EFFECT OF GROWTH REGULATORS ON FLOWER AND FRUIT DROP IN CHILLI (*Capsicum annuum* L.)

By

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Dedicated

To

My beloved family

DECLARATION

I hereby declare that this thesis entitled "**Effect of growth regulators on flower and fruit drop in chilli (*Capsicum annuum* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Effect of growth regulators on flower and fruit drop in chilli (*Capsicum annuum* L.)**" is a record of research work done independently by Ms. Sreeja Rajendran 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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LIST OF ABBREVIATIONS

^0C	Degree Celsius
Fig.	Figure
ppm	parts per million
IAA	Indole-3 acetic acid
IBA	Indole-3 butyric acid
NAA	Naphthalene acetic acid
GA	Gibberellic Acid
cv.	Cultivar
rpm	Rotations per minute
nm	Nanometer
M	Molar
ha	Hectare
μ	Micro
LAI	Leaf area index
SLW	Specific leaf weight
LAR	Leaf area ratio
CGR	Crop growth rate
RGR	Relative growth rate
NAR	Net assimilation rate
RS	Root-shoot
C_1	Control (water spray)
C_2	Control (No spray)

Introduction

1. INTRODUCTION

The concept of hormonal regulation of plant growth dates back to nearly a century. Julius Sachs noticed from his experiments on plants that special substances are responsible for the formation and growth of different organs. With this information, scientists discovered that the growth and behaviour of many plants could be changed and often controlled by applying small amount of organic chemicals to roots, stems, buds, leaves or flowers. These chemicals have come to be known as 'growth regulators'. The growth regulators impart their effects by modifying plant growth and development through changes in the endogenous levels of naturally occurring hormones. There are numerous reports of studies carried out by different workers in various crops and hence the role of different growth regulators in seed germination, seed dormancy, flowering, sex expression, hybrid seed production, fruit set, fruit ripening etc. has been well established. This manipulation of physiological efficiency of crop plants by the use of growth regulators has emerged as a new era for achieving quantum jump in productivity.

India is the largest producer, consumer and exporter of spices in the world. Spices constitute 12 per cent of total agricultural commodities exported from India. During 1997 -98, the country earned a foreign exchange worth rupees 1352.1 crores by the export of 218750 tonnes of spices in raw as well as value added forms (Sivaraman and Peter, 1999).

Chilli (*Capsicum annuum* L.) is one of the most important solanaceous spice cum vegetable crop valued for its aroma and flavour, which it imparts to food and beverages. It forms an important indispensable adjunct in the

common Indian dishes and is used either in green form as a vegetable or dried form as chilli powder. Extracts of chillies are used in the manufacture of ginger beer and other beverages. Chillies also form a rich source of vitamin C in its fresh state. It has unique medicinal properties and is used internally as a powerful stimulant and carminative and externally as a counter-irritant.

The geographical distribution of this crop extends to tropical and sub-tropical parts of a number of countries in the world. It's adaptability to varying agroclimatic conditions makes it suitable for growing in almost all regions in India. It is practically grown all over India and there is not a single household in the country where it is not utilized in one form or the other.

India is the largest producer of chillies contributing to 25 percent of world's production. It is cultivated in an area of 5.73 lakh hectares (Attavar, 2000) with a production of 8.21 lakh tonnes (Peter, 2000) as per 1997-98 data. In India, chilli occupies an important place among the cash crops of Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu accounting for 75 per cent of country's net area and production.

Eventhough chilli is cultivated in a larger area, the production per unit area is less, despite good agronomic practices. It's productivity relies greatly on external factors which includes the weather conditions during critical phases of crop growth as well as internal physiological factors. In chillies, the poor yield can be attributed to the very low percentage of fruit set (15-30) as reported by Rajamani *et al.* (1990). The heavy drop of flowers and fruits is one of the major problems reducing the fruit set and hence the yield drastically. Flower drop is a serious problem in chillies causing great reduction in yield up to even 94 per cent as reported by Krishnamohan *et al.*

(1993). Flower drop is a complex phenomenon influenced by abiotic stresses like temperature, sunlight, rainfall and soil reaction. Flower drop was increased when chilli plants were exposed to severe water stress and high irradiance, whereas at low irradiance, flower drop was found to be due to low dry matter accumulation (Jaafer *et al.*, 1994). During normal growth, auxins produced by reproductive organs prevent formation of an abscission zone at the base of the pedicel. When stress is imposed like low light intensity or heat stress, ethylene is generated by the reproductive structures resulting in their abscission (Wein *et al.*, 1989). By reducing flower drop, high yield can be expected.

It has been claimed that the application of growth regulators prevents flower and fruit drop and increases production in various crops. Promising results in solanaceous vegetables have been obtained by Mote *et al.* (1975), Usha and Peter (1988), Singh (1995) etc. Application of growth regulators has gained importance as one of the latest technology to increase the yield of vegetables.

Hence the present investigation was carried out in chillies with four growth regulators viz. Indole-3- acetic acid, Naphthalene acetic acid, Triacontanol in the form of Vipul and gibberellin. The objectives of the investigation were envisaged as:

1. To study the effect of these growth regulators on flowering and flower drop.
2. To study the effect of the above growth regulators on fruiting and fruit drop.
3. To assess the effect of these growth regulators on morphological, growth, biochemical and yield parameters.

Review of Literature

2. REVIEW OF LITERATURE

Chilli (*Capsicum annuum* L.) is an important commercial spice cum vegetable crop grown for domestic as well as export market. It is valued for its aroma and flavour which it imparts to food and beverages. Flower shedding is one of the most limiting factor in stepping up chilli production. Flower drop is a complex phenomenon causing a great reduction in yield up to even 94 per cent (Krishnamohan *et al.*, 1993). All the flowers produced by chilli plants do not set fruits and the percentage of fruit set is very low i.e. about 5 per cent as reported by Gopalratnam (1933). Application of growth regulators prevents flower and fruit drop and increases production in various crops. Promising results have been obtained by Negi and Singh (1956) in cotton, Jagirdar and Choudry (1967) in mango and Mukherji and Roy (1966) in tomato.

The present investigation was carried out to study the effect of different growth regulators viz. IAA, NAA, Triacontanol and GA in preventing flower and fruit drop in chilli and also to know the effects of these growth regulators on various morphological, biochemical, growth and yield parameters. Correlation studies of the different parameters with yield was also undertaken. A review of the information available on these aspects is presented in this chapter.

2.1 Morphological characters

Nanjappa (1965) studied the effects of GA, IAA, and NAA at different concentrations on chilli and reported that foliar spray of gibberellic acid 50

ppm increased the height of plants and reduced the number of flowers produced subsequent to spraying. Foliar spray of NAA 5 ppm showed 45 per cent higher fruit set over control and NAA 10 ppm reduced the flower drop by 27 per cent.

In tomato, an improvement of fruit set was shown by Mehrota *et al.* (1970) when foliar application of NAA 10 ppm and $GA_3$10 ppm were given at flowering.

In a study carried out by Chandra and Shivraj (1972) in chilli, the number of flowers formed in GA treated plants did not show significant difference compared to control. The flower shedding was less when foliar sprays of GA 25 ppm and 50 ppm were given. Also spraying of IAA 25 ppm and NAA 10 ppm showed increased flowering and fruit set with a reduction in flower and fruit drop.

An increase in the height of GA treated tomato plants to an extend of 60 per cent under pot culture and 22 per cent under field conditions was reported by Irulappan and Muthukrishnan (1974).

Jayanandam *et al.* (1976) reported that when NAA 15 ppm and 1BA 20 ppm were sprayed thrice in chilli at 15 days intervals, there was an increase in flower production. NAA and 1BA also had a role in reducing flower drop. The percentage fruit set was more in NAA treated plants. Good fruit set was obtained with planofix (NAA) 10 ppm in tomato by Kanwar *et al.* (1976) and in chillies by Chandra *et al.* (1976).

Warade and Singh (1977) conducted a study to investigate the role of planofix (NAA 4.5 per cent) in preventing flower drop and increasing fruit set

in chillies. Early flowering was reported with planofix 200 ppm sprayed at 4-5 leaf stage. Planofix 200ppm sprayed during the bloom stage gave a maximum fruit set of 70.5 per cent against 52.16 per cent in control.

Increased fruit set in brinjal has also been reported with foliar spray of IAA 100 ppm by Bisaria and Bhatnagar (1978).

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 at 20 days after flowering.

Oenofeghara (1981) reported that when tomato seedlings were sprayed with NAA 25 ppm and 50 ppm, it promoted flower primordia formation. IAA more than 125 ppm was found to be toxic.

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 stage earlier than untreated controls.

Patil *et al.* (1985) reported that in chillies, double foliar sprays of planofix 10 ppm once at flowering and then after five weeks of flowering decreased flower shedding and gave the best fruit set.

Foliar sprays of triacontanol 2mg per litre applied at 30 days after transplanting and again at blooming stage were effective in checking flower drop and enhancing fruit yield in chillies (Srinivas *et al.*,1986).

In a study carried out by Maurya and Lal (1987), when roots of seven week old chilli seedlings were dipped in aqueous solutions of GA 150 ppm and transplanted, the plants showed maximum plant height (62.66 cm) and

seedlings dipped in NAA 50 ppm showed the minimum plant height (51.28 cm). NAA 150 ppm resulted in minimum number of fruits due to premature fruit drop. Miniraj and Shanmugavelu (1987) opined that in chillies, foliar sprays of triacontanol 1 and 2 ppm one at 30 days after transplanting and then at full bloom stage resulted in plants coming to flower earlier than control. Plants sprayed with Triacontanol 1 ppm produced 499.1 flowers per plant while control plants produced only 355.5 flowers per plant. These plants also had a higher fruit set of 52.21 per cent againt 34.27 per cent in control.

In the summer and monsoon trials carried out by Usha and Peter (1988) in chilli cv. KAU cluster, foliar sprays of triacontanol (as Vipul) 0.5ml per litre at 15, 30 and 60 days after transplanting gave the highest reduction in flower drop during summer. Whereas, during the monsoon season, foliar sprays of NAA 15 ppm at 15,30 and 60 days after transplanting was found to be the most effective in reducing flower drop.

Doddamani and Panchal (1989) reported that in Byadagi chilli (*Capsicum annuum* Linn. var. acuminatum), foliar sprays of NAA 10 ppm before flowering gave the highest plant height (99.36 cm) and highest fruit set (29.83 per cent).

In chillies, foliar sprays of triacontanol 1.25 ppm given at 20,40,60 and 80 days after transplanting resulted in higher number of flowers produced per plant (560.50) compared to the control (393.26). The percentage of fruit set was also found to be maximum (52.93) in triacontanol 1.25 ppm compared to control (29.32). This was reported by Rajamani *et al.* (1990). In irrigated field trials by Rao *et al.* (1990), when chilli cultivars G_4 and LCA-235 were given foliar sprays of NAA 20 ppm at flower initiation and at peak flowering

stages, the number of flower buds shed decreased from 422 per m^2 in control to 288 per m^2 in NAA treated plants. The corresponding values for fruit set were 61 per cent and 47.6 per cent for the treated and control plants respectively.

Phookan *et al.* (1991) reported an increased plant height up to 30 ppm NAA in tomato. In an experiment conducted by Ramanandam *et al.* (1991) to study the effect of growth regulators on fruit set in brinjal, triacontanol 5 ppm applied as foliar spray resulted in highest percentage fruit set.

El-Asdoudi (1993b) studied the effect of gibberellins on flowering and fruiting in *Capsicum annuum* cv. California Wonder plants and reported that the maximum fruit set of 61.2 to 63.3 per cent was observed in plants sprayed with GA_3 15ppm.

El-Asdoudi and Ouf (1993) opined that in tomato the tallest plants were got from 3 foliar sprays of GA 50 ppm given at 15 days interval. Kar *et al.* (1993) observed the best fruit retention and yield in tomato cv. Pusa Early dwarf with both NAA 15 ppm and NAA 25 ppm given as a seed presoak and a foliar spray at 30 days after transplanting. Krishnamohan *et al.* (1993) found that foliar sprays of IAA at 10 ppm and 25 ppm at the time of flowering were insignificant in retaining the reproductive structures in chilli. Singh *et al.* (1993) reported that in chilli cultivars Pant C_1, Pusa Jwala and NP 46-A, foliar sprays of NAA 40 ppm applied during 40 and 60 days after transplanting improved the plant height and resulted in maximum percentage of fruit set.

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 the height of plants. In tomato, Singh (1995) obtained early induction of flowering and an improvement of fruit set by foliar sprays of NAA 5-10 ppm. Good fruit set was obtained in *Capsicum annuum* cv. Pantnagar by foliar sprays of NAA 20 ppm (Singh and Lal, 1995).

An increase in plant height was observed by Tomar and Ramagery (1997) when seedlings of tomato cultivars, Sweet 72, SK-1 and CO-3 were transplanted to the field after soaking their roots for 30 minutes in GA_3 50 ppm.

2.2 Growth parameters

Gazizova (1986) observed that in wheat, the relative growth rate of the ear was increased by 35 per cent when the roots were treated with 100 ppm IAA.

Miniraj and Shanmugavelu (1987) reported an increase in the number of leaves in chillies when the plants were given foliar spray of Triacontanol 2 ppm 30 days after transplanting and again at full bloom stage. Increase in number of leaves by triacontanol treatment may be due to delayed senescence of leaves as reported by Billa (1981) and increased uptake of nutrients. Same was reported by Pocock (1979) in sugarbeet and Gunasekaran (1982) in tomato.

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

Katayama and Akita (1989) reported that when seedlings of Japonica rice cv. Tanginbozu and Nipponbare were grown in nutrient solution with 1 and 10 ppm GA_3, the net assimilation rate was found to increase with increasing GA_3 concentration. It was attributed to increased sink activity of leaf sheaths. Narwadkar and Anser Wadekar (1989) observed that when mango grafts were sprayed with 200 and 700 ppm IAA, there was an increase in number of leaves and total leaf area.

