters showed the maximum values at the second stage (30-45 DAT), which is the peak period for metabolic activities in terms of development of sink structures and active translocation of photoassimilates (Patil and Dhomne, 1998).

The CGR and RGR were found to vary among treatments and were found to follow a similar trend. The plants treated with NAA and CCC recorded the maximum CGR and RGR values. Though the values increased as the stages advanced, for all the treatments, the percentage increase was found to vary among the treatments. The plants treated with 2,4-D 2 ppm (T_{12}) showed the maximum increase of CGR during both the seasons with 181.95 and 43.25 per cent during rabi and summer respectively while the per cent increase of RGR was maximum for 2,4-D during rabi and PCPA during summer. The plants treated with PCPA recorded the least per cent increase of CGR. The maximum value of CGR was observed in plants treated with CCC at all levels followed by NAA treatments. In rabi, though CCC 75 ppm recorded the highest CGR during first stage, the maximum CGR during second stage was recorded by NAA 30 ppm. This might be

due to the retardant action of CCC. In summer CCC 50 ppm recorded the maximum CGR values during both the stages with 0.413 and 0.605 g m^{-2} day^{-1}.

The RGR represents the efficiency of the plants as a producer of new materials or it denotes the efficiency index of plants. Like CGR the plants treated with CCC recorded the maximum values for RGR followed by NAA treatments. The plants treated with PCPA and 2,4-D recorded comparatively lower values for both CGR and RGR than control.

The LAI also showed a increasing trend up to 45 DAT and the per cent increase was more from first to second stage when compared to second to third stage. In rabi, the LAI was more or less same for all the treatments whereas NAA 30 ppm recorded the maximum LAI during the second and third stage with 6.52 and 9.11 respectively. When the per cent increase was calculated it was observed that NAA 30 ppm recorded a comparatively higher per cent increase when compared to other treatments with 71.57 and 39.72 per cent from first to second and second to third stage respectively. During summer, the CCC treated plants recorded higher LAI at all the three stages. Similar results were reported by Nawalagatti *et al.* (1991) and Reddy and Patil (1981). As LAI is a function of both the number of functional leaves and the average area of the leaf the increase in LAI over the stages can be attributed to increase in leaf area over the stages. It may also be due to the increase in leaf number as reported by Subramanian (1980).

The NAR measures the average productivity of the leaves. It denotes the increase in plant dry weight per unit assimilatory individual per unit time. The NAR was found to be higher in CCC treated plants, which was 19.71 per cent over the control at the second stage during rabi. This may be due to high translocation efficiency due to CCC treatments that was reflected from the high yield recorded during rabi season even at low LAI values. The role of hormones is a very important factor that affects source-sink relationship. The data indicated that NAR was increased during the second stage. The plants treated with CCC produced the maximum NAR during rabi whereas CCC and NAA treated plants produced maximum NAR during summer. This was in accordance with the reports of Sujatha and Rao (2001) in finger millet. The per cent increase was maximum for 2,4-D 2 ppm during both the seasons with 106.00 and 24.21 per cent during rabi

and summer respectively. This increase in NAR resulted in increased total dry matter production as evidenced from high per cent increase of RGR and CGR values but not the yield.

On comparing the NAR and LAI values it was observed that increase in LAI resulted in decrease in NAR i.e., LAI is inversely related to NAR, which is in accordance with Watson (1958). This may be due to the mutual shading of the lower leaves by the expanding upper leaves, as LAI indicates the leafiness of the plant. A negative correlation between LAI and NAR was observed by Patil and Dhomne (1998). The shading might have resulted in decreased photosynthetic efficiency, which in turn reflected on the NAR values. The LAI at which maximum NAR was recorded can be considered as the critical LAI. In this study a LAI of 5-5.2 and 6.7-6.8 during second and third stage in rabi and 6.1-6.5 and 6.6 during second and third stage in summer was found to be critical which recorded the maximum NAR. Though the CCC treated plants produced the maximum NAR the LAI was comparatively lower which was according to the concept of negative correlation between LAI and NAR. The superiority of the CCC and NAA treated plants might be due to the improved crop architecture brought through the chemical manipulation as suggested by Nawalagatti *et al.* (1991) in groundnut.

The LAI and LAD followed a similar trend during both the seasons. LAD increased with increase in LAI. Maximum LAD was recorded in plants treated with NAA in rabi and CCC in summer. This might be due to the high chlorophyll retention capacity and stress tolerance of the plants treated with CCC in summer. NAR and LAD, like LAI were negatively correlated. LAD was more for the NAA treated plants (10, 20 and 30 ppm) resulted in higher RGR values that indicate high dry matter production, which was evident from the high LAI values. But the per unit area production of photo assimilates was low. In CCC treated plants the LAD was comparatively lesser than in NAA thereby reducing the LAI and dry matter production but high NAR. This indicates the improved partitioning capacity of the CCC treated plants as evidenced from the increased yield.

The CCC and NAA treated plants improved all the growth parameters than control while the PCPA and 2,4-D treated plants reduced all the characters than control.

5.3 EARLINESS

Earliness in flowering and fruiting is an indication of early transformation of plants to reproductive phase (Das and Rabha, 1999) and it is considered as a desirable character and helps the farmers to market the produce early in the season. Days to first flower and first harvest are considered as indicators of earliness. In the present investigation, the rabi season crop was early for the number of days to first flower (33.32) and first harvest (62.25) compared to summer crop.

Days to first flower and first harvest did not vary significantly among the treatments during the first season i.e., rabi. However, significant difference was observed among treatments for both the characters during summer. Though there was no significant difference during rabi, the plants treated with NAA at all concentrations (T_4, T_5 and T_6) produced flowers and fruits earlier than other treatments.

Earliness was noticed in the plants treated with PCPA in summer. The plants treated with PCPA 50 ppm (T_2) flowered earlier (33.50 days) and the plants treated with PCPA 25 ppm (T_3) recorded the early yield (70.50 days). The overall performance of the crop during summer was not encouraging as the rabi season crop. This was mainly because of the high temperature and uneven distribution of summer showers. Another probable reason may be the reduced water uptake with high transpiration and photodegradation of exogenous growth substances.

In the present study, the PCPA treatments reduced the number of days taken for first flowering and first harvest by 10 days when compared to control. The earliness in flowering and harvest by PCPA treatments is in accordance with the findings of Kalloo (1986) who observed that PCPA is very effective in increasing yield especially under high temperature conditions. Treatment with PCPA might have increased the endogenous auxin, which in turn influenced the production of flower primordia.