Ray (1991) studied the effect of foliar sprays of triacontanol 0.5-1mg per litre in chilli varieties Arka Basant and California Wonder. The treated plants had a high leaf area, relative growth rate, crop growth rate and leaf area index.

El-Asdoudi (1993 a) observed that when seeds of *Capsicum annuum* cv. California Wonder were treated with GA_3 30,100 and 300 ppm, the root to shoot ratio decreased with increase in GA_3 concentration applied to apex of the plant. Krishnamohan *et al.* (1993) reported a leaf area index value of 0.36 at 45 days after transplanting in chillies sprayed with IAA 25 ppm at flowering. NAA 40 ppm applied as foliar spray at 40 and 60 days after transplanting resulted in greatest increase in leaf area (Singh *et al.*,1993). Takagaki (1993) observed that in *Capsicum annuum*, changes in relative growth rate was found to be influenced by fruit growth and fruit size. Much dry matter accumulation was noted in large fruits.

2.3 Physiological parameters

Eriksen *et al.* (1981) conducted a hydroponics experiment in tomato where the plants were grown in nutrient solution in which triacontanol was

added twice a week. After four weeks, photosynthesis in younger leaves was inhibited by 39 per cent in control compared to only 27 per cent inhibition in triacontanol treated plants.

Zhang *et al.* (1985) reported that in capsicum cv. Bruinsma Wonder, treatment of seeds with NAA, IAA and IBA all at 200 ppm reduced the transpiration rate. NAA treatment increased dry matter accumulation by higher rate of photosynthesis.

IAA application to mango grafts at 200 and 500 ppm was reported to decrease the rate of transpiration (Narwadkar and AnserWadekar, 1989).

In experiments conducted with potted trees of lemon cultivar Pant Lemon-1, IAA 20 ppm and triacontanol (as mixtallol) 2 and 4 ppm when sprayed on one month old shoots were found to increase the net photosynthetic rate. But GA_3 20 ppm was noted to have the opposite effect (Sharma and Singh, 1990).

Takagaki (1993) studied the influence of day temperature on four *Capsicum annuum* varieties and reported that transpiration rate and stomatal conductance was increased under the influence of day temperature.

Application of IAA to the polato stolons in lanolin paste was found to enhance the photosynthetic rate (Puzina *et al.*, 1998).

2.4 Biochemical parameters

Plant growth regulators have been reported to affect quality in many vegetables (Chhonkar and SenGupta, 1972). Chandra and Shivraj (1972) observed an increase in chlorophyll and carbohydrate content in chillies when

the plants were given two foliar sprays of NAA 25 ppm and NAA 10 ppm 25 days after transplanting and again at 50 days after transplanting.

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

Chaubey and Chaturvedi (1982) reported a protein content of 4.99 g per 100 g of dry matter in tomato fruits whose seedling roots were treated with NAA 20 ppm for one hour.

In a greenhouse trial carried out by Patil *et al.* (1985), NAA 20 ppm spray at flower opening stage followed by two more successive sprays at an interval of 30 days was found to be most effective in increasing capsaicin content, carbohydrate and protein content of chilli fruits. Umajyothy and Shanmugavelu (1985) reported that in brinjal, two sprays of triacontanol 1ppm, 2,4-D 10 ppm + boron 2 ppm applied once at 15 days after transplanting and then at the time of flowering resulted in an increase in protein content of 13.62 per cent as against the control (9.08 per cent).

Miniraj and Shanmugavelu (1987) studied the effect of triacontanol on growth, yield, quality and nutrient uptake in chillies. Foliar spray of triacontanol 2 ppm on the 30th day after transplanting and again at full bloom stage recorded the highest capsaicin content of 4.99 mg per g in fruits as against the control (3.28 mg per g). A slight increase in total soluble sugars was also seen due to triacontanol application.

Bal *et al.* (1988) observed a greater increase in reducing sugar in fruits of ber cv. Umran with the treatment of NAA 25 ppm. Omar *et al.* (1988)

reported that increasing GA_3 concentration was found to reduce both chlorophyll-a and chlorophyll-b contents together with leaf carotenoid content in *Vicia faba* plants which were sprayed with GA 250 ppm and 500 ppm 21 days after sowing and again after 30 days. Sidda Reddy (1988) found an increase in reducing sugars and protein content of potato with foliar sprays of mixtallol at 1 or 2 mg per litre.

Chrungoo and Farooq (1989) observed that application of GA_3 at 100 mg per corm in *Saffron crocus* bought about the degradation of reserve carbohydrates. NAA at 100 mg per corm promoted the accumulation of reducing sugars.

IAA and GA_3 both at concentration of 50 ppm sprayed on to maize, cowpea and *Vicia faba* increased the chlorophyll and carotenoid contents (Shaddad and El-Tayeb, 1990).

In tomato, a TSS content of 5.5 ^{0} Brix was observed in fruits by Phookan *et al.* (1991), when foliar spray of NAA 40 ppm was given at flowering stage. In control, the TSS content was only 4.2^0 Brix.

Deli *et al.* (1992) have reported that the total carotenoid content of ripe fruts in chilli was about 3.2g per 100g dry weight. In a potting trial conducted by El-Sayed (1992), three month old *Capsicum annuum* plants when subjected to water stress conditions, the proline content of the leaves was increased significantly. In control plants, proline oxidase activity was much higher. Janardhanan (1992) reported that in pigeon pea cv. CO-5, Cowpea cv. CO-3 and soyabean cv. CO-1, seed treatment with triacontanol

1ppm for 24 hours increased the leaf chlorophyll and carotenoid contents in all these three crops.

El-Asdoudi (1993b) observed a marked reduction in sucrose content in the fruits of *Capsicum annuum* cv. California wonder plants which were given foliar spray of GA_3 at 15 and 30 ppm.

Monge *et al.* (1994) reported that GA_3 1000 ppm sprays given 14 days after full bloom in peach trees significantly reduced the chlorophyll-a and chlorophyll-b content.

Mosquera and Mendez (1994) monitored the changes in photosynthetic pigments of *Capsicum annuum* fruits. The chlorophyll pigments disappeared during ripening stage and the concentration of carotenoids were highest at fully ripe stage. Zrust (1994) observed that in potato tubers, the most drought resistant cultivars had the highest tuber proline content when subjected to water stress.

Foliar sprays of 2 and 4 ppm mixtallol were found to significantly increase the chlorophyll content of leaves of rape cv. 601 (Zhou *et al.*, 1995).

Belakbir *et al.* (1996) reported a decrease in soluble carbohydrate concentration and an increase in concentration of glucose, fructose and sucrose in pepper fruits when foliar sprays of GA_3 were given at flowering stage and further at 30 and 60 days after flowering. El-Said (1996) described the chemical composition of sweet pepper cv. Gedeon and hot pepper cv. Pical. The total carbohydrates were found to decrease with increasing maturity. Protein concentration fluctuated but tended to decrease with

increasing maturity. Capsaicin content increased with increasing maturity reaching 230 mg per 100g in hot pepper.

Chemical analysis of fruits of *Capsicum annuum* L. by Hyun *et al.* (1997) revealed that the concentration of total capsaicinoids was 5.4 mg per 100g fresh weight. Carotenoids had a total concentration of 6.5 mg per 100g fresh weight. Ishikawa *et al.* (1997) reported that in *Capsicum annuum*, chlorophyll content was highest at 2 weeks after flowering and declined gradually.

Belakbir *et al.* (1998) reported that in chillies, GA_3 sprays given during flower initiation stage followed by two successive applications at 30 days interval increased the soluble solid content of fruits.

2.5 Yield parameters

One of the latest low cost technologies to increase the yield of vegetables is through the application of plant growth regulators. The great potentialities of IAA, NAA and GA for maximising the yield in vegetable crops have been emphasized by various research workers like Prasad and Tyagi (1963), Srivastava and Adhikari (1972) and Sinha and Pal (1983). Increased yields by application of triacontanol on vegetables has also been reported by Gunashekaran (1982), Mamat *et al.* (1983) and Ries *et al.* (1978). Chandra and Shivaraj (1972) could obtain maximum yield in chilli with two foliar sprays of NAA 10 ppm, one at 25 days after transplanting and the other at 50 days after transplanting. It was found to be related to the rise in total carbohydrate content which in turn increased the number of fruits harvested per picking.

Around 27 percent extra yield over control was observed by Jayanandam *et al.* (1976) in chilli when NAA 15 ppm was sprayed thrice at 15 days interval. In trials with tomato cv. Pusa Ruby, NAA 15ppm applied 20 days after transplanting gave the best results with regard to yield ie. 1.56 kg per plant (Prasad and Prasad, 1977).

Eriksen *et al.* (1981) observed that when tomato plants were grown in nutrient solution in which triacontanol was added twice a week, it caused significant increase in dry weight. In three year trials with *Capsicum annuum* cv. NP-46-A and one year trial with cv. Pusa Jwala by Pandita *et al.* (1980), planofix 10 ppm applied once at the beginning of flowering and then 3 weeks later resulted in highest yield of 103-107 quintals per hectare. Sinha and Pal (1980) studied the effect of plant growth regulators on vegetative growth and yield of *Capsicum annuum* L.var. Bullnose. Planofix applied at flowering stage had the most beneficial effect on plant productivity ie. 464.4 g per plant compared to control (280.6 g per plant).

Hariharan and Unnikrishnan (1983) reported that in chillies, germination was hastend by soaking the seeds in both 30 and 50 ppm NAA. The treated plants produced larger fruits with bigger seeds. In field trials of Tobasco pepper, triacontanol 1.25 mg per litre applied as soil drench (25 ml per plant) at transplanting significantly increased early ripening, number of fruits and total yield (Mamat *et al.*, 1983). Watkins and Cantliffe (1983) observed that in *Capsicum annuum*, GA 100 ppm was slightly more effective in stimulating germination rate. Auxin application were not found to alter germination rates.

In a greenhouse trials by Patil *et al.* (1985) with NAA and GA, foliar application of NAA 20 ppm during the period of first flower opening followed by two successive sprays at an interval of 30 days was most effective in increasing yield and number of fruits per plant. Uma jyothi and Shanmugavelu (1985) reported that in brinjal, the highest number of fruits per plant (20.4) were obtained with two foliar sprays of triacontanol 2 ppm + boron 4 ppm applied 15 days after transplanting and then at 30 days after transplanting. In control, the number of fruits were 10.8 per plant with an yield of 0.91 kg per plant.

Mayura and Lal (1987) studied the effect of NAA, IAA and GA on growth of vegetable chilli by dipping the roots of seven week old seedlings in aqueous solutions of growth regulators. They observed that GA 150 ppm gave the maximum number of fruits (22.16 per plant), fruit weight (48.4 g per plant), fruit length 8.06 cm and yield of 280.66 quintals per hectare. IAA 50 ppm recorded fruit length 6.72 cm and fruit weight of 39.04 g per plant. Minimum number of fruits and yield were recorded by NAA 150 ppm. An increase in dry matter accumulation through higher photosynthesis was reported by Zhang *et al.* (1985) when seeds of green house grown capsicum seedling cultivars were treated with NAA 200 ppm.

NAA 10 ppm applied as foliar sprays before flowering in Byadagi chilli was found to give the greatest fruit yield (13.93 quintal per hectare), number of fruits per plant (182), fruit length (12.01 cm) and fruit thickness of 13 mm (Doddamani and Panchal, 1989). Foliar sprays of mixtallol 2mg per litre resulted in considerable enhancement in the yield of tomato (Shukla and Prabhakar, 1989).

Shaddad and El-Tayeb (1990) reported that the foliar sprays of IAA and GA_3 on maize, cowpea and *Vicia faba* plants increased the plant fresh weight and dry weight probably by increasing water use efficiency.

In an experiment conducted by Pandita *et al.* (1991) on bhindi cv. Pusa Sawani, two foliar sprays of IAA 50 ppm gave maximum early fruit yield. Phookan *et al.* (1991) observed that in tomato var. Pusa Early dwarf, the number of fruits per plant were found to decrease with increasing concentrations of NAA sprays given at flowering stage. NAA 10 ppm gave the highest number of fruits per plant (48.88) and highest yield. Ray (1991) reported that in chilli, foliar sprays of triacontanol 0.5-1 mg per litre exhibited a higher dry matter accumulation.

El-Asdoudi (1993a) found that the foliar sprays of GA_3 30 ppm decreased the stem fresh weight in chillies. Three foliar sprays of GA_3 100 ppm given at 15 days interval in tomato cv. Carmello gave the highest yield. GA sprays were found to decrease the fruit volume as well as the number of seeds per fruit in tomato (El-Asdoudi and Ouf, 1993). Singh *et al.*, (1993) opined that NAA 40 ppm applied as foliar spray at 40 and 60 days after transplanting in chilli cultivars Pant C-1 gave the greatest shoot and root fresh weight and maximum fruit yield (89.8 quintals per hectare). In control, the fruit yield was 54.49 quintals per hectare.

Singh and Lal (1994) obtained an increased fruit yield of 35.9 per cent with NAA 40 ppm sprayed at flower bud initiation stage and again 20 days later in *Capsicum annuum* plants of cultivars Pusa Jwala, NP 46-A and Pant C-1.

Sharma (1995), observed that in tomato cv. Solangola, foliar sprays of triacontanol 7.5 ppm applied at 4 and 8 weeks after transplanting increased the number of fruits per plant, the yield of fruits and thousand seed weight. An enhanced germination of 66.5 per cent as against 52 per cent in control was reported by Singh and Lal (1995) with NAA 20 ppm in Capsicum cv. Pantnagar. NAA 20 ppm was also gave a higher seed yield.

In capsicum cv. Gedeon (sweet pepper), fresh weight and dry weight increased with increasing maturity with peak values at 30-40 days after fruit set and then declined due to senescence and water loss. In hot pepper cv. Pical, the fresh and dry weight continued to increase up to the final sampling date. This was reported by El-Said (1996).