Seasonal variation was observed in the effect of NAA and PCPA in inducing earliness in rabi and summer respectively. The bioregulator NAA was

found to have positive effect during rabi by directly increasing the endogenous growth substances like auxins and gibberellins which in turn might have helped in the early transformation of plants to reproductive phase. According to Menon (1981), NAA acts through fundamental processes like nucleic acid synthesis, enzyme synthesis and activation. This may be due to higher dry matter accumulation in the reproductive parts. Auxins are also reported to maintain the rate of RNA synthesis thereby delaying senescence (Osborne, 1963). The earliness and increased number of flowers by NAA can be attributed to the reason that florigen or flowering hormone which was synthesized under the influence of endogenous IAA, influencing the production of flower primordia. Similar results were obtained by Singh and Chhonkar (1965) in cabbage by the application of NAA.

All the bioregulators had a positive influence in inducing earliness when compared to control. In case of CCC the retardant property of the chemical might have restricted the vegetative growth resulting in an early transformation to reproductive phase. The reduction in endogenous gibberellin content through the application of CCC can also be a possible reason.

5.4 EXTROVERT STIGMA

Extrovert stigma is a condition of the exertion of the style due to high temperature condition. This affects anthesis and results in reduced fruit set.

Extrovert stigma was not observed during rabi season whereas it was pronounced in summer because of the high temperature. There was significant difference among the treatments in influencing the extrovert stigma percentage during summer.

Plants treated with CCC 75 ppm (T_9) recorded the least extrovert stigma (55 per cent) followed by treatment with PCPA 75 ppm (T_3) and CCC 50 ppm (T_8), which recorded 57.50 and 59.00 per cent respectively.

High temperature has been found to increase flower abscission and heterostyly. This may be due to the reduction in concentration of IAA or an increase in ABA, caused by high temperature. Exogenous application of auxin has

been found to be beneficial, under high temperature condition, to balance the auxin level (Abdalla and Verkerk, 1968; Levy *et al.*, 1978; El-Abd *et al.*, 1986). Kalloo (1986) has reported that PCPA was very effective for tomato in summer. Joseph and Peter (1980) observed a reduction in stylar length due to application of 2,4-D in tomato.

Though PCPA and CCC showed profound effect in decreasing the extrovert stigma percentage, all the bioregulators reduced the percentage of extrovert stigma considerably when compared to control.

5.5 FRUIT SET

Fruit set is the proportion of flowering that produces a fruit of a minimal size in the population of flowers, which appears to reach anthesis normally (Picken, 1984). This critical stage is affected by environmental factors and bioregulators.

Seasonal variation was observed for the percentage fruit set. The Percentage of fruit set was high during rabi (80.36) compared to summer (25.11) and was significantly influenced by the growth regulator treatments during both seasons. Stigma exertion beyond anther cone account for pollination failure and the length of the style is increased with increase in temperature (Rudich *et al.*, 1977). Extreme temperatures also limit the germination of pollen grains and inhibit the tube growth (Dempsey, 1970). Moreover stigma receptivity is also impaired by high temperature.

In rabi maximum percentage (93.00) of fruit set was obtained by treating plants with NAA 30 ppm (T_6) and was followed by CCC 50 ppm (89.20 per cent). The fruit set percentage was above 85 per cent in all the concentrations of NAA and CCC except NAA 25 ppm (80.60). In summer maximum percentage of fruit set was observed in plants under CCC and PCPA treatments. Treatment with CCC 75 ppm recorded the highest fruit set (42.00) followed by PCPA 75 ppm (T_3) and CCC 50 ppm (T_8). Application of all the bioregulators at all concentrations showed a significant increase in fruit set per cent than the control plants and water spray. The effect of bioregulators on increasing fruit set was more pronounced during summer.

The increased fruit set by NAA can be attributed to the preventive effect of NAA against flower drop (Akhtar *et al.*, 1996). It has also been documented that treatment with auxin activated carbohydrate metabolism and initiated fruit set. This is in accordance with the reports of Rajamani *et al.* (1990) in chilli and Lee *et al.* (1997) in brinjal. Treatment with NAA might have increased fruit set by stimulating more number of ovaries and preventing their subsequent abscission (Usha, 1988).

The cause for flower drop is attributed to the exhaustion of growth substances (Addicot and Lynch, 1955). External application of NAA might have co-interacted the low levels of auxins leading to increased fruit set. Treating the plants with NAA increased flower and fruit retention by decreasing the shedding of fertilised flowers. It is also suggested that the diffusable auxins moving from a dominant sink acts as a correlative signal resulting in abscission of competitive sinks. The plant bioregulators like auxins increased the allocation of dry matter to the developing fruits and seeds and thereby indicating their influence in reproductive potential of the plant (Zayed *et al.*, 1986).

Increased fruit set percentage by CCC may be due to its retardation effect that results in a sudden transformation from vegetative to reproductive phase. The bioregulator CCC also acts as an effective antitranspirant and decreases the stomatal closure resulting in an increase in water use efficiency of the crop. It prevents the stomatal opening by rapidly blocking H^+ extursion and K^+ influx and initiate closure by rapid release of osmotica, in particular K^+, Cl^- and malate, which results in shrinking of guard cells thereby decreasing transpiration (Moore, 1989).

Increased fruit set by CCC may be due to the increase in the number of flowers formed in the inflorescence due to the inhibiting level of endogenous gibberellins (Abdul *et al.*, 1978). It may also be due to the increase of endogenous levels of natural auxin and by the decrease of the gibberellin content by external application of growth retardants like CCC (Das, 1985). The application of CCC protects the natural auxins from enzymatic destruction (Henry and Gordan, 1980). This increased content of native auxins might have prevented flower abscission and increased fruit set. Moreover because of its retardant property CCC might have favoured the diversion of more assimilates to the reproductive parts (Islam and

Mitchsi, 1993). This relieves the plants off water and carbohydrate stress which could otherwise induce flower drop as reported by Rudich (1986) and Reddy and Shah (1987). The application of CCC also increases the chlorophyll retention activity of plants even during summer and hence helps the crop to overcome the stress. The increase in fruit set by CCC may be due to the decrease in diffusible GAs by the CCC, while also reducing the abortion induced by high temperature.