NAA 20 ppm was found to be more effective than mixtallol (triacontanol) 2ppm in improving dry matter production in *Vigna mungo* cv. T_9 (Mahla *et al.*, 1999). Seed treatment of maize, rice and sunflower with triacontanol 10 ppm was found to significiantly increase germination by Niranjana *et al.* (1999). In a study conducted by Singh (1999) in hybrid tomato, 500 ppm IBA + 500 ppm IAA was found to be more effective in increasing the number of fruits per plant and yield. The increase in yield was due to induction of early flowering, fruiting and maximum number of fruits per plant. Thakur *et al.* (1999) observed that in pot experiments of bell pepper variety Yolo Wonder, foliar sprays of 5 ppm mixtallol applied 30 days after transplanting produced more number of fruits than control. Vijayaraghavan (1999) reported that in bhendi, seed treatment of GA 50 ppm recorded the highest germination percentage, total dry matter production, number of fruits per plant and yield of fruits.

2.6 Biotic factors

Leaf curl caused by a virus is one of the most serious disease taking a heavy toll of the crop. Bhatt and Verma (1958) observed that when NAA was sprayed on streak virus infected tomato plants, typical virus symptoms disappeared from the leaves and stems and the plants exhibited normal growth.

Nariani (1963) reported that application of GA 100 ppm three times at weekly intervals on leaf curl infected plants of tobasco pepper suppressed the leaf curl symptoms and there was a reversion of stunting effect of virus in about 3-4 weeks after the last spray. Similar effect have been observed with GA 150 ppm on leaf curl infected tomato plants (Lal and Singh, 1961).

Reddy and Yaragunataiah (1981) observed that in leaf curl infected tomato plants, three foliar sprays of GA 200 ppm at 15 days interval reversed the stunting effect of plants induced by the tomato leaf curl virus.

2.7 Environmental factors

The productivity of chilli relies greatly on the external factors which includes weather conditions prevailing during critical phases of crop growth as well as internal factors (Rajamani *et al.*, 1990).

Gopalratnam (1933) has reported maximum fruit set in chillies at 20^0C. Higher night temperatures favoured vegetative growth at the expense of reproductive growth in chillies (Nanjappa, 1965).

In experiments on cv. Cambell Red Chief Delicious apple trees, Byres *et al.* (1991) noted that when fruits were 20 mm in diameter, shading of the whole trees for 3 days caused 98 per cent fruit abscission. Konsens *et al.* (1991) observed

that a day-night temperatures of 32-27^0 C reduced the pod set due to enhanced abscission of flower buds, flower and young pods in snapbean.

The abscission of reproductive structures in bell pepper is a major production problem in the north eastern United States and is often caused by periods of high temperatures (Wein, 1990).

In chillies, shading was observed to increase the drop of flower buds to the tune of 90.5 per cent in 50 per cent shading. This was reported by Krishnamohan *et al.* (1993).

Aloni *et al.* (1994) reported that heat stress caused abscission of flowers in pepper plant and suggested that the susceptibility of pepper to heat stress is due to ethylene produced under high temperature stress. Jaafar *et al.* (1994) observed that flower abortion was accelerated when *Capsicum annuum* cv. Blue star plants were exposed to severe water stress and high irradiance. Rylski *et al.* (1994) reported that weather conditions can seriously affect flowering of pepper and tomato with malformed ovaries and production of non viable pollen.

Around 58-60 per cent flower drop was observed by Bhatt *et al.* (1999) under 100 per cent irradiance in *Capsicum annuum* var. Arka Gaurav.

2.8 Correlation studies

A positive association of ripe fruit yield with number of flowers, percentage fruit set and negative correlation with plant height, fruit length and fruit girth was reported by Vijayalakshmi *et al.* (1988) in chilli.

Kaul and Sharma (1989) revealed that in chillies fruit yield was significantly and positively associated with plant height, leaf area, fruit length, number of fruits per plant, dry matter content and TSS content.

Rani *et al.* (1996) reported that in *Capsicum annuum*, yield displayed significant positive correlation with plant height, number of fruits per plant, fruit length, mean fruit weight and dry matter production.

Rani (1997) showed that in *Capsicum annuum*, number of fruits per plant showed negative correlation with each of fruit length, fruit diameter and thousand seed weight and did not show any correlation with the yield characters studied.

2.9 Economics of cultivation

Jayanandam *et al.* (1976) has reported that NAA 15 ppm recorded 170 kg extra yield of dry pods per hectare valued at Rs. 680. The cultivator has to invest an extra amount of Rs. 60 towards the spraying of hormone and will be benefited by Rs. 620 per hectare.

Materials and Methods

3. MATERIALS AND METHODS

To suit the objectives planned, the field experiment was taken up in the Instructional Farm, College of Agriculture, Vellayani during 1999 -2000. Analysis of the various biochemical parameters were carried out in the laboratory at the Department of Plant Physiology. Statistical analysis of the data collected relating to different parameters were done. Particulars of materials used and methodologies followed in the investigation are presented in this chapter.

3.1 Materials

3.1.1 Experimental site

The experiment was carried out in the D block of Instructional Farm attached to the College of Agriculture, Vellayani. The farm is situated at 8.5^0 North latitude and 76.9^0 East longitude at an altitude of 29 meters above mean sea level.

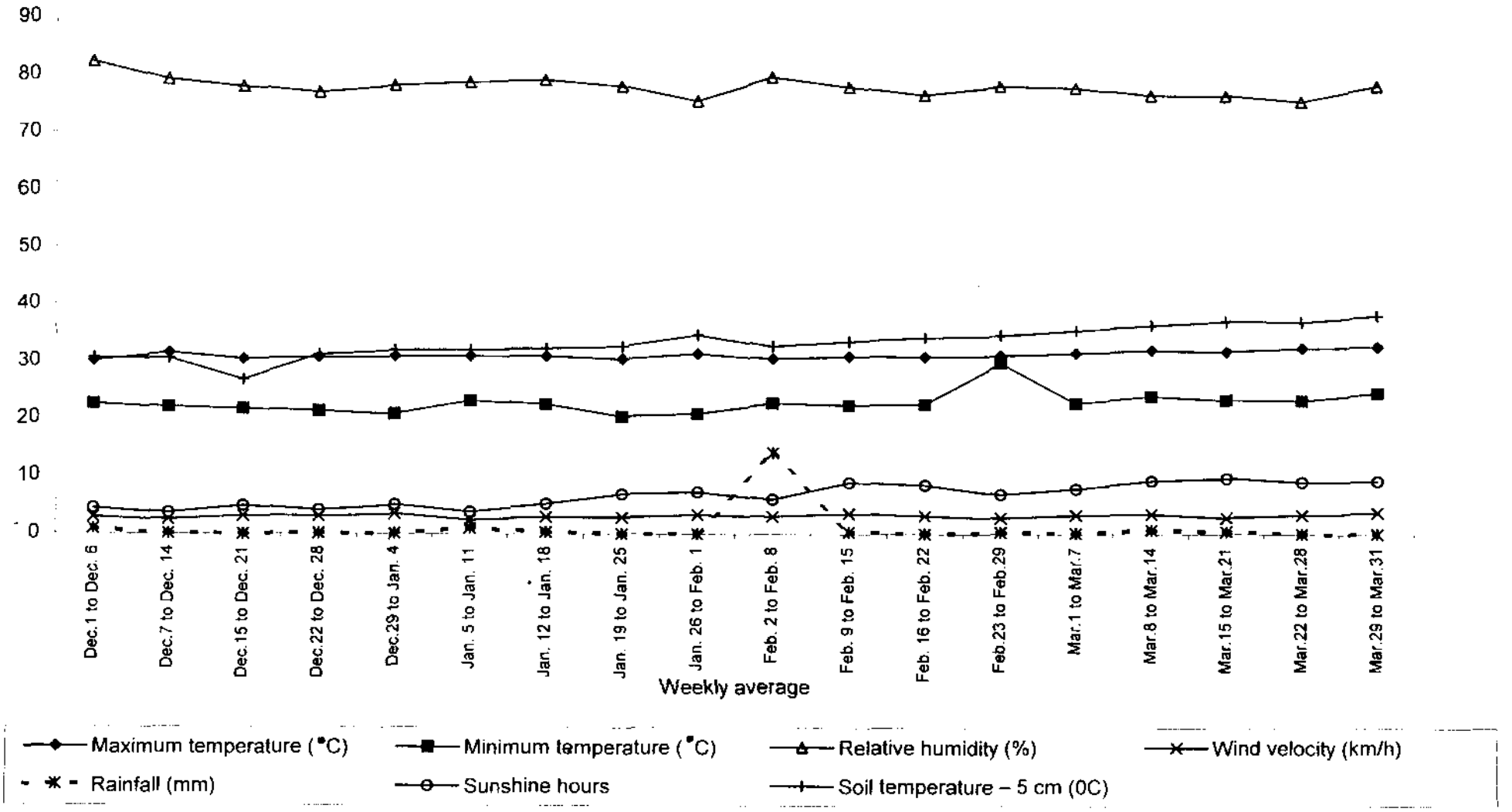
3.1.2 Soil

Prior to the conduct of the experiment, composite samples of soil were drawn from a depth of 0-15 cm and analysed for physico-chemical properties and the data are presented in Appendix-I. The soil of the experimental site was red sandy clay loam belonging to the order oxisol and taxonomic class, loamy kaolinitic, rhodic haplustox (Vellayani series). It was acidic in reaction, medium in available nitrogen and high in phosphorus and potassium content.

Plate 1 View of the experimental field


Title: EFFECT OF GROWTH REGULATORS ON
FLOWER &FRUIT DROP IN CHILLI
DESIGN RBD , REPLICATION 03
VARIETY Jwalasakhi
TREATMENTS-16
PLOT SIZE-

Fig. 1 Weather data for the cropping period - December 1999 to March 2000



3.1.3 Environmental conditions

The experimental site enjoyed a humid tropical climate. The data on various weather parameters like rainfall, maximum and minimum temperature, sunshine hours, wind velocity and relative humidity during the cropping period is given in Appendix-II and graphically presented in Figure-1. In general, the weather conditions were favourable for the satisfactory growth of the crop.

3.1.4 Season

The experiment was conducted during the period from December 1999 to March 2000.

3.1. 5 Variety

The variety used was Jwalasakhi, a high yielding variety of vegetable chilli evolved by Kerala Agricultural University by crossing Vellanotchi, a popular cultivar of South Kerala with Pusa Jwala. It has got high yielding potential, ideal for culinary purposes and is suited for high density planting. The seed material was obtained from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

3.1.6 Growth regulators

The growth regulators used (Appendix-II) were Indole-3-acetic acid(IAA), Naphthalene acetic acid (NAA), gibberellic acid (GA) each at concentrations of 10,20,30 and 40 ppm and Triacontanol (Vipul) at concentrations of 1,2,3 and 4 ppm.

Table 1 Growth regulators

Sl. No.	Name	Price	Brand
1.	Indole-3 acetic acid	Rs. 355 / 5g	SRL
2.	Naphthalene acetic acid	Rs. 140 / 25g	SRL
3.	Triacontanol (Vipul)	Rs. 35/100 ml	Godrej Agrovet. Ltd., Bombay
4.	Gibberellic acid	Rs. 181 / g	SRL

3.1.7 Nursery

50 gram of seeds were sown in 30 pots filled with potting mixture. The seeds were sown during November 1999 and the seedlings were irrigated almost every day. Hand weeding and plant protection measures were undertaken periodically as per KAU package of practices recommendation (1996). The seedlings were ready for transplanting in 30-35 days.

3.2 Particulars

3.2.1 Design and layout

The experiment was laid out in randomised block design. The details of layout are given below:

Treatments : 18

Replications : 3

Number of plots : 54

Plot size : 2.25 x 2.25 m

Number of plants in a plot : 25

Spacing : 0.45 x 0.45 m

3.2.2 Treatments

The treatments included four growth regulators each at four different concentrations, one water spray and one control. Hence, there were 16 treatments and 2 controls and the number of replications were three. The details of treatments are as follows:

T_1 - IAA at 10 ppm

T_2 - IAA at 20 ppm

T_3 - IAA at 30 ppm

T_4 - IAA at 40 ppm

T_5 - NAA at 10 ppm

T_6 - NAA at 20 ppm

T_7 - NAA at 30 ppm

T_8 - NAA at 40 ppm

T_9 - Triacontanol at 1ppm

T_{10} - Triacontanol at 2 ppm

T_{11} - Triacontanol at 3 ppm

T_{12} - Triacontanol at 4 ppm

T_{13} - GA at 10 ppm

T_{14} - GA at 20 ppm

T_{15} - GA at 30 ppm

T_{16} - GA at 40 ppm

C_1 - Control with water spray

C_2 - Control with no growth regulator and no water spray.

3.2.3 Details of cultivation

The main field was dug twice and plots of 2.25 x 2.25 m were laid out with bunds of 0.20 m width between plots. Bunds of width 0.30 m were laid on the boundary of the field and in between replications. Individual plots

were again dug and perfectly levelled. Ridges were taken at a spacing of 0.45 m and the seedlings were planted at a spacing of 0.45 m on these ridges. The plants were given uniform irrigation. Necessary shade was also provided for a week after transplanting.

3.2.4 Maintenance of the crop

Gap filling was done a week after transplanting. The crop was hand weeded at 25 days interval. Need based plant protection measures were undertaken to control pests and diseases.

3.2.5 Schedule of spraying

Two sprays of growth regulators were given:

1) During pre-flowering stage i.e., 20 days after transplanting.

2) During flowering stage i.e., 40 days after transplanting.

The solutions of IAA, NAA and GA were prepared by dissolving the weighed quantity in 95 percent ethyl alcohol and then making up to the required volume. In case of triacontanol, concentrations of 1, 2, 3 and 4 ppm were prepared as Vipul 0.2ml, 0.4ml, 0.6ml and 0.8ml per litre of water respectively (Rajamani *et al.*, 1990). All the four growth regulators at different concentrations were given as foliar sprays twice as indicated above. In the case of water spray, distilled water was used. The spraying was done with knapsack sprayer till runoff started on the foliage. Teepole was used as a spreader.