Higher fruit set due to PCPA treatment in summer may be attributed to increased percentage of introvert stigma. The decreased fruit set in summer can be attributed to the high temperature. It is reported that as the temperature increases, the rate of stem elongation (Calvert, 1964) and shoot:root dry weight ratio (Kristoffersen, 1963) are also increased. The conditions that induce higher shoot:root ratio are more detrimental to reproductive development. One of the most obvious effects of temperature is the premature failure as increasing temperature triggers abortion. High temperature is particularly detrimental 9-5 days before anthesis during sporogenesis (Calvert, 1969). Water availability also affects flower formation and later fruit enlargement (Wudiri and Henderson, 1985). It was also reported that severe stress reduces fruit set by 40 to more than 90 per cent.

5.6 FRUITS PER PLANT

Number of fruits per plant was high for the plants treated with 2,4-D 0.5 ppm (20.86) during rabi. The other 2,4-D treatments (1 and 2 ppm) were also on par with 2,4-D 0.5 ppm. Similar results were obtained by Singh and Kumar (1988). The increased fruit number might be due to the decrease in size of the fruits, which might be due to the reduced vegetative growth of the plants treated with 2,4-D.

In summer, the number of fruits was maximum in plants treated with PCPA 75 ppm, CCC 50 and 75 ppm. This may be due to the decreased percentage of extrovert stigma and increased percentage of fruit set recorded by these treatments. All the bioregulator treatments increased the number of fruits than control during both the seasons. Phookan *et al.*, 1991 in tomato, have reported increase in number of fruits by NAA and CCC application. Akhtar *et al.* (1996) also obtained similar results.

Treatment with higher concentration on PCPA was also effective in increasing the fruit number during both the seasons. NAA at higher concentrations was found to be effective during rabi while CCC (50 and 75 ppm) was found to be effective during summer. This is in accordance with the reports of Singh and Uphadhyay (1967) for NAA and Zayed *et al.* (1986) for CCC. Auxin directed the transport of nutrients, hormones and photosynthates as reported by Krishnamoorthy (1981) must have favoured increased fruit set and number of fruits. Increased chlorophyll content resulting from CCC application (Sutti, 1989) together with high C/N ratio resulting from the reduced vegetative growth explains the retention of more number of fruits (Rukmani, 1990). Increase in fruit number by bioregulator application has also been reported by Sorte *et al.* (2001) in brinjal.

The number of fruits per plot was maximum in 2,4-D treated plants during rabi while PCPA and CCC treated plants recorded the maximum number of fruits during summer.

5.7 FRUIT SIZE

In both the seasons, fruits from plants treated with CCC 50 and 75 ppm (T_8 and T_9) recorded higher fruit weight and volume. The maximum fruit weight was recorded by the plants treated with CCC 75 ppm (35.35 g in rabi and 32.64 g in summer), which was on par with CCC 50 ppm (35.07 g and 31.94 g in rabi and summer respectively). The plants treated with CCC 75 ppm (T_9) produced fruits with maximum volume in both the seasons with 37.15 cm^3 and 34.00 cm^3 during rabi and summer respectively.

The increase in fruit weight and volume may be the output of increased photosynthetic efficiency, which resulted in accumulation of carbohydrate leading to formation of larger and heavier fruits. This is in accordance with the findings of Sharma (1995) and Muralidharan *et al.* (2000) in tomato. The increased fruit weight and volume by CCC application may be due to its chlorophyll retention ability in the leaf, which in turn increases the translocation from source to sink (reproductive parts). The bioregulator CCC also acts as a stress hormone that enables the plant to tolerate drought and high temperature prevailing during summer, thereby overcoming the adverse climatic conditions. Application of CCC

might also have increased the overall photosynthetic potential which might have enabled the crop to produce more drymatter and accumulate in reproductive parts. A significant increase in fruit weight with the application of bioregulators indicated a higher partitioning of assimilates towards vegetative growth. This might have enabled the crop to produce higher dry matter production and accumulation in reproductive parts. It also enhanced the photosynthesis and reproductive efficiency in plants which developed morphological alteration in plant height, number branches, leaf area, etc.

All the bioregulators except 2,4-D had a positive influence on fruit size than control during both the seasons. 2,4-D had negative effect on fruit weight and volume. The plants treated with 2,4-D 2 ppm (T_{12}) recorded the minimum fruit weight (26.73 g) and fruit volume (28.10 cm^3) in rabi. In summer the plants treated with 2,4-D 0.5 ppm (T_{10}) recorded the minimum fruit weight (28.63 g) and those treated with 2,4-D 2 ppm recorded the minimum fruit volume (27.40 cm^3). This is in contradiction with the reports of Raj (1985) who reported that 2 ppm of 2,4-D increased fruit length and average fruit weight in chilli and Singh and Kumar (1988) who reported 2,4-D 5 ppm increased fruit weight in okra.

5.8 FRUIT YIELD

In the present study, maximum fruit yield per plant was obtained from CCC treated plants in both the seasons. The plants treated with CCC 75 ppm (T_9) produced the maximum yield of 0.63 kg during rabi and 0.20 kg during summer. The increase in fruit yield was 33.18 and 383.33 per cent over control during rabi and summer respectively, which accounts to an additional yield of 4.47 and 4.46 tonnes per hectare during rabi and summer respectively. In rabi the treatments CCC 50 (T_8) ppm, NAA 30 ppm (T_6) and CCC 25 ppm (T_7) were on par with CCC 75 ppm with fruit yield of 0.62, 0.61 and 0.59 kg per plant respectively. In summer the treatments PCPA 75 ppm (0.20 kg) and CCC 50 ppm (0.19 kg) were on par with CCC 75 ppm.

In both the seasons fruit yield per plot was maximum from the plot that received CCC 75 ppm with 12.64 and 4.06 kg during rabi and summer respectively. All the bioregulator treatments increased the yield over control. The

per cent increase was more pronounced during summer than rabi. The treatment T_9 (CCC 75 ppm) increased the yield by 34.18 and 383.33 per cent during rabi and summer respectively.

The increase in yield by CCC treatment can be attributed to the control of early vegetative growth and regulation of early flowering as reported by Arora and Kalloo (1984) in tomato and Belakbir *et al.* (1998) in chilli. Increased chlorophyll content resulting from CCC application explains the yield increase due to its application (Usha, 1988).

The increase in yield may also be due to increase in the utilization of photosynthates and nutrients for the development of fruit as a result of reduction in vegetative growth as reported by Pandita and Hooda (1979), Sekhon and Singh (1985) and Phookan *et al.* (1991). The increase in yield by CCC can also be due to delay in senescence of leaves and increase in lateral branches (Bangal *et al.*, 1982).