3.2.6 Harvest

The crop was ready for first harvest, 48 days after transplanting and subsequent harvests were made at an interval of 10 days. On the whole, 7-8 pickings were carried out.

3.3 Observations

Observations related to morphological, growth and yield characters were recorded in five stages of crop growth viz. vegetative stage (S_1), flower initiation stage (S_2), peak flowering stage (S_3), maturation stage (S_4) and ripening stage (S_5). Two plants were tagged in each plot as the observational plants leaving the border rows. All observations were recorded from these plants and the mean values were taken.

3.3.1 Morphological characters

3.3.1.1 Number of days to produce first flower

The number of days from transplanting to the production of first flower was recorded.

3.3.1.2 Number of days to produce first fruit

The number of days taken for the appearance of first fruit was recorded from the observational area.

3.3.1.3 Intensity of flowering

The total number of flowers produced from flower initiation to maturation stage were taken as such as the intensity of flowering.

3.3.1.4 Intensity of flower drop

The intensity of flower drop was recorded in percentage as per formula :

$$\frac{\text{Number of flowers dropped}}{\text{Total number of flowers}} \times 100$$

3.3.1.5 Intensity of fruiting

The total number of fruits were recorded till the last harvest of the crop and the intensity of fruiting was calculated as :-

$$\frac{\text{Number of fruits}}{\text{Number of flowers}} \times 100$$

3.3.1.6 Intensity of fruit drop

The intensity of fruit drop was observed in percentage as:

$$\frac{\text{Number of fruits dropped}}{\text{Number of fruit drop + Number of fruits}} \times 100$$

3.3.1.7 Plant height

The height of plants in cm was measured from the base of the plant to the growing tip of the plants. Observations were recorded on the tagged plants at all the five growth stages.

3.3.2 Growth Parameters

3.3.2.1 Leaf area (LA)

L1 3000 area meter with conveyor belt was employed for assessing the leaf area of the whole sampling unit and expressed as cm^2 $plant^{-1}$.

3.3.2.2 Leaf area index (LAI)

The leaf area index was calculated by employing the formula of Williams (1946).

$$\frac{\text{Leaf area per plant}}{\text{Area occupied per plant}}$$

3.3.2.3 Specific leaf weight (SLW)

Specific leaf weight was calculated by using the formula suggested by Pearce *et al.* (1968) and expressed in g m^{-2}.

$$\frac{\text{Leaf dry weight per plant}}{\text{Leaf area per plant}}$$

3.3.2.4 Leaf area ratio (LAR)

The leaf area ratio was worked of by using the formula of Hunt (1990) and expressed as $m^2\ g^{-1}$.

$$\frac{\text{Leaf area per plant}}{\text{Total plant dry weight}}$$

3.3.2.5 Crop growth rate (CGR)

The CGR was worked out by using the formula of Watson (1958) and expressed in g m^{-2} day^{-1}

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

Where,

W_1 and W_2 = Whole plant dry weight at t_1 and t_2 respectively

t_1 and t_2 = Time interval in days.

P = Ground area on which W_1 and W_2 have been estimated.

3.3.2.6 Net assimilation rate (NAR)

The method proposed by Gregory *et al.* (1917) which was modified by Williams (1946) was employed for calculating NAR on leaf area basis and the values were expressed in mg cm^{-2} day^{-1}.

$$\frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where,

W_1 and W_2 = Dry weights of whole plant at t_1 and t_2 respectively

L_1 and L_2 = Leaf area at time intervals of t_1 and t_2 respectively

t_1 and t_2 = Time in days.

3.3.2.7 Relative growth rate (RGR)

The RGR was determined by the formula suggested by Williams (1946) and expressed in mg g^{-1} day^{-1}.

$$\frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 = Plant dry weight at time t_1 and t_2 respectively

t_1 and t_2 = Time interval in days.

3.3.2.8 Root-shoot ratio

The ratio of root dry weight to shoot dry weight is expressed as root-shoot ratio. The root and shoot portion of uprooted sample plants were cut and separated. The root and shoot portions were dried separately in oven at

50^0C for 3 days. The dry weights of root and shoot were recorded separately and the ratio was worked out.

3.3.3 Physiological parameters

A separate experiment with all the sixteen treatments and two controls (C_1 and C_2) were carried out with three replications. 20 days after transplanting, the plants were sprayed with the different growth regulators as specified for the field study. Different physiological parameters like the photosynthetic rate, transpiration rate and stomatal conductance were recorded using Photosynthesis System, CI-301 PS manufactured by CID, Inc, Vancouver, Washington State, USA. For reading these parameters, the plants were taken to Forestry College and Research Institute, Mettupalayam 30 days after transplanting and the Photosynthesis System available in the Department of Forest Biology was utilized for the study.

3.3.4 Biochemical parameters

3.3.4.1 Photosynthetic pigments

Photosynthetic pigments viz. chlorophyll-a, chlorophyll-b, total chlorophyll and chlorophyll a/b ratio were estimated by the method described by Arnon (1949).

A representative sample of 1g of leaf tissue was weighed and ground with 20ml of 80 per cent acetone using a pestle and mortar. The homogenate was centrifuged at 5000 rpm for 5 minutes. The supernatant was collected and made up to 100ml with 80 per cent acetone. The optical density (OD) value of the extract was measured at 663 and 645 nm using 80 per cent acetone as blank in a spectrophotometer. The amount of pigments were

calculated using the following formula and expressed as mg of pigments g^{-1} of fresh leaf.

$$\text{mg chlorophyll-a per g tissue} = 12.7\,(A_{663}) - 2.69(A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{mg chlorophyll-b per g tissue} = 22.9\,(A_{645}) - 4.68\,(A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{mg total chlorophyll per g tissue} = 20.2\,(A_{645}) + 8.02\,(A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll a/b ratio per g tissue} = \frac{\text{mg chlorophyll-a per g tissue}}{\text{mg chlorophyll-b per g tissue}}$$

Where,

A = Absorbance at specific wavelengths

V = Final volume of chlorophyll extract in 80 per cent acetone

W = Fresh weight of tissue extracted.

3.3.4.2 Protein content

The protein content of fresh leaf was estimated by the method developed by Lowry *et al.* (1951). Five hundred mg of leaf material was ground well with a pestle and mortar in 10ml of the buffer. 0.1 and 0.2 ml of supernatant was used for protein estimation and the residue was discarded. The volume was made up to 1ml and was allowed to stand for 10 minutes after adding 5ml of alkaline copper solution. To this 0.5ml of Folin-Ciocalteau's reagent was added, mixed well and incubated at room

temperature in dark for 30 minutes. The intensity of blue colour developed was read at 660 nm using spectrophotometer. Protein content of different samples were calculated by referring the standard curve which was prepared using bovine serum albumin and expressed as mg of protein per gram of sample.

3.3.4.3 Total carbohydrates

The total carbohydrates of fresh leaves was estimated by Anthrone method (Hedge and Hofreiter, 1962). 100 mg of sample was weighed into a boiling tube. It was hydrolysed by keeping it in a boiling water bath for three hours with 5ml of 2.5 N HCl and cooled to room temperature. The volume was made up to 100ml after neutralising it with solid sodium carbonate. 0.5 and 1ml of supernatant were used for the estimation of carbohydrates. The volume was made up to 1ml and 4 ml of anthrone reagent was added. After heating for 8 minutes, it was cooled rapidly and the optical density of the green to dark green colour was read in a spectrophotometer at 630 nm. The amount of carbohydrates present in the sample was estimated using the standard curve prepared from standard glucose and the amount of carbohydrate as mg per 100 mg of sample was computed as :

$$\frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

3.3.4.4 Leaf proline content

Proline accumulation in leaf was estimated by the method of Bates *et al.* (1973). The proline content was estimated as μ moles g^{-1} fresh weight. Five hundred mg of leaf material was macerated with 10ml of 3 per cent

sulphosalicylic acid. This was centrifuged at 3000 rpm for 10 minutes. The supernatant was used for proline estimation and the residue was discarded. 2ml of supernatant + 2 ml of glacial acetic acid + 2ml of 6 M orthophosphoric acid were taken and boiled at 100^0C in a water bath for about 1 hour and then cooled. The contents were transferred to a separating flask. To this 4 ml of toluene was added and shaken well for 20-30 seconds. The lower layer was discarded and the upper layer was taken for estimating the OD values at 520 nm in a spectrophotometer. Proline content was calculated by referring the standard curve which was prepared by using pure proline. The proline content in μ moles per g tissue was expressed as follows :

$$\frac{\mu \text{ gram proline per ml x ml toluene}}{115.5} \times \frac{5}{\text{g sample}}$$

Where,

115.5 = Molecular weight of proline

3.3.4.5 Reducing sugars

Ripe fruits were pulped in a blender and filtered through Whatman No.4 filter paper. About 25 ml of filtered juice was transferred to a 250 ml volumetric flask. 100ml of water was added and neutralized with IN NaOH. It was allowed to stand for ten minutes after adding 2 ml of lead acetate. Then 2ml of potassium oxalate was added to remove excess of lead and the volume was made up to 250 ml with water. 5ml each of Fehling's solution A and B were pipetted into a conical flask. 50ml of distilled water along with 2 or 3 glass beads were added and the contents were boiled vigorously. While boiling, the clarified fruit juice was added till the blue colour just disappeared. It was again boiled for 1 minute after adding 0.5 ml of

methylene blue indicator. The titration was completed as quickly as possible by adding 2 to 3 drops of sugar solution until the brick red colour of cuprous oxide became dominant. The content of reducing sugar was calculated as per the following formula and expressed as g of glucose per 100g of juice :

$$0.05 \times \frac{250}{V} \times \frac{250}{50} \times \frac{100}{W}$$

Where,

V(ml) = Titre value

W(g) = Weight of fruit juice taken for analysis.

3.3.4.6 Carotenoids

The carotenoid content of red ripe fruits was estimated by the method described by Jensen (1978). A representative sample of 200 mg of fresh fruit was cut into small pieces and homogenised in a blender using 80 per cent acetone. The homogenate was made up to 100 ml with 80 per cent acetone and kept overnight in dark. The optical density of the extract was read at 450 nm using spectrophotometer. The carotenoids present in the extract was calculated using the following formula.

$$C = \frac{D \times V \times f \times 100}{2500}$$

Where,

C = Total amount of carotenoids in mg.

D = Absorbance at 450 nm in a 1cm cell.

E = Volume of the original extract in ml.

f = Dilution factor.

2500 = Average extinction coefficient of the pigments.

3.3.4.7 Capsaicin content

Capsaicin content of red ripe fruits was estimated by Folin-Denis method as described by Mathew *et al.*(1971). The fruits were dried in hot air oven and finely powdered. To 1 g of the representative sample, 10ml acetone was added and kept overnight. From this, aliquats of 1ml was pipetted, added 25ml of freshly prepared Na_2Co_3 solution and shook vigorously. The volume was made up to 100ml and after 30 minutes and the optical density was measured at 725nm in a UV-spectrophotometer. The capsaicin content was calculated in μ grams from the standard curve which was prepared by using pure capsaicin.

3.3.5 Yield parameters

3.3.5.1 Total fresh weight

One plant from the observational area was uprooted and the fresh weight was taken and expressed as g $plant^{-1}$. The observations were recorded in all the five growth stages.

3.3.5.2 Total dry weight

The above said samples were dried to constant weights in a hot air oven at a temperature of 50^0C and the total dry weight was taken and expressed as g $plant^{-1}$.

3.3.5.3 Total number of fruits per plant

The total number of fruits from the observational plants were counted during each harvest and the mean was calculated.

3.3.5.4 Total weight of fruits per plant

The weight of fruits harvested from the tagged plants were recorded and the average was calculated.

3.3.5.5 Fruit length

From the selected plants, 15 fruits were taken at random from the second harvest. Fruit length in cm were measured and the average was worked out.

3.3.5.6 Fruit breadth

Fruits used for measuring the length were used for recording the breadth of fruits. The breadth was measured at the broadest part of the fruits.

3.3.5.7 Colour of fruit at ripening

The colour of ripe fruits was determined by visual observations.

3.3.5.8 Thousand seed weight

Red ripe fruits from each replication in every treatment was picked at random and dried in the sun. The seeds were extracted and thousand seed weight was recorded in gram.

3.3.5.9 Germination percentage of seeds

Fifty seeds were taken at random from each treatment and kept for germination by the petri dish method. The germination percentage of seeds was worked out as :

$$\frac{\text{Number of seeds germinated}}{\text{Number of seeds}} \times 100$$

3.3.5.10 Harvest index

The harvest index of each treatment was computed on fresh weight basis.

$$\text{Harvest index} = \frac{EY}{EY + BY}$$

Where,

EY = Economic yield ie. the total fruit yield

BY = Biological yield ie. the fresh weight of whole plant.

3.3.6 Biotic factors

3.3.6.1 Reaction towards pests and diseases

The incidence of leaf curl, colletotrichum fruit rot and mite infestation were noted as percentage by visual observations. They were given the rating of low, medium and high.

3.3.7 Economics of cultivation

The economics of cultivation was based on the cost of cultivation and prevailing price of crop produce.

Net income (Rs. ha^{-1}) = Gross income - Total expenditure

$$\text{Benefit-cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.3.8 Statistical analysis

The data generated from the experiment were subjected to analysis of variance technique (ANOVA) as applied to randomised block design described by Cochran and Cox (1965), after appropriate transformations wherever needed. Important correlation were estimated and taken for significance (Snedecor and Cochran, 1967).

Results

4. RESULTS

The present investigation was carried out to study the influence of growth regulators viz. IAA, NAA, Triacontanol and GA on flower and fruit drop in chilli *(Capsicum annuum* L.). Relevant observations were made at different stages of the crop growth. The data recorded from the experiment were statistically analysed. The results are presented under the appropriate heads viz., morphological, physiological, biochemical, yield, biotic parameters and correlation studies.

4.1 Morphological parameters

4.1.1 Number of days to produce first flower

The data on days to produce first flower is presented in Table 2. The number of days to produce first flower ranged from 23.17 (T_7) to 31.67 (T_4). T_6(23.50), T_{12}(24.50), T_3(24.67) and T_5, T_9 , T_{13} , T_{14} with a value of 26.33 were found to be on par with T_7. These treatments also showed lower values than C_1 (28.84) and C_2 (28.0).

4.1.2 Number of days to produce first fruit

The data on days to produce first fruit is given in Table 2. The values ranged from 28.67(T_6) to 35.50 (T_8). Statistical analysis revealed no significant difference between the treatments. The control showed values of 34.34 (C_1) and 32.50 (C_2).

Table 2 Effect of different growth regulators on morphological characters

Treatment	Growth regulator	Concentration (ppm)	Number of days to produce first flower	Number of days to produce first fruit	Intensity of flowering (No. per plant)	Flower drop (per cent)	Intensity of fruiting (per cent)	Fruit drop (per cent)
T_1	IAA	10	27.17	29.83	92.00 (46.80)	35.38 [40.61]	53.77 (58.92)	16.76
T_2	IAA	20	30.00	33.50	110.50 (76.32)	48.20 [19.10]	41.28 (22.05)	17.37
T_3	IAA	30	24.67	34.67	129.50 (106.63)	61.39	32.61	15.39 [2.34]
T_4	IAA	40	31.67	32.83	67.00 (6.90)	30.94 [48.06]	57.22 (69.18)	17.66
T_5	NAA	10	26.33	30.50	64.00 (2.12)	42.13 [29.28]	47.03 (39.05)	17.18
T_6	NAA	20	23.50	28.67	85.17 (35.90)	57.16 [4.06]	32.06	16.25
T_7	NAA	30	23.17	29.00	89.00 (42.01)	46.84 [21.38]	37.97 (12.27)	16.89
T_8	NAA	40	29.67	35.50	96.17 (53.45)	54.89 [7.87]	40.27 (19.07)	16.79
T_9	Triacontanol	1	26.33	30.33	88.33 (40.94)	39.16 [34.27]	50.02 (47.90)	16.41
T_{10}	Triacontanol	2	27.50	32.83	81.67 (30.31)	44.90 [24.63]	47.02 (39.03)	17.43
T_{11}	Triacontanol	3	28.33	32.50	60.50	46.76 [21.51]	44.03 (30.18)	17.21
T_{12}	Triacontanol	4	24.50	30.83	102.17 (63.02)	57.52 [3.45]	34.93 (3.28)	17.83
T_{13}	GA	10	26.33	30.83	73.33 (17.00)	31.65 [46.87]	55.09 (62.89)	16.94
T_{14}	GA	20	26.33	31.50	64.17 (2.39)	36.79 [38.25]	50.25 (48.58)	17.32
T_{15}	GA	30	28.00	33.17	82.67 (31.91)	63.98	30.91	16.84
T_{16}	GA	40	28.83	29.17	75.83 (20.99)	53.66 [9.93]	38.59 (14.10)	17.67
C_1	Control	Water spray	28.84	34.34	62.67	59.58	33.82	15.76
C_2	Control	No spray	28.00	32.50	58.33	51.34	43.54	14.45
Mean			27.17	31.86	82.38	47.90	42.80	16.78
F value			3.95**	0.86	3.15**	3.83**	41.29**	3.12**
CD			3.19	-	30.05	14.64	11.17	1.38

** Significant at 0.01 level

( ) Indicates percentage increase over C_1 [ ] Indicates percentage decrease over C_1

4.1.3 Intensity of flowering

Data on intensity of flowering is presented in Table 2. Statistical difference was observed among the different treatments. T_3 (129.50) produced the maximum number of flowers and C_2 (58.33) recorded the lowest number of flowers. T_2 (110.50) and T_{12} (102.17) were on par with T_3. C_1 recorded a value of 62.67.

4.1.4 Intensity of flower drop (per cent)

Data on intensity of flower drop is presented in Table 2. Statistical analysis revealed significant difference among the treatments. The minimum percentage of flower drop was recorded in T_4 (30.94) and the maximum in T_{15} (63.98). T_1 (35.38), T_5 (42.13), T_9 (39.16), T_{10} (44.90), T_{14} (36. 79) and T_{13} (31.65) were on par with T_4. C_1 and C_2 showed values of 59.58 and 51.34 respectively.

4.1.5 Intensity of fruiting (per cent)

Data on intensity of fruiting is presented in Table 2. Significant difference was observed among the different treatments. The treatment values ranged from 57.22 (T_4) to 30.91 per cent (T_{15}). T_1 (53.77), T_5 (47.03), T_9 (50.02), T_{10} (47.02), T_{13} (55.09) and T_{14} (50.25) were on par with T_4. The control values were 33.82 (C_1) and 43.54 (C_2).

4.1.6 Intensity of fruit drop (per cent)

Data on intensity of fruit drop is presented in Table 2. The minimum number of fruit drop was observed in C_2 (14.45) and the maximum drop in T_{12} (17.83). T_3 (15.39) and C_1 (15.76) were on par with C_2.

4.1.7 Plant height (cm)

The data on plant height recorded in five stages of crop growth are presented in Table 3. A steady increase in plant height was observed from S_1 stage to S_4 stage followed by a slow rate of increase in S_5 stage. T_{16} (38.93) recorded the maximum value with a 16.94 per cent increase over C_1 (33.29). The other best treatments observed were T_{15} (38.33) and T_{14} (38.18). The lowest value was recorded in T_1(30.08).

Statistical analysis revealed a significant difference among the treatments in S_2 stage only. In S_1 stage T_5, T_{13}, T_{11} showed higher values (20.50, 18.50, and 18.0 respectively) compared to C_1 (13.50) and C_2 (13.33). T_{16} (32.58) recorded the highest plant height in S_2 stage and it was on par with T_{14}(30.33), T_{15} (31.16), T_{10} (30.61) and T_5 (27.33). These treatments also showed higher values than C_1 (25.83) and C_2 (26.58). In S_3 stage, T_{11} (44.58) showed the maximum value and T_7 (32.25) the minimum value. The control values were C_1 (37.00) and C_2 (39.25). T_{16} (51.83 and 53.25) showed the highest values in $S_4$and S_5 stages respectively. T_{14} (51.0, 51.75) and T_{15} (50.50, 51.66) recorded higher values than control in S_4 and S_5 stages respectively.

4.2 Growth parameters

4.2.1 Leaf area (cm^2 $plant^{-1}$)

The data relating to leaf area in five crop growth stages are presented in Table 4. A conspicuous increase in leaf area was observed from S_1 to

Table 3 Effect of different growth regulators on plant height (cm)

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	16.83	19.83	33.61	41.00	42.16	30.08
T_2	IAA	20	14.83	23.36	39.50	46.33	46.41	34.08 (2.37)
T_3	IAA	30	16.00	23.28	37.00	46.83	47.58	34.13 (2.52)
T_4	IAA	40	16.00	23.91	37.50	43.50	44.33	33.04
T_5	NAA	10	20.50	27.33	40.00	42.16	44.33	34.66 (4.11)
T_6	NAA	20	14.50	26.36	39.16	45.58	46.41	34.40 (3.33)
T_7	NAA	30	16.83	23.75	32.25	41.00	42.66	31.29
T_8	NAA	40	15.00	23.51	37.08	45.66	46.83	33.61 (0.96)
T_9	Tria-contanol	1	15.33	26.11	38.16	45.50	46.41	34.30 (3.03)
T_{10}	Tria-contanol	2	11.56	30.61	42.50	47.20	47.83	35.94 (7.96)
T_{11}	Tria-contanol	3	18.00	25.41	44.58	48.16	50.58	37.34 (12.16)
T_{12}	Tria-contanol	4	16.83	25.38	40.91	46.00	47.75	35.37 (6.25)
T_{13}	GA	10	18.50	25.00	37.25	43.66	45.33	33.94 (1.95)
T_{14}	GA	20	19.16	30.33	38.66	51.00	51.75	38.18 (14.68)
T_{15}	GA	30	16.33	31.16	42.00	50.50	51.66	38.33 (15.13)
T_{16}	GA	40	15.50	32.58	41.50	51.83	53.25	38.93 (16.94)
C_1	Control	Water spray	13.50	25.83	37.00	39.83	50.33	33.29
C_2	Control	No spray	13.33	26.58	39.25	42.66	43.91	33.14
	Mean		15.86	26.12	38.77	45.56	47.11	
	F value		1.40	2.48*	1.42	1.38	1.40	
	CD		-	5.78	-	-	-	

* Significant at 0.05 level

( ) Indicates percentage increase over C_1

Table 4 Effect of different growth regulators on leaf area (cm^2 $plant^{-1}$)

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	44.50	173.78	343.44	257.69	171.88	198.26
T_2	IAA	20	94.83	98.18	488.38	300.59	112.71	218.93
T_3	IAA	30	138.54	200.54	555.74	496.87	438.93	366.12 (36.76)
T_4	IAA	40	62.03	92.17	740.35	389.90	39.38	264.76
T_5	NAA	10	47.30	138.25	562.82	294.08	25.08	213.50
T_6	NAA	20	67.74	99.81	1094.87	654.46	214.29	426.22 (59.21)
T_7	NAA	30	21.02	99.98	437.96	259.47	80.92	179.87
T_8	NAA	40	33.17	220.92	620.05	412.93	205.72	298.55 (11.52)
T_9	Tria-contanol	1	40.10	150.73	419.67	265.60	111.43	195.50
T_{10}	Tria-contanol	2	21.90	203.23	1195.85	700.31	204.61	465.18 (73.76)
T_{11}	Tria-contanol	3	49.71	112.35	421.43	395.29	369.08	269.57 (6.98)
T_{12}	Tria-contanol	4	31.29	63.37	401.68	244.01	85.94	165.26
T_{13}	GA	10	38.56	159.39	547.70	326.41	105.10	235.43
T_{14}	GA	20	32.65	95.28	692.86	517.60	342.20	336.11 (25.55)
T_{15}	GA	30	41.86	175.17	501.77	319.91	138.06	235.34
T_{16}	GA	40	28.47	126.86	1233.84	744.97	256.07	478.04 (78.57)
C_1	Control	Water spray	33.72	57.62	526.36	415.76	305.07	267.77
C_2	Control	No spray	47.68	85.86	508.01	394.86	281.31	263.55
	Mean		48.61	130.75	627.37	410.59	193.76	
	F value		421.64**	807.42**	1757.70**	41548.95**	21172.00**	
	CD		3.87	4.83	18.17	2.12	0.72	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

S_3stage and thereafter a decline in leaf area is seen in S_4 and S_5 stages. T_{16} (478.04) recorded the maximum leaf area with a 78.57 per cent increase over C_1(267.77). T_{12} (165.26) recorded the minimum value and C_2 recorded a value of 263.55.

A significant difference among the treatments was observed in all the five stages. In S_1 stage, T_3 (138.54) recorded the maximum leaf area and T_7 (21.02) the minimum. The control values were C_1 (33.72) and C_2 (47.68). T_8 (220.92) recorded the highest value and C_1 (57.62) the lowest value in S_2 stage. T_{16} (1233.84) recorded the highest value in S_3 stage and T_1 (343.44) the lowest value. The control values were C_1 (526.36) and C_2 (508.01). In S_4 stage also, T_{16} (744.97) showed the maximum leaf area and T_{12} (244.01) the minimum leaf area. The values ranged from 438.93 (T_3) to 25.08 (T_5) in S_5 stage.

4.2.2 Leaf area index

The data on leaf area index (LAI) is given in Table 5. A distinct increase in LAI was seen from S_1 to S_3 stages. But during S_4 and S_5 stages, a decrease in LAI was recorded in all the treatments. T_{10} and T_{16} both recorded the maximum LAI value of 0.23 showing a 91.66 per cent increase over C_1 (0.12). T_{12}(0.08) recorded the minimum value.

Statistical analysis revealed a significant difference among the treatments in all the stages. T_3 (0.07) recorded the highest value and T_7, T_{10} T_{12}, T_{16} and C_1 all with a value of 0.01 showed the lowest value in S_1 stage.

Table 5 Effect of different growth regulators on leaf area index

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.02	0.09	0.17	0.13	0.08	0.09
T_2	IAA	20	0.05	0.05	0.24	0.15	0.06	0.11
T_3	IAA	30	0.07	0.10	0.27	0.25	0.22	0.18 (50.0)
T_4	IAA	40	0.03	0.05	0.37	0.19	0.02	0.13 (8.34)
T_5	NAA	10	0.02	0.07	0.28	0.14	0.01	0.10
T_6	NAA	20	0.03	0.05	0.54	0.32	0.11	0.21 (75.0)
T_7	NAA	30	0.01	0.05	0.22	0.13	0.04	0.09
T_8	NAA	40	0.02	0.11	0.31	0.20	0.10	0.14 (16.66)
T_9	Tria-contanol	1	0.02	0.07	0.21	0.13	0.05	0.03
T_{10}	Tria-contanol	2	0.01	0.10	0.59	0.35	0.10	0.23 (91.66)
T_{11}	Tria-contanol	3	0.02	0.06	0.15	0.19	0.18	0.12
T_{12}	Tria-contanol	4	0.01	0.03	0.20	0.12	0.04	0.08
T_{13}	GA	10	0.02	0.08	0.27	0.16	0.05	0.11
T_{14}	GA	20	0.02	0.05	0.34	0.26	0.17	0.16 (33.34)
T_{15}	GA	30	0.02	0.09	0.25	0.16	0.07	0.11
T_{16}	GA	40	0.01	0.06	0.61	0.37	0.13	0.23 (91.66)
C_1	Control	Water spray	0.01	0.02	0.25	0.20	0.15	0.12
C_2	Control	No spray	0.02	0.04	0.25	0.19	0.13	0.12
	Mean		0.02	0.06	0.30	0.20	0.09	
	F value		376.52**	874.36**	84.13**	146716.10**	12699.01**	
	CD		0.002	0.002	0.040	0.002	0.002	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

In S_2 stage, the LA1 values ranged from 0.11 (T_8) to 0.02 (C_1). T_{16}(0.61) recorded the maximum value in S_3 stage, which was on par with T_{10}(0.59). T_{11} (0.15) showed the lowest value and this was lower than C_1 and C_2 (0.25). In S_4 stage, the values ranged from T_{10} (0.35) to T_{12} (0.12). C_1 and C_2 recorded values of 0.20 and 0.19 respectively. In S_5 stage, T_{11} (0.18) recorded the maximum value and T_5 (0.01) the minimum. C_1 and C_2 showed values of 0.15 and 0.13 respectively.