In chilli it was reported that the increase in yield may be due to stimulated branching and better fruit characteristics by application of CCC (Mahmoud, 1983a).

According to Marisiddaiah and Gowda (1978), the enhanced yield due to growth retardants could be due to the cumulative effects of greater vigour with decreased plant height and additional sites for inflorescence and possibly more efficient utilisation of photosynthates in the ultimate production and development of fruits. Arora and Kalloo (1984) reported similar findings.

The increase in yield by NAA may be due to the augmentation of auxin supply from leaves by the foliar application of NAA thereby helping in development of better root system for more uptake of nutrients from the soil. NAA sprayed crop allows higher degree of translocation of carbohydrates from stem to fruits.

A probable reason for the increased yield by growth regulators is that the plant remained physiologically more active to build up sufficient food stock for developing flowers and fruit ultimately leading to increased yield (Randhawa and Singh, 1970). The increase in the fruit yield by CCC and NAA may also be due to

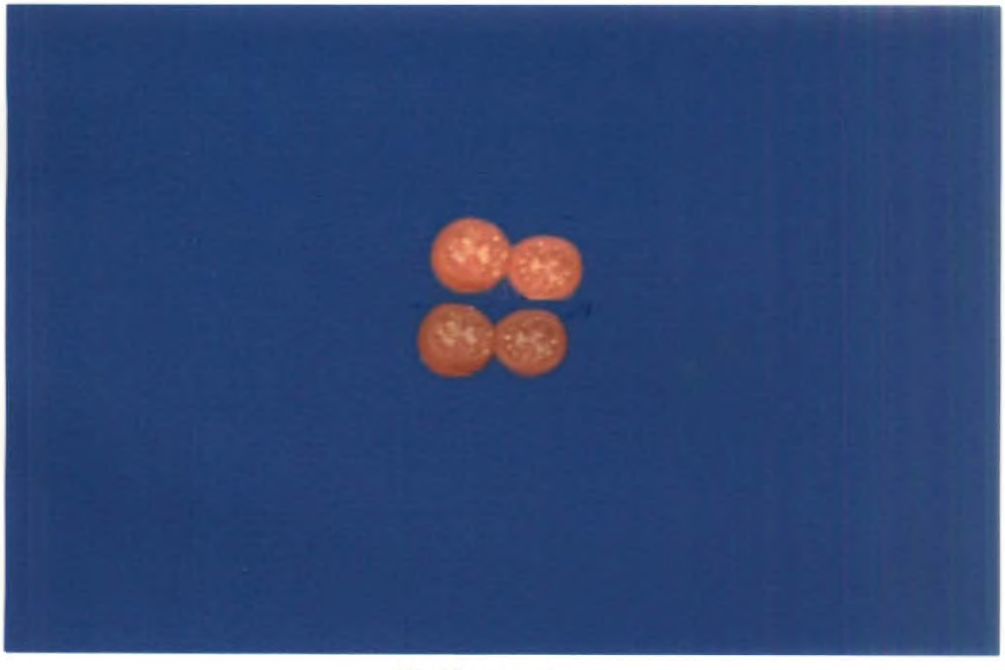
the increase in the number of branches and fruit set percentage during both the seasons. The yield increase by PCPA during summer might be due to the increased per cent of introvert stigma and number of fruits. The superiority in productivity by CCC and NAA is manifested mainly by through their influence in reducing flower and fruit drop.

The vegetative malformation observed during rabi seasons by PCPA application might have reduced the formation of active photosynthetic source area and well developed sink for dry matter production and accumulation respectively. The increased chlorophyll b content in PCPA sprayed plant might have disturbed the normal enzyme production system and other biochemical and physiological activities of the plant (Resmi, 2001).

5.9 FRUIT CHARACTERS

Seeds per fruit did not show a positive influence on the seed number as control plants recorded the maximum number of seeds per fruit (145.00) followed by water spray (129.50). Among the bioregulators CCC treated plants recorded the maximum number of seeds per fruit. Though primarily seed number is not a factor influencing fruit size it has been reported that seed number and fruit size are directly correlated which might be a reason for the increased fruit size of CCC treated plants. The plants treated with PCPA at higher concentrations (25 and 50 ppm) and 2,4-D at all concentrations produced parthenocarpic fruits with only seed remnants. It has been reported that 4-CPA increases the endogenous IAA content and it was supposed that 4-CPA, a synthetic auxin, could induce fruit growth by its own auxin activity. These facts suggested that the main factor for parthenocarpic fruit set induced by exogenous plant hormones was not the appliied plant hormones themselves, but the newly synthesised IAA (Lee *et al.*, 1997). He also reported that auxin treatment might activate carbohydrate metabolism and initiate fruit set. Corella *et al.* (1986) observed that auxin treatment reduced the proportion of fruits with seeds. Similar results were obtained by El-Habbasha *et al.* (1999). Ali (1964) proved that auxins are the agents, which stimulate the ovaries to develop. He demonstrated that synthetic auxins (like 2,4-D and PCPA) induced unpollinated ovaries to develop into full sized fruits and retaining them till maturity.

a) PCPA and 2,4-D



b) Control

Plate 4. Parthenocarpic fruits by application of bioregulators

Percentage of cracked fruits was calculated and the character was influenced by the application of bioregulators. It was more during rabi (34.29 per cent) than summer (18.32 per cent). During both the seasons the plants treated with CCC recorded the minimum cracking percentage. CCC 75 ppm (T9) recorded 27 per cent cracking during rabi and CCC 25 ppm (T7) recorded 12 per cent during summer which was 37.93 and 47.83 per cent respectively less than control. All the bioregulator treatments reduced the cracking per cent when compared to control.

High per cent of cracking during rabi may be due to the fact that cracking is common during rainy season when rain follows a dry spell. Moreover presence of water on the surface of the fruits was found to be conducive to cracking. Low per cent of cracking due to treatment with CCC might be due to the thick foliage causing shading of the fruits and low sugar content. This is in accordance with the findings of Nueuchi (1963) who reported that cracking and sugar content are directly related. Higher sugar level causes a difference in water potential in the fruits resulting in the movement of more water from other plant parts, thus exerting a greater pressure on fruit skin which results in cracking (Kumar, 1995). This may be due to high elasticity of fruit skin. The pectin content of the fruits has also been reported to influence cracking in fruits. The friable nature of the pectin molecules would have contributed to make outer skin of the fruit less rigid (Kumar, 1995). Low acidity, thicker fruit skin and pericarp have also been reported as possible reasons for low crack incidence.