4.2.3 Specific leaf weight (g m^{-2})

The data on specific leaf weight (SLW) is presented in Table 6. S_5 stage recorded the highest value for SLW. The highest value was recorded by T_5 (1.30) followed by T_{12} (1.21). T_3 (0.44) showed the minimum value, while C_1 and C_2 recorded SLW values of 0.57 and 0.58 respectively.

A significant difference was observed among the different treatments in all the five stages. T_{16} (0.63) recorded the highest value in S_1 stage and T_{14} (0.58) was on par with T_{16}. C_1 (0.43) and C_2 (0.28) both showed a higher value than T_1 (0.05) which recorded the lowest value. In S_2 stage, SLW values ranged from 1.24 (T_{12}) to 0.35 (T_8). The control values observed were C_1 (1.05) and C_2 (0.61). T_{12} (0.58) recorded the highest value and C_2 (0.22) showed the lowest value in S_3 stage. In S_4 stage, the maximum SLW was recorded by T_5 (1.17) and the lowest by both T_3 (0.41) and C_2 (0.41). The values ranged from 3.86 (T_5) to 0.31 (T_3) in S_5 stage.

Table 6 Effect of different growth regulators on specific leaf weight (g m^{-2})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.05	0.96	0.57	0.88	0.98	0.68 (19.29)
T_2	IAA	20	0.33	0.57	0.32	0.86	0.99	0.61 (7.01)
T_3	IAA	30	0.17	0.97	0.36	0.41	0.31	0.44
T_4	IAA	40	0.35	0.81	0.31	0.97	1.03	0.69 (21.05)
T_5	NAA	10	0.18	0.91	0.41	1.17	3.86	1.30 (128.07)
T_6	NAA	20	0.27	0.90	0.32	0.92	0.52	0.58 (1.75)
T_7	NAA	30	0.30	0.82	0.31	0.74	1.25	0.68 (19.29)
T_8	NAA	40	0.26	0.35	0.29	0.69	0.86	0.49
T_9	Tria-contanol	1	0.40	0.65	0.39	0.83	1.80	0.79 (38.59)
T_{10}	Tria-contanol	2	2.16	0.83	0.36	0.91	1.68	0.80 (40.35)
T_{11}	Tria-contanol	3	0.28	0.74	0.55	0.70	0.71	0.62 (8.77)
T_{12}	Tria-contanol	4	0.26	1.24	0.58	0.87	1.22	1.21 (112.28)
T_{13}	GA	10	0.48	0.74	0.31	0.68	1.88	0.77 (35.08)
T_{14}	GA	20	0.58	0.72	0.27	0.60	0.52	0.47
T_{15}	GA	30	0.29	0.45	0.26	0.68	0.90	0.55
T_{16}	GA	40	0.63	0.52	0.30	0.83	1.29	0.70 (22.87)
C_1	Control	Water spray	0.43	1.05	0.36	0.54	0.66	0.57
C_2	Control	No spray	0.28	0.61	0.22	0.41	1.05	0.58
	Mean		0.42	0.76	0.36	0.76	1.19	
	F value		168.83**	223.85**	11034.20**	5.88**	62.08	
	CD		0.10	0.04	0.002	0.22	0.28	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

4.2.4 Leaf area ratio ($m^2 g^{-1}$)

The data on leaf area ratio (LAR) recorded in five stages are presented in Table 7. T_3 (1.02) was observed to have the highest LAR value followed by T_1 (1.01). C_1 and C_2 recorded values of 0.55 and 0.91 respectively and T_{12} (0.38) showed the lowest value.

Statistical analysis revealed a significant difference among the treatments. T_1 (3.60) recorded the highest LAR value and T_8 (0.47) the lowest value in S_1 stage. T_8 recorded lower value compared to C_1 (0.77) and C_2 (1.10). In S_2 stage, T_8 (1.54) showed the highest value compared to C_1 (0.27) and C_2 (0.77) and T_{12} (0.25) recorded the lowest value. In S_3 stage, C_2 (2.15) was observed to show the highest value and T_{14} (2.03) along with T_{16} (1.96) were on par with C_2. The lowest value was recorded by T_{15} (0.57). C_2(0.36) recorded the highest value in S_4 stage followed by T_8 (0.33) and T_5 (0.10) showed the lowest value. In S_5 stage, the LAR values ranged from 0.53 (T_3) to 0.01 (T_5). The control values were C_1 (0.14) and C_2 (0.19).

4.2.5 Crop growth rate ($g\ m^{-2}\ day^{-1}$)

Data on crop growth rate (CGR) is presented in Table 8. An increase in CGR was observed up to P_3 stage in most of the treatments followed by a decline in P_4 stage. The highest CGR value was recorded by T_{10} (2.24) and the lowest by C_2 (0.65).

Table 7 Effect of different growth regulators on leaf area ratio ($m^2 g^{-1}$)

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	3.60	0.64	0.58	0.13	0.13	1.01 (84.36)
T_2	IAA	20	2.04	0.56	1.14	0.14	0.03	0.78 (41.81)
T_3	IAA	30	2.67	0.67	0.90	0.32	0.53	1.02 (85.09)
T_4	IAA	40	0.83	0.43	1.71	0.15	0.02	0.62 (12.72)
T_5	NAA	10	1.71	0.63	0.69	0.10	0.01	0.62 (12.72)
T_6	NAA	20	0.72	0.58	1.65	0.29	0.11	0.67 (21.81)
T_7	NAA	30	0.77	0.47	1.56	0.20	0.03	0.60 (9.09)
T_8	NAA	40	0.47	1.54	1.06	0.33	0.09	0.69 (25.45)
T_9	Tria-contanol	1	0.93	0.72	0.61	0.29	0.06	0.52
T_{10}	Tria-contanol	2	1.41	0.53	1.76	0.21	0.11	0.80 (45.45)
T_{11}	Tria-contanol	3	1.23	0.41	0.73	0.24	0.09	0.54
T_{12}	Tria-contanol	4	0.56	0.25	0.96	0.13	0.03	0.38
T_{13}	GA	10	0.69	0.53	0.99	0.17	0.04	0.48
T_{14}	GA	20	0.61	0.75	2.03	0.25	0.10	0.74 (34.54)
T_{15}	GA	30	1.02	1.41	0.57	0.29	0.09	0.67 (21.81)
T_{16}	GA	40	0.92	0.66	1.96	0.24	0.09	0.77 (40.00)
C_1	Control	Water spray	0.77	0.27	1.32	0.29	0.14	0.55
C_2	Control	No spray	1.10	0.77	2.15	0.36	0.19	0.91
	Mean		1.22	0.59	1.22	0.22	0.10	
	F value		226.39**	480.96**	30.32**	261.73**	359.97**	
	CD		0.15	0.04	0.27	0.01	0.02	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

Table 8 Effect of different growth regulators on crop growth rate (g m^{-2} day^{-1})

Treat-ment	Growth regulator	Concen-tration (ppm)	Vegetative stage to flower initiation stage (P_1)	Flower initiation stage to peak flowering stage (P_2)	Peak flowering stage to maturation stage (P_3)	Maturation stage to ripening stage (P_4)	Mean
T_1	IAA	10	0.80	0.98	2.24	1.10	1.28 (25.49)
T_2	IAA	20	0.39	0.78	2.82	1.76	1.43 (40.19)
T_3	IAA	30	0.75	0.98	1.54	1.33	1.15 (12.74)
T_4	IAA	40	0.42	0.68	3.68	2.29	1.76 (72.54)
T_5	NAA	10	0.58	1.81	3.24	0.34	1.49 (46.07)
T_6	NAA	20	0.24	1.51	2.65	0.74	1.28 (25.49)
T_7	NAA	30	0.57	0.22	1.71	1.92	1.10 (7.84)
T_8	NAA	40	0.22	1.03	1.14	1.68	1.01
T_9	Tria-contanol	1	0.52	0.41	0.96	1.23	0.78
T_{10}	Tria-contanol	2	1.12	0.91	4.30	2.63	2.24 (119.60)
T_{11}	Tria-contanol	3	0.70	0.95	1.82	4.62	2.02 (98.02)
T_{12}	Tria-contanol	4	0.60	0.51	2.25	0.93	1.07 (4.90)
T_{13}	GA	10	0.75	0.77	2.29	0.42	1.05 (2.94)
T_{14}	GA	20	0.23	0.66	2.94	2.09	1.48 (45.09)
T_{15}	GA	30	0.26	2.30	0.38	0.87	0.95
T_{16}	GA	40	0.49	1.35	4.00	0.68	1.63 (59.80)
C_1	Control	Water spray	0.50	0.91	1.56	1.11	1.02
C_2	Control	No spray	0.21	0.39	1.44	0.59	0.65
	Mean		0.51	0.95	2.27	1.46	
	F value		1566.22**	37.29**	867.70**	363.70**	
	CD		0.02	0.24	0.10	0.15	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

Statistical analysis revealed a significant difference among the different treatments in all the stages. In P_1 stage, T_{10} (1.12) recorded the highest value and C_2 (0.21) the lowest. T_{15} (2.30) was observed to show the maximum value and C_2 (0.39) the minimum at P_2 stage. The values ranged from 4.30 (T_{10}) to 0.38 (T_{15}) in P_3 stage and control recorded value of C_1 (1.56) and C_2 (1.44). In P_4 stage, T_{11} (4.62) recorded the maximum value followed by T_{10} (2.63) compared to C_1(1.11) and C_2 (0.59) and T_5 (0.34) recorded the lowest value.

4.2.6 Relative growth rate (mg g^{-1} day^{-1})

Data on relative growth rate (RGR) is presented in Table 9. P_1 stage recorded the highest RGR value and thereafter a decline was observed in P_2, P_3 and P_4 stages. T_{10} (0.033) recorded the highest mean value with a 65.0 per cent increase over C_1 (0.020). The lowest value was recorded by T_{14} (0.015).

The difference between the treatments were observed to be statistically significant in all the stages. P_1 stage showed RGR values ranging from 0.083 (T_1) to 0.007 (T_{14}) . C_1 (0.042) and C_2 (0.024) recorded higher values than T_{14}. In P_2 stage, T_{15} (0.054) recorded the maximum RGR and T_7 (0.006) showed the minimum value. T_{14} (0.026) recorded the maximum RGR value in P_3 stage and T_2, T_4, T_{10}, T_{16} with value of 0.025 and T_7 (0.024) were on par with T_{14}. T_3 and T_8 recorded the minimum value of 0.014. In P_4 stage,

Table 9 Effect of different growth regulators on relative growth rate (mg g^{-1} day^{-1})

Treat-ment	Growth regulator	Concen-tration (ppm)	Vegetative stage to flower initiation stage (P_1)	Flower initiation stage to peak flowering stage (P_2)	Peak flowering stage to maturation stage (P_3)	Maturation stage to ripening stage (P_4)	Mean
T_1	IAA	10	0.083	0.021	0.015	0.005	0.031 (55.0)
T_2	IAA	20	0.035	0.023	0.025	0.006	0.022 (10.0)
T_3	IAA	30	0.047	0.019	0.014	0.010	0.022 (10.0)
T_4	IAA	40	0.027	0.020	0.025	0.008	0.020
T_5	NAA	10	0.056	0.032	0.018	0.007	0.028 (40.0)
T_6	NAA	20	0.016	0.031	0.016	0.004	0.016
T_7	NAA	30	0.056	0.006	0.024	0.008	0.023 (15.0)
T_8	NAA	40	0.018	0.037	0.014	0.011	0.020
T_9	Tria-contanol	1	0.040	0.013	0.016	0.008	0.019
T_{10}	Tria-contanol	2	0.081	0.018	0.025	0.009	0.033 (65.0)
T_{11}	Tria-contanol	3	0.053	0.020	0.015	0.013	0.025 (25.0)
T_{12}	Tria-contanol	4	0.059	0.014	0.022	0.005	0.020
T_{13}	GA	10	0.050	0.015	0.017	0.003	0.021 (5.0)
T_{14}	GA	20	0.007	0.024	0.026	0.005	0.015
T_{15}	GA	30	0.030	0.054	0.005	0.004	0.023 (15.0)
T_{16}	GA	40	0.049	0.033	0.025	0.002	0.027 (35.0)
C_1	Control	Water spray	0.042	0.020	0.015	0.006	0.020
C_2	Control	No spray	0.024	0.020	0.022	0.007	0.018
	Mean		0.041	0.023	0.018	0.006	
	F value		83.964**	31.700**	17.488**	5.065**	
	CD		0.010	0.010	0.002	0.002	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

the values ranged from 0.013 (T_{11}) to 0.002 (T_{16}). C_1 and C_2 recorded values of 0.006 and 0.007 respectively.

4.2.7 Net assimilation rate (mg cm^{-2} day^{-1})

Data on net assimilation rate (NAR) is presented in Table 10. The highest mean value was recorded by T_2 (0.75) followed by T_5 (0.73). The lowest mean value was recorded by C_2 (0.20). T_2 showed 50 per cent increase over C_1 (0.50).