Control plants and plants treated with 2,4-D recorded maximum number of cracked fruits. High percentage of cracking due to 2,4-D may be due to the defoliation caused by 2,4-D as its herbicidal effects (Kalloo, 1986).

Locule number per fruit was influenced by bioregulators during rabi while they did not have any influence during summer. The plants treated with NAA and 2,4-D produced fruits with maximum number of locules. The bioregulators PCPA and CCC treated plants produced fruits with comparatively low number of locules when compared to control. The plants treated with 2,4-D produced fruits with 5 locules and NAA 10 and 30 ppm produced fruits with 4 locules. Almost all the other bioregulators produced fruits with an average number of 2.5 locules per fruit. The locule number was more during rabi (3.18) than

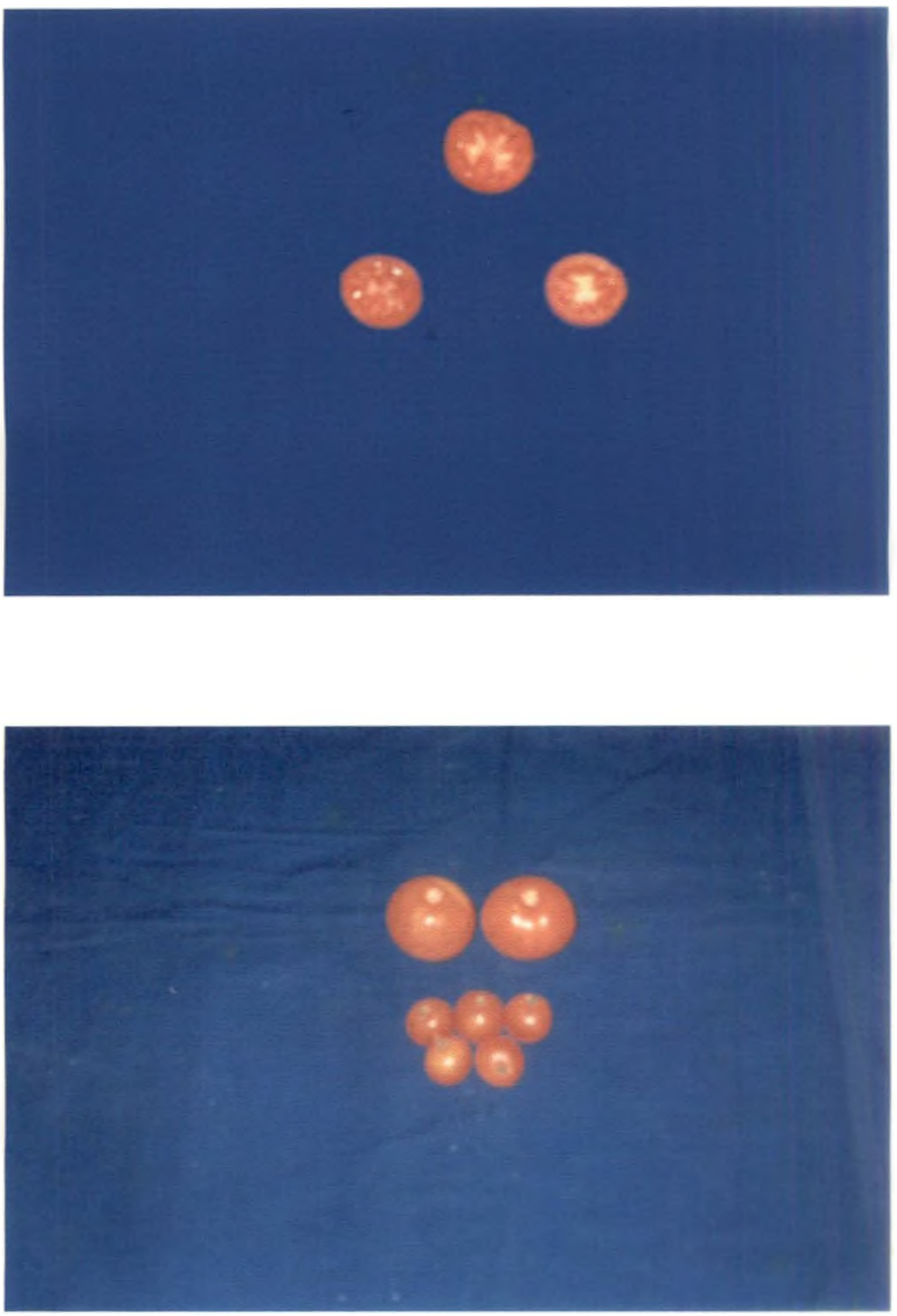


Plate 5. Locule number and fruit size by application of bioregulators

summer (2.75). This may be due to the fact that locule number was found to increase at low temperature compared to high temperature as reported by Kalloo (1986).

5.10 BIOCHEMICAL CHARACTERS

Bioregulators have been reported to increase the TSS and ascorbic acid content. But in the present study, during rabi all the bioregulators except PCPA (at all concentrations) recorded a lower value of TSS than control while during summer no bioregulator had a positive influence on TSS. This was contradictory to the reports of Bokhari (1982), Bisaria and Rastogi (1988), Phookan *et al.* (1991) and Akhtar *et al.* (1996) who reported that bioregulators (NAA and CCC) increasd TSS in tomato fruits.

The plants treated with PCPA 50 ppm recorded the highest TSS value (6.70° Brix) during summer, which may be due to the accelerated photosynthetic efficiency and translocation of photosynthates from leaves to fruits (Singh and Saxena, 1983, Bisaria and Rastogi, 1988 and Muralidharan *et al.*, 2000). This may also be due to the continued mobilization of more sugars at fruit set which was in accordance with the reports of Satti and Oebker, 1986.

Ascorbic acid content was also not influenced by bioregulators. The plants treated with CCC 75 ppm recorded the maximum ascorbic acid content of 46.00 mg per 100 g fruit in rabi while all the bioregulators were found to be ineffective in influencing the ascorbic acid content of the fruit during summer. Control plants recorded the maximum ascorbic acid content of 41.00 mg per 100 g of the fruit. In rabi also all the other bioregulators had a negative influence on the ascorbic acid content of the fruits. The results were contradictory to the reports of Ram *et al.* (1973), Dod *et al.* (1989), Phookan *et al.* (1991) and Akhtar *et al.* (1996) who reported that NAA increased ascorbic acid content in many vegetables like cabbage, chilli and tomato. A decrease in ascorbic acid content due to the application of CCC has also been reported by Phookan *et al.* (1991), which also contradicted the results of the present study. Similar results were also obtained by Shadeque and Pandita (1981) in potato and Arora *et al.* (1983) in tomato.

The increased ascorbic acid content recorded by CCC might be due to the catalytic conversion of sucrose or hexose to ascorbic acid by the bioregulator as reported by Muralidharan *et al.* (2000) by triacontonal application in tomato.

5.11 INCIDENCE OF PEST AND DISEASES

The bioregulator treatments were found to reduce the incidence of *Cercospora* leaf spot during rabi. All the bioregulator treatments reduced the per cent incidence of the leaf spot. PCPA treated plants recorded the least per cent leaf spot incidence (9-10) followed by CCC (11-14 per cent). Control plants recorded the highest per cent of leaf spot incidence (40 per cent). Among the bioregulator treatments NAA recorded the relatively higher per cent of the disease incidence. Influence of bioregulators in reducing disease incidence has been reported by Kalloo (1986) who reported that PCPA reduced the incidence of tomato leaf curl virus. Arora *et al.* (2000) reported that CCC has a limited fungicidal property. The fungicidal properties of triazoles were due to their capacity to inhibit the biosubstance ergosterol, which is a vital component of fungal membrane.

From the study it can be inferred that CCC 75 ppm sprayed at 15, 30 and 45 DAT improved plant vigour, fruit size in terms of average fruit weight and volume and average fruit yield per plant during both rabi and summer season. The CCC application (50 and 75 ppm) was found to be economical with a B:C ratio of 2.04. The bioregulator NAA was found to be effective in increasing fruit set during rabi, while PCPA was found to be effective during summer.

Summary

6. SUMMARY

The present study on "Efficacy of bioregulants on growth and productivity in tomato (*Lycopersicon esculentum* Mill.)" was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara, during 2002-2003, to explore the effects of bioregulators namely PCPA, NAA, CCC and 2,4-D each at three different concentrations applied at three different stages of the crop growth. The bacterial wilt resistant variety, Sakthi, from the Kerala Agricultural University was used for the study. The salient findings of the study are summarised below.

1. The bioregulators significantly influenced vegetative and reproductive characters during both the seasons viz., Rabi and Summer.

2. The performance of the crop was better during rabi than summer in terms of productivity of the crop, which was due to the high temperature and water stress during the summer season.

3. The bioregulator NAA had a positive influence on the height of the plant while all the other treatments had a negative influence on the character. The bioregulator NAA at 20 ppm recorded the maximum height (57.15 cm) during rabi and that of 10 ppm recorded the maximum height (43.15 cm) during summer. NAA at higher concentration was found to decrease the plant height. At higher concentrations PCPA had a positive influence during summer.

4. All the bio-regulators except 2,4-D during rabi and PCPA (25 and 50 ppm) during summer positively influenced the number of branches. Application of CCC 75 ppm recorded the maximum number of branches during both rabi and summer with 7.90 and 5.55 respectively. The least number of branches was recorded by 2,4-D.

5. Treatment of plants with CCC and NAA improved the growth parameters like RGR, LAI, CGR and LAD over control while the treatments with PCPA

and 2,4-D resulted in negative effect, except for CGR during summer by 2,4-D application. The NAR was found to be positively influenced by all the bioregulators.

6. In the present study, bioregulators had no significant influence on earliness during rabi whereas the treatments significantly influenced the days to first flower and first harvest during summer. The plants treated with PCPA were the first to flower thus resulting in early yield. They were early by 8-10 days when compared to control.

7. The exertion of stigma above the anther cone i.e., extrovert stigma, a condition due to high temperature was observed during summer and the character was influenced by the bioregulators. Plants treated with CCC 75 ppm recorded the least per cent of extrovert stigma, which was 39.56 per cent less than that of control.

8. Severe vegetative malformation was observed in PCPA treated plants, which was to the extent of 90 per cent, at all the concentrations. Fruit malformation was observed to a limited extent in 2,4-D and CCC treated plants.

9. Percentage fruit set, number of fruits and fruit yield were highly influenced by the bioregulators. The effect was more pronounced during summer than rabi. The yield increase was up to 383 per cent in summer whereas it was up to 34 per cent in rabi. The CCC treatments were found to be more effective during both the seasons while NAA was found better during rabi and PCPA during summer.

10. Fruit size (fruit weight and volume) was also influenced by the bioregulators. All the bioregulators except 2,4-D (all concentrations) increased the fruit size than control. The plants treated with CCC produced fruits with the maximum weight and volume.

11. Percentage of cracked fruits was more during rabi than summer and all the bioregulators significantly influenced cracking. The plants treated with CCC recorded the least cracking per cent in both the seasons.

12. Parthenocarpic fruits with only seed remnants were produced by the plants treated with PCPA (at higher concentrations) and 2,4-D (all concentrations).

13. The number of locules per fruit was significantly influenced by the bioregulators during rabi while the effect was insignificant during summer. The plants treated with 2,4-D (0.5 ppm) produced fruits with maximum number of locules (5.00).

14. The influence of bioregulants on the biochemical characters like TSS and ascorbic acid was insignificant during both the seasons. The PCPA treated plants during rabi and CCC 75 ppm treated plants during summer slightly increased TSS and ascorbic acid respectively. Control plants recorded maximum TSS and ascorbic acid during summer.

15. The incidence of *Cercospora* leafspot was observed during rabi. The bioregulants effectively reduced the incidence of leaf spot. Plants treated with PCPA recorded the least per cent of leaf spot incidence (9-10) while control plants recorded 40 per cent incidence of the disease.