Statistical analysis revealed a significant difference among the different treatments. In P_1 stage, T_{10} (1.21) recorded the highest NAR value compared to C_1(1.0) and C_2 (0.30). T_{12} (1.17) was on par with T_{10} and T_8 (0.18) recorded the lowest value. In P_2 stage, the values ranged from 0.65 (T_{15}) to 0.08 (T_7) and C_1 and C_2 recorded values of 0.37 and 0.16 respectively. In P_3 stage, the highest value was recorded by T_{12} (0.78) followed by T_{15} (0.71) and the lowest value by T_5 (0.07). The values in P_4 stage ranged from 1.97 (T_2) to 0.13 (T_{16}). C_1 (0.32) and C_2 (0.15) recorded higher values than T_{16}.

4.2.8 Root-shoot ratio

The data on root-shoot (RS) ratio is presented in Table 11. The highest RS ratio was recorded by T_{10} (0.69), which showed more than 100 per cent increased over C_1 and T_9 (0.28) showed the lowest value. C_1 and C_2 recorded values of 0.31 and 0.37 respectively.

Table 10 Effect of different growth regulators on net assimilation rate (mg cm^{-2} day^{-1})

Treat-ment	Growth regulator	Concen-tration (ppm)	Vegetative stage to flower initiation stage (P_1)	Flower initiation stage to peak flowering stage (P_2)	Peak flowering stage to maturation stage (P_3)	Maturation stage to ripening stage (P_4)	Mean
T_1	IAA	10	0.73	0.35	0.33	0.40	0.45
T_2	IAA	20	0.36	0.29	0.40	1.97	0.75 (50.0)
T_3	IAA	30	0.42	0.25	0.22	0.34	0.30
T_4	IAA	40	0.49	0.19	0.37	1.30	0.58 (16.0)
T_5	NAA	10	0.59	0.47	0.07	1.80	0.73 (46.0)
T_6	NAA	20	0.25	0.32	0.08	0.66	0.16
T_7	NAA	30	0.99	0.08	0.50	0.22	0.44
T_8	NAA	40	0.18	0.31	0.29	1.19	0.49
T_9	Tria-contanol	1	0.54	0.14	0.35	0.78	0.45
T_{10}	Tria-contanol	2	1.21	0.14	0.25	0.31	0.47
T_{11}	Tria-contanol	3	0.81	0.36	0.48	1.07	0.68 (36.0)
T_{12}	Tria-contanol	4	1.17	0.25	0.78	0.54	0.68 (36.0)
T_{13}	GA	10	0.78	0.22	0.32	0.19	0.37
T_{14}	GA	20	0.32	0.20	0.54	0.43	0.37
T_{15}	GA	30	0.24	0.65	0.71	0.35	0.48
T_{16}	GA	40	0.59	0.24	0.24	0.13	0.30
C_1	Control	Water spray	1.00	0.37	0.32	0.32	0.50
C_2	Control	No spray	0.30	0.16	0.22	0.15	0.20
	Mean		0.60	0.27	0.35	0.67	
	F value		175.55**	117.58**	608.06**	641.26**	
	CD		0.07	0.03	0.02	0.06	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

Table 11 Effect of different growth regulators on root-shoot ratio

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.33	0.97	0.28	0.11	0.15	0.36 (16.12)
T_2	IAA	20	0.75	0.49	0.54	0.13	0.46	0.47 (51.61)
T_3	IAA	30	0.39	0.66	0.33	0.22	0.43	0.40 (29.03)
T_4	IAA	40	1.12	0.23	0.62	0.39	0.51	0.57 (83.87)
T_5	NAA	10	1.37	0.27	0.34	0.12	0.32	0.48 (54.83)
T_6	NAA	20	1.03	0.53	0.16	0.18	0.50	0.48 (54.83)
T_7	NAA	30	0.44	0.76	0.25	0.36	0.25	0.41 (32.25)
T_8	NAA	40	0.48	1.32	0.34	0.49	0.20	0.56 (80.64)
T_9	Tria-contanol	1	0.23	0.20	0.36	0.32	0.33	0.28
T_{10}	Tria-contanol	2	1.83	0.48	0.36	0.28	0.31	0.69 (122.58)
T_{11}	Tria-contanol	3	0.48	0.31	0.49	0.21	0.11	0.32 (3.22)
T_{12}	Tria-contanol	4	1.42	0.43	0.04	0.43	0.28	0.52 (67.74)
T_{13}	GA	10	0.98	0.21	0.18	0.41	0.47	0.45 (45.16)
T_{14}	GA	20	0.74	0.26	0.33	0.25	0.32	0.38 (22.58)
T_{15}	GA	30	0.39	0.60	0.08	0.31	0.77	0.43 (38.70
T_{16}	GA	40	0.91	0.26	0.48	0.19	0.15	0.39 (25.80)
C_1	Control	Water spray	0.43	0.35	0.43	0.17	0.19	0.31
C_2	Control	No spray	0.50	0.36	0.47	0.10	0.44	0.37
	Mean		0.76	0.48	0.34	0.25	0.34	
	F value		3435.13**	6627.00**	2259.10**	1015.67**	2021.83**	
	CD		0.02	0.01	0.01	0.01	0.01	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

The difference between the treatments were statistically significant in all the stages. S_1 stage recorded the highest value of 1.83 (T_{10}) and T_9 (0.23) recorded the lowest value. C_1 (0.43) and C_2 (0.50) recorded higher values than T_9. The values ranged from 1.32 (T_8) to 0.20 (T_9) in S_2 stage compared to C_1 (0.35) and C_2 (0.36). In S_3 stage, T_4 (0.62) recorded the maximum value and T_{12} (0.04) the minimum. In S_4 stage, T_8 (0.49) recorded the highest value and C_2 (0.10) the lowest value. The RS ratio ranged from 0.51 (T_4) to 0.11(T_{11}) in S_5 stage. Control showed values of 0.19 (C_1) and 0.44 (C_2).

4.3 Physiological parameters

4.3.1 Photosynthetic rate (micromoles m^{-2} s^{-1})

Data on photosynthetic rate (P_s) is presented in Table 12. Statistical analysis revealed significant difference among the treatments. The maximum photosynthetic rate was observed in T_4 (28.09). C_1 and C_2 recorded values of 4.08 and 2.85 respectively. T_3 (10.06), T_5 (4.52), T_{12} (4.39), T_{13} (10.02), T_{14} (4.89) and T_{16} (13.85) recorded higher values than C_1.

4.3.2 Transpiration rate (milli mol m^{-2} s^{-1}).

Data on transpiration rate (E) is presented in Table 12. The highest value was recorded by T_{14} (0.74). T_9(0.73) and C_1 (0.72) were on par with T_{14}.

Table 12 Effect of different growth regulators on physiological parameters

Treat-ment	Growth regulator	Concen-tration (ppm)	Photosynthetic rate (P_s) micromol m^{-2} s^{-1} *	Transpiration rate (E) millimol m^{-2} s^{-1} *	Stomatal conductance (C) millimol m^{-2} s^{-1}
T_1	IAA	10	0.08	0.57	51.60
T_2	IAA	20	0.06	0.22	17.30
T_3	IAA	30	10.06	0.28	20.90
T_4	IAA	40	28.09	0.09	4.70
T_5	NAA	10	4.52	0.32	26.30
T_6	NAA	20	1.04	0.49	38.50
T_7	NAA	30	0.77	0.46	40.30
T_8	NAA	40	0.44	0.20	15.10
T_9	Tria-contanol	1	1.41	0.73	70.63
T_{10}	Tria-contanol	2	0.51	0.15	14.40
T_{11}	Tria-contanol	3	0.67	0.34	24.80
T_{12}	Tria-contanol	4	4.39	0.12	9.10
T_{13}	GA	10	10.02	0.11	7.50
T_{14}	GA	20	4.89	0.74	68.00
T_{15}	GA	30	1.44	0.14	10.40
T_{16}	GA	40	13.85	0.64	65.50
C_1	Control	Water spray	4.08	0.72	78.00
C_2	Control	No spray	2.85	0.38	32.30
	Mean		4.95	0.37	33.18
	F value		85.32**	261.19**	3598.37**
	CD		2.11	0.04	1.11

** Significant at 0.01 level

* Note: The values of photosynthetic rate and transpiration rate studied are not fully reliable (may be due to some instrumental error)

4.3.3 Stomatal conductance (milli mol m^{-2} s^{-1})

Data on stomatal conductance (C) is presented in Table 12. The highest value was recorded by C_1 (78.0) followed by T_9(70.63).

4.4 Biochemical parameters

4.4.1 Photosynthetic pigments

a) Chlorophyll-a content (mg g fresh weight $^{-1}$)

Data on chlorophyll-a content is presented in Table 13. An increase in chlorophyll-a content was observed till S_3 stage and thereafter a decrease was seen in S_4 and S_5 stages. T_3 (0.54) recorded the highest value with a 35 percent increase over C_1 (0.40). The next best treatment was T_8 (0.53). T_{13} (0.31) recorded the lowest value.

A significant difference was observed among the different treatments in all the five crop stages. In S_1 stage, T_9 (0.08) recorded the highest value followed by T_5 and T_{14} both with a value of 0.07. The lowest value of 0.05 was recorded by T_1, T_2, T_3, T_{11}, T_{13} and C_2. T_8 and T_{14} recorded the highest value of 0.47 in S_2 stage and the lowest value of 0.05was recorded by T_{11} and C_2. The chlorophyll-a values ranged from 1.11(T_9) to 0.44 (T_{15}) in the S_3 stage. In S_4 stage, T_3 (0.89) recorded the highest value and T_{14} recorded the lowest value of 0.25. In S_5 stage also, T_3 (0.84) showed be highest value and T_{14} (0.76) and T_6 (0.75) were observed to be on par with T_3. T_{13} was observed to show the lowest value of 0.25.

Table 13 Effect of different growth regulators on chlorophyll-a content (mg g fresh weight^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.05	0.42	0.79	0.48	0.47	0.34
T_2	IAA	20	0.05	0.38	0.71	0.65	0.57	0.47 (17.50)
T_3	IAA	30	0.05	0.33	0.60	0.89	0.84	0.54 (35.00)
T_4	IAA	40	0.06	0.30	0.55	0.25	0.61	0.35
T_5	NAA	10	0.07	0.30	0.53	0.76	0.50	0.43 (7.50)
T_6	NAA	20	0.06	0.32	0.57	0.51	0.75	0.44 (10.00)
T_7	NAA	30	0.06	0.32	0.58	0.57	0.59	0.44 (10.00)
T_8	NAA	40	0.06	0.47	0.92	0.54	0.70	0.53 (32.50)
T_9	Tria-contanol	1	0.08	0.08	1.11	0.37	0.70	0.48 (20.00)
T_{10}	Tria-contanol	2	0.06	0.06	0.72	0.59	0.59	0.40
T_{11}	Tria-contanol	3	0.05	0.05	0.80	0.57	0.47	0.38
T_{12}	Tria-contanol	4	0.06	0.06	0.73	0.43	0.50	0.35
T_{13}	GA	10	0.05	0.27	0.49	0.51	0.25	0.31
T_{14}	GA	20	0.07	0.47	0.86	0.25	0.76	0.48 (20.00)
T_{15}	GA	30	0.06	0.25	0.44	0.68	0.66	0.41 (2.57)
T_{16}	GA	40	0.06	0.40	0.74	0.37	0.40	0.39
C_1	Control	Water spray	0.06	0.06	0.55	0.65	0.70	0.40
C_2	Control	No spray	0.05	0.05	0.73	0.48	0.43	0.34
	Mean		0.05	0.25	0.69	0.53	0.58	
	F value		2.06*	87.44**	24.04**	84.96**	17.97**	
	CD		0.01	0.05	0.09	0.05	0.10	

** Significant at 0.01 level

* Significant at 0.05 level

( ) Indicates percentage increase over C_1

b) Chlorophyll-b content (mg g fresh weight^{-1})

Data on chlorophyll-b content is presented in Table 14. In most treatments, chlorophyll-b content increased till the S_3 stage and then decreased in S_4 and S_5 stages. The highest chlorophyll-b value was recorded by T_3 (0.80) and the lowest by T_{16} (0.24). The control values were C_1 (0.31) and C_2 (0.38).

In S_1 stage, the chlorophyll-b values ranged from 0.09 (T_9, T_{16}) to 0.04 (T_1, T_3). T_8 (0.50) showed the highest value in S_2 stage. T_{14} (0.36) was on par with T_8 and C_1 (0.21) recorded the lowest value. In S_3 stage, T_8 (0.93) showed the maximum value and T_4 (0.84) was observed to be on par with T_8. C_1 (0.37) recorded the lowest value. The chlorophyll-b values ranged from 1.74 (T_3) to 0.30 (T_{10}) in S_4 stage. In S_5 stage, T_3(1.23) recorded the maximum value and T_4 (0.33) the minimum.

c) Total chlorophyll content (mg g fresh weight^{-1})

Data on total chlorophyll content is presented in Table 15. A steady increase in total chlorophyll content was observed from S_1 to S_3 stage followed by a decline in the next two stages. T_3 (1.13) recorded the highest total chlorophyll value followed by T_9 (0.97). T_{13} (0.62) recorded the lowest value. C_1 and C_2 recorded values of 0.75 and 0.80 respectively.

No significant difference was observed among the treatments in S_1 stage. T_9 (0.89) showed the highest value in S_2 stage and C_1 and T_{13} both with a value of 0.51 recorded the lowest value. T_{14} (0.83), T_1(0.82) and

Table 14 Effect of different growth regulators on chlorophyll-b content (mg g fresh weight^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.04	0.40	0.76	0.46	0.45	0.42 (35.48)
T_2	IAA	20	0.06	0.34	0.62	0.68	0.62	0.46 (48.38)
T_3	IAA	30	0.04	0.35	0.65	1.74	1.23	0.80 (158.06)
T_4	IAA	40	0.05	0.45	0.84	0.43	0.33	0.42 (35.48)
T_5	NAA	10	0.07	0.25	0.42	1.36	0.60	0.54 (74.19)
T_6	NAA	20	0.07	0.30	0.53	0.39	0.82	0.42 (35.48)
T_7	NAA	30	0.05	0.30	0.55	0.49	0.53	0.38 (22.58)
T_8	NAA	40	0.08	0.50	0.93	0.54	0.82	0.57 (83.87)
T_9	Tria-contanol	1	0.09	0.30	0.51	0.39	0.73	0.41 (32.25)
T_{10}	Tria-contanol	2	0.06	0.39	0.72	0.30	0.57	0.40 (29.03)
T_{11}	Tria-contanol	3	0.05	0.38	0.71	0.54	0.49	0.45 (45.16)
T_{12}	Tria-contanol	4	0.07	0.32	0.58	0.45	0.61	0.40 (29.03)
T_{13}	GA	10	0.05	0.24	0.43	0.45	0.37	0.30
T_{14}	GA	20	0.07	0.36	0.65	0.39	0.35	0.36 (16.12)
T_{15}	GA	30	0.06	0.26	0.46	0.60	0.66	0.40 (29.03)
T_{16}	GA	40	0.09	0.24	0.42	0.45	0.45	0.24
C_1	Control	Water spray	0.05	0.21	0.37	0.41	0.51	0.31
C_2	Control	No spray	0.05	0.32	0.59	0.45	0.49	0.38
	Mean		0.06	0.32	0.59	0.58	0.59	
	F value		1.43	14.75**	16.68**	403.04**	21.23**	
	CD		-	0.06	0.11	0.05	0.13	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

Table 15 Effect of different growth regulators on total chlorophyll content (mg g fresh weight^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.09	0.82	1.55	0.94	0.92	0.86 (14.66)
T_2	IAA	20	0.11	0.72	1.32	1.33	1.21	0.93 (24.00)
T_3	IAA	30	0.10	0.68	1.26	1.57	2.06	1.13 (50.66)
T_4	IAA	40	0.13	0.55	0.97	0.64	1.07	0.67
T_5	NAA	10	0.15	0.55	0.95	1.55	1.08	0.85 (13.33)
T_6	NAA	20	0.13	0.65	1.18	0.89	1.68	0.90 (20.00)
T_7	NAA	30	0.11	0.62	1.13	1.06	1.12	0.80 (16.66)
T_8	NAA	40	0.14	0.66	1.19	1.08	1.51	0.91 (21.33)
T_9	Tria-contanol	1	0.17	0.89	1.62	0.76	1.42	0.97 (29.33)
T_{10}	Tria-contanol	2	0.12	0.78	1.44	1.18	1.16	0.93 (24.00)
T_{11}	Tria-contanol	3	0.10	0.81	1.51	1.10	0.90	0.88 (17.33)
T_{12}	Tria-contanol	4	0.12	0.72	1.32	0.89	1.11	0.83 (10.66)
T_{13}	GA	10	0.10	0.51	0.92	0.95	0.62	0.62
T_{14}	GA	20	0.15	0.83	1.52	0.64	1.24	0.87 (16.00)
T_{15}	GA	30	0.13	0.57	0.90	1.29	1.31	0.84 (12.00)
T_{16}	GA	40	0.11	0.58	1.58	0.81	0.74	0.81 (8.00)
C_1	Control	Water spray	0.11	0.51	0.91	1.07	1.16	0.75
C_2	Control	No spray	0.11	0.74	1.32	0.93	0.92	0.80
	Mean		0.12	0.69	1.25	1.03	1.17	
	F value		1.29	19.40**	25.70**	221.27**	54.33**	
	CD		-	0.08	0.14	0.05	0.13	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

T_{11}(0.81) were on par with T_9. In S_3 stage, T_9 (1.62) recorded the maximum value and T_{16} (1.58), T_1 (1.55), T_{14} (1.52) and T_{11} (1.51) were on par with T_9. T_{15} (0.90) recorded the lowest value. The total chlorophyll values ranged from 1.57(T_3) to 0.64 (T_4, T_{14}) in S_4 stage. In S_5 stage, the maximum value was 2.06 (T_3) and the minimum value was 0.62 (T_{13}).

d) Chlorophyll a/b ratio

Data on chlorophyll a/b ratio is presented in Table 16. The maximum chlorophyll a/b ratio observed was 1.43 (C_1) followed by 1.24 (T_{14}). C_2 recorded a value of 1.08.

In S_1 stage, no significant difference was observed among the different treatments. T_3 (1.47) recorded the highest value and T_8(0.85) the lowest value. T_9 (1.55) recorded the highest value in S_2 stage. C_1 (1.36) and T_3 (1.27) were on par with T_9. In S_3 stage, the values ranged from 2.20 (T_9) to 0.88 (T_{16}). C_1 and C_2 recorded values of 1.48 and 1.24 respectively. The highest chlorophyll a/b value was 1.99 (T_{10}) and the lowest value recorded was 0.51 (T_3) in the S_4 stage. S_5 stage recorded the maximum value of 2.18 (T_{14}) and a minimum value of 0.68 (T_3).

4.4.2 Protein content (mg g^{-1})

Data on protein content of leaves at five stages of crop growth are presented in Table 17. The protein content increased from S_1 stage to S_5 stage in most of the treatments. T_{12} recorded the maximum protein content

Table 16 Effect of different growth regulators on chlorophyll a/b ratio

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	1.28	1.16	1.03	1.05	1.05	1.11
T_2	IAA	20	1.03	1.09	1.14	0.95	0.97	1.03
T_3	IAA	30	1.47	1.27	1.08	0.51	0.68	1.00
T_4	IAA	40	0.86	1.14	1.33	0.55	1.39	1.05
T_5	NAA	10	0.99	1.09	1.29	0.56	0.83	0.95
T_6	NAA	20	0.93	1.01	1.08	1.31	0.93	1.05
T_7	NAA	30	1.28	1.16	1.04	1.35	1.14	1.19
T_8	NAA	40	0.85	0.92	0.99	1.00	0.85	0.92
T_9	Tria-contanol	1	0.90	1.55	2.20	0.94	0.88	1.29
T_{10}	Tria-contanol	2	1.13	1.06	0.99	1.99	1.07	1.24
T_{11}	Tria-contanol	3	1.32	1.22	1.13	1.06	0.99	1.14
T_{12}	Tria-contanol	4	0.95	1.10	1.26	0.95	0.81	1.01
T_{13}	GA	10	1.30	0.90	1.17	1.13	0.69	1.03
T_{14}	GA	20	0.96	1.14	1.32	0.63	2.18	1.24
T_{15}	GA	30	1.02	1.00	0.99	1.14	1.00	1.03
T_{16}	GA	40	1.18	1.03	0.88	0.87	1.21	1.03
C_1	Control	Water spray	1.24	1.36	1.48	1.57	1.53	1.43
C_2	Control	No spray	1.12	1.18	1.24	1.04	0.85	1.08
	Mean		1.10	1.13	1.20	1.03	1.05	
	F value		0.99	1.98**	8.62**	67.50**	9.74**	
	CD		-	0.31	0.28	0.13	0.32	

** Significant at 0.01 level

Table 17 Effect of different growth regulators on protein content (mg g^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.46	0.83	1.20	2.07	2.21	1.35 (16.37)
T_2	IAA	20	0.47	0.98	1.49	2.01	1.97	1.38 (18.96)
T_3	IAA	30	0.43	1.17	1.91	2.14	2.03	1.53 (31.89)
T_4	IAA	40	0.47	0.89	1.30	1.83	2.20	1.33 (14.65)
T_5	NAA	10	0.41	0.84	1.26	2.11	1.98	1.32 (13.79)
T_6	NAA	20	0.48	0.97	1.46	2.68	2.30	1.57 (35.34)
T_7	NAA	30	0.51	0.93	1.35	1.87	2.81	1.49 (28.44)
T_8	NAA	40	0.45	0.89	1.32	2.23	2.89	1.55 (33.62)
T_9	Tria-contanol	1	0.44	0.78	1.13	2.19	2.91	1.49 (28.44)
T_{10}	Tria-contanol	2	0.47	0.97	1.48	2.22	2.90	1.60 (37.93)
T_{11}	Tria-contanol	3	0.44	0.79	1.04	1.80	1.90	1.19
T_{12}	Tria-contanol	4	0.43	1.16	1.86	2.30	2.53	1.65 (42.24)
T_{13}	GA	10	0.51	0.90	1.30	2.12	1.91	1.34 (15.51)
T_{14}	GA	20	0.44	1.05	1.66	2.11	2.75	1.60 (37.93)
T_{15}	GA	30	0.45	0.73	0.94	2.44	2.16	1.34 (15.51)
T_{16}	GA	40	0.44	0.79	1.16	2.26	1.15	1.16
C_1	Control	Water spray	0.41	0.69	0.97	1.66	2.09	1.16
C_2	Control	No spray	0.38	0.68	0.95	1.65	1.93	1.11
	Mean		0.44	0.89	1.97	2.26	2.25	
	F value		1.81	23.88**	57.59**	10.80**	196.03**	
	CD		-	0.08	0.11	0.22	0.09	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

of 1.65. This was followed by T_{10} and T_{14} both of which recorded a value of 1.60. C_1 and C_2 recorded values of 1.16 and 1.11 respectively.

In S_1 stage, no significant difference was observed among the treatments. The highest value of 0.51 was recorded by both T_7 and T_{13} whereas C_2 (0.38) recorded the lowest value. In S_2 stage, T_3 was on par with T_{12} with values of 1.17 and 1.16 respectively. C_2 (0.68) recorded the lowest value. The values ranged from 1.91 (T_3) to 0.94 (T_{15}) in S_3 stage. T_{12} (1.86) was on par with T_3. The highest value in S_4 stage was 2.68 (T_6) and the lowest value observed was that of C_2(1.65). In S_5 stage, the highest value was recorded by T_9 (2.91) and the treatments T_{10}(2.90), T_8(2.89) were on par with T_9. The lowest value was that of T_{16}(1.15).

4.4.3 Total carbohydrates (mg glucose 100 g sample^{-1})

Data on total carbohydrate content of leaves is presented in Table 18. There was a steady increase in total carbohydrate content from S_1 stage to S_3 stage and thereafter declined in S_4 and S_5 stages. T_{16} (112.50) recorded the highest value followed by T_1 (86.03) and C_2 (38.0) recorded the lowest value.

Statistical analysis revealed a significant difference among the different treatments in all the five stages of the crop growth. In S_1 stage, T_8 (65.63) recorded the maximum carbohydrate content and T_2 (50.66) the minimum value. T_{16} (65.05), T_1(64.58), C_1 (62.68), T_{15} (62.18), T_{14} (60.64) and T_7 (60.19) were on par with T_8. T_1 (102.68) and C_2 (40.24) recorded the highest and lowest values in the S_2 stage. The carbohydrate

Table 18 Effect of different growth regulators on carbohydrate content (mg glucose 100 g sample^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	64.58	102.68	154.67	59.18	49.14	86.03 (53.51)
T_2	IAA	20	50.66	64.42	64.56	50.21	41.65	54.3
T_3	IAA	30	52.45	54.94	55.14	48.87	43.94	51.06
T_4	IAA	40	53.35	53.93	52.90	67.70	13.49	48.27
T_5	NAA	10	54.96	49.92	37.66	78.01	23.44	48.79
T_6	NAA	20	57.95	67.24	82.04	48.42	18.02	57.73 (3.01)
T_7	NAA	30	60.19	60.13	60.07	38.55	57.02	55.19
T_8	NAA	40	65.63	73.16	80.70	63.21	24.23	61.38 (9.52)
T_9	Tria-contanol	1	57.02	59.04	58.73	24.66	21.20	44.13
T_{10}	Tria-contanol	2	56.73	56.93	60.52	20.17	13.90	41.65
T_{11}	Tria-contanol	3	55.47	59.42	53.81	54.24	28.51	50.29
T_{12}	Tria-contanol	4	52.22	49.14	46.07	36.76	26.90	42.21
T_{13}	GA	10	54.74	54.36	51.11	37.66	78.43	55.26
T_{14}	GA	20	60.64	76.24	95.49	121.05	24.97	75.67 (35.02)
T_{15}	GA	30	62.18	66.74	78.01	43.04	44.47	58.88 (5.06)
T_{16}	GA	40	65.05	96.22	134.50	134.50	132.26	112.50 (100.74)
C_1	Control	Water spray	62.68	61.99	56.48	56.04	43.04	56.04
C_2	Control	No spray	57.94	40.24	23.76	53.79	14.30	38.00
	Mean		58.02	63.70	69.23	57.55	39.57	
	F value		2.95**	64.75**	143.86**	190.88**	1546.61**	
	CD		7.53	5.41	7.49	5.91	2.65	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

content ranged from 154.67 (T_1) to 23.76(C_2) in the S_3 stage. In S_4 and S_5 stages, T_{16} recorded the maximum values of 134.50 and 132.26 whereas T_{10} (20.17) and T_4 (13.49) showed the minimum values respectively.

4.4.4 Leaf proline content (μ moles g^{-1})

Data on leaf proline content is presented in Table 19. T_{10} (1.92) recorded the highest value followed by T_1 (1.62) and T_{13} (0.18) recorded the lowest value. The control values were 0.38 (C_1) and 0.33 (C_2).

The treatments were observed to be statistically significant in all the stages. In S_1 stage, T_{10} (0.38) recorded the maximum leaf proline content and T_{12} (0.01) the minimum. Treatment T_{16} (2.02) was observed to show the highest value and T_{13} (0.002) the lowest value in S_2 stage. The leaf proline content ranged from 1.0 (T_1) to 0.03 (T_8) in S_3 stage. T_3 (0.73) recorded the highest value and T_9 (0.02) the lowest value in S_4 stage. T_7 (0.68), T_1, T_{15} with a value of 0.66 and T_2 (0.61) were on par with T_3. In S_5 stage, T_{10} (