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* Originals not seen

Appendices

APPENDIX-Ia

Weather data during Rabi August 2002 to December 2002

	Maximum temperature (°C)		Minimum temperature (°C)		Rainfall (mm)	Soil temp. (°C)		Humidity (%)		Wind velocity (kmph)		Sunshine (hrs)		Evaporation (mm)	
	Total	Avg.	Total	Avg.	Total	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.
2-8 July 02	212.3	30.3	164.9	23.6	57.0	221.0	31.6	658	94	25.7	3.7	36.1	5.2	23.6	3.4
9-15 July 02	205.6	29.4	161.6	23.1	126.1	211.4	30.2	659	94	27.8	4.0	20.7	3.0	21.4	3.1
16-22 July 02	207.6	29.7	158.6	22.7	58.0	214.2	30.6	664	95	26.3	3.8	18.8	2.7	21.7	3.1
23-29 July 02	209.0	29.9	160.1	22.9	70.4	212.9	30.4	649	93	25.6	3.7	26.7	3.8	20.3	2.9
30 July-5 Aug 02	196.9	28.1	157.8	22.5	83.6	202.3	28.9	664	95	283	4.0	5.1	0.73	16.6	2.4
6-12 Aug 02	199.9	28.6	155.3	22.2	94.0	203.6	29.1	665	95	26.7	3.8	6.5	0.9	19.5	2.8
13-19 Aug 02	195.1	27.9	159.4	22.8	337.0	196.9	28.2	659	94	25.8	3.7	18.0	2.6	14.9	2.1
20-26 Aug 02	210.9	30.1	163.7	23.4	13.8	212.0	31.1	654	93	26.1	3.7	38.0	5.4	26.6	3.8
27 Aug-2 Sep 02	216.0	30.9	168.6	24.1	3.8	244.2	34.9	651	93	26.8	3.8	50.7	7.3	30.1	4.3
3-9 Sep 02	208.9	29.8	162.5	23.2	98.7	224.8	32.1	656	94	26.0	3.7	38.2	5.5	24.1	3.4
10-16 Sep 02	214.6	30.7	160.0	22.9	0.0	240.5	34.4	646	92	25.7	3.7	60.9	8.7	30.8	4.4
17-23 Sep 02	219.4	31.3	159.9	22.8	0.0	258.2	36.9	639	91	25.4	3.6	57.8	8.3	30.3	4.3
24-30 Sep 02	227.8	32.5	158.8	22.7	21.5	267.8	38.3	632	90	25.4	3.6	57.4	8.2	30.8	4.4
1-7 Oct 02	225.7	32.2	163.1	23.3	51.0	242.5	34.6	624	89	22.7	3.2	39.7	5.7	26.0	3.7
8-14 Oct 02	205.0	29.3	161.6	23.1	268.3	207.9	29.7	653	93	24.5	3.5	14.9	2.1	12.8	1.8
15-21 Oct 02	210.6	30.1	161.1	23.0	25.1	216.2	30.9	645	92	19.7	2.8	30.1	4.3	24.4	3.5
22-28 Oct 02	220.2	31.5	164.4	23.5	9.9	228.1	32.6	647	92	21.5	3.1	41.9	6.0	23.0	-
29 Oct-4 Nov 02	221.2	31.1	163.3	23.3	33.4	219.1	31.3	591	84	35.6	5.1	40.2	5.7	30.6	4.4
5-11 Nov 02	222.3	31.8	164.8	23.5	8.7	228.1	32.6	627	90	24.0	3.4	33.2	4.7	22.0	3.1
12-18 Nov 02	218.2	31.2	162.6	23.9	9.4	216.9	31.0	579	83	35.4	5.1	32.8	4.7	29.1	4.2
19-25 Nov 02	219.1	31.3	163.4	23.3	4.0	231.4	33.1	543	78	37.7	5.4	47.5	6.8	30.2	4.3
26 Nov-2 Dec 02	230.4	32.9	158.0	22.6	-	246.4	35.2	553	79	37.5	4.5	64.7	9.2	31.5	4.5
3-9 Dec 02	225.0	32.1	162.6	23.2	-	239.7	34.2	512	73	66.9	9.6	53.1	7.6	41.6	5.9
10-16 Dec 02	224.6	32.1	170.0	24.3	-	237.9	34.0	485	69	82.6	11.8	75.5	10.8	61.4	8.8
17-23 Dec 02	225.2	32.2	146.6	20.9	-	227.8	32.5	483	69	58.3	8.3	58.2	8.3	45.6	6.5
24-31 Dec 02	260.1	32.5	164.3	20.5	-	273.3	34.2	595	74	33.0	4.1	74.1	9.3	41.7	5.2

APPENDIX-Ib

Weather data during Summer January 2003 to July 2003

	Maximum temperature (°C)		Minimum temperature (°C)		Rainfall (mm)	Soil temp. (°C)		Humidity (%)		Wind velocity (kmph)		Sunshine (hrs)		Evaporation (mm)	
	Total	Avg.	Total	Avg.	Total	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.	Total	Avg.
1-7 Jan 03	230.0	32.9	156.7	22.4	-	237.0	33.9	463	66	62.9	9.0	60.6	8.6	48.7	7.0
8-10 Jan 03	227.1	32.1	167.0	23.9	-	235.7	33.7	439	63	70.1	10.0	62.3	8.9	57.9	8.3
15-21 Jan 03	230.5	32.9	162.5	23.2	-	238.2	34.0	437	62	70.2	10.0	68.4	9.8	55.6	7.9
22-28 Jan 03	241.9	34.6	154.1	22.0	-	242.4	34.6	506	72	48.4	6.9	69.3	9.9	48.1	6.9
29 Jan-4 Feb 03	237.2	33.90	158.1	22.6	23.6	238.0	34.0	539	77	37.7	5.4	61.2	87	38.5	5.5
5-11 Feb 03	243.7	34.8	165.6	23.7	0.2	254.0	36.3	499	71	49.3	7.0	68.7	9.8	44.7	6.4
12-18 Feb 03	249.8	35.7	169.3	24.2	2.9	263.1	37.6	559	80	34.3	4.9	68.6	9.8	37.9	5.4
19-25 Feb 03	245.6	35.1	166.1	23.7	65.4	259.8	37.1	617	88	21.7	3.1	64.7	9.2	37.0	5.3
26 Feb-4 Mar 03	263.3	33.8	162.9	23.3	70.0	241.3	34.5	639	91	22.6	3.2	60.7	8.7	32.7	4.7
5-11 Mar 03	246.7	35.2	169.2	24.2	0.0	267.2	38.2	588	84	28.3	4.0	61.3	8.8	40.0	5.1
12-18 Mar 03	243.6	34.8	170.0	24.3	83.4	273.2	39.0	617	88	28.1	4.0	57.3	8.2	36.1	5.2
19-25 Mar 03	239.7	34.2	163.5	23.4	10.4	256.0	36.0	559	80	29.4	4.2	60.8	8.7	38.2	5.5
26 Mar-1 April 03	238.5	34.1	174.2	24.9	1.0	275.6	39.4	646	92	19.1	2.7	57.0	8.1	33.2	4.1
2-8 April 03	238.4	34.1	172.2	24.6	6.2	266.2	38.0	600	86	20.0	2.9	46.9	6.7	27.6	3.9
9-15 April 03	241.1	34.4	175.0	25.0	5.8	271.0	38.7	618	88	19.7	2.8	54.1	7.7	37.5	5.4
16-22 April 03	244.5	34.9	175.6	25.1	0.7	276.9	39.6	614	88	22.1	3.2	56.9	8.1	35.0	5.0
23-29 April 03	247.5	35.4	175.3	25.0	10.5	278.6	39.8	568	81	28.9	4.1	81.8	8.2	42.0	6.0
30 April-6 May 03	236.2	33.7	173.1	24.7	8.0	265.6	37.9	588	84	27.5	3.9	41.3	5.9	34.2	4.9
7-13 May 03	237.9	34.0	178.8	25.5	0.5	262.9	37.6	601	86	23.6	3.4	37.4	5.3	31.8	4.5
14-20 May 03	240.7	34.4	182.2	26.0	1.2	271.9	38.8	612	87	26.0	3.7	54.8	7.8	39.9	5.7
21-27 May 03	240.7	34.4	182.2	26.0	1.2	271.9	38.8	612	87	26.0	3.7	548	7.8	39.9	5.7
28 May-3 June 03	243.2	34.7	180.1	25.7	0.2	270.2	38.6	614	88	26.8	3.8	50.2	7.2	41.2	5.9
4-10 June 03	233.6	33.4	173.5	24.8	59.4	250.3	35.8	634	91	22.1	3.6	47.0	6.7	35.2	5.0
11-17 June 03	216.4	30.9	165.7	23.7	164.3	224.4	32.1	623	89	26.3	3.8	29.9	4.3	21.2	3.0
18-24 June 03	193.8	27.7	160.5	22.9	309.6	198.4	28.3	664	95	18.8	2.7	2.8	0.4	16.1	2.3
25 June-1 July 03	208.0	29.7	159.0	22.7	46.9	211.3	30.2	647	92	18.6	2.7	20.1	2.9	22.6	3.2
2-8 July 03	202.2	28.9	155.9	22.3	100.9	204.2	29.2	631	90	16.9	2.4	16.5	2.4	21.0	3.0
9-15 July 03	204.6	29.2	159.0	22.7	153.6	208.8	29.8	649	93	23.0	3.3	15.2	2.2	21.8	3.1
16-22 July 03	205.4	29.3	164.0	23.4	100.4	208.6	29.8	668	95	18.6	2.7	17.9	2.6	19.6	2.8
23-29 July 03	211.0	30.1	160.5	22.9	128.1	208.2	29.8	659	94	22.4	3.2	19.6	2.8	25.8	3.7
30 July-5 Aug 03	217.5	31.1	165.1	23.6	25.0	220.7	31.5	652	93	20.2	2.9	27.9	4.0	31.0	4.4

APPENDIX-II

Economics of bioregulator application

Treatment	Yield ($t\ ha^{-1}$)	Total returns* (Rs.)	Additional cost (Rs.)	Cost of production (Rs.)	B:C ratio
PCPA 25 ppm	10.25	82,000	2255.0	43762.2	1.87
PCAP 50 ppm	10.05	80,400	4180.0	45687.2	1.75
PCPA 75 ppm	10.82	86,560	6105.0	47612.2	1.81
NAA 10 ppm	9.45	75,600	501.0	42008.2	1.79
NAA 20 ppm	9.81	78.480	635.0	42142.2	1.86
NAA 30 ppm	10.16	81,280	843.3	42350.5	1.91
CCC 25 ppm	9.71	77,680	1509.6	43016.8	1.80
CCC 50 ppm	11.34	90,720	2857.7	44364.9	2.04
CCC 75 ppm	11.59	92,720	3868.8	45376.0	2.04
2,4-D 0.5 ppm	8.27	66,160	436.2	41943.4	1.57
2,4-D 1.0 ppm	8.13	65,040	542.5	42049.7	1.54
2,4-D 2.0 ppm	8.12	64,960	754.9	42262.1	1.53
Water spray	7.61	60,880	330.0	41837.2	1.45
Control	7.12	56,960	-	41507.2	1.37

* At the rate of Rs.8 per kg.

EFFICACY OF BIOREGULANTS ON GROWTH AND PRODUCTIVITY IN TOMATO (*Lycopersicon esculentum* MILL.)

By
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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara during August 2002-July 2003 to study the efficacy of three levels of bioregulators viz., PCPA (25, 50 and 75 ppm), NAA (10, 20 and 30 ppm), CCC (25, 50 and 75 ppm) and 2,4-D (0.5, 1.0 and 2.0 ppm) on growth, fruit set, yield and quality in tomato. The bioregulators were sprayed at three different stages of the crop growth viz., 15, 30 and 45 DAT. The bacterial wilt resistant variety Sakthi was used for the study. The experiment was laid out in Randomized Block Design with two replications.

All the bioregulators significantly influenced the vegetative characters like height of the plant and number of branches. While the treatments with NAA increased the height of the plant, CCC reduced the same. Treatment of plants with CCC at all concentrations increased the number of branches. The bioregulators PCPA and 2,4-D had a negative influence on the plant height and number of branches as they recorded a lower height and number of branches than control. The growth parameters like RGR, NAR, LAI, CGR and LAD were positively influenced by CCC and NAA while the PCPA and 2,4-D treatments reduced the same, except NAR and CGR.

Earliness was influenced by the bioregulators during summer. The plants treated with PCPA flowered earlier (5-10 days than control) and produced early yield (10-15 days than control). NAA was found to be effective in inducing earliness during rabi.

All the bioregulators were effective in increasing the per cent fruit set, number of fruits and fruit yield. The bioregulator CCC during both the seasons, NAA during rabi and PCPA during summer were effective in increasing per cent fruit set. The treatments with CCC increased the per cent fruit set, number of fruits and yield per plant by 57.67, 42.74 and 61.53 per cent respectively. Treating the plants with CCC 75 ppm was found to be effective in increasing the productivity of the crop during both rabi and summer with 17.54 and 5.63 tonnes per hectare respectively, while control recorded 13.07 and 1.17 tonnes per hectare during rabi

and summer respectively. The increase in the yield over control was 34.20 per cent during rabi and 381.19 per cent during summer.

Plants treated with PCPA resulted in severe vegetative malformations, up to an extent of 90 per cent. The malformations noticed were upward cupping of leaves and thickening of lamina. Fruit malformations were noticed in 2,4-D and CCC treated plants. The biochemical characters like TSS and ascorbic acid were not highly influenced by the bioregulators. *Cercospora* leaf spot incidence was reduced by the bioregulator treatments with PCPA recording 75 per cent less incidence of the disease than control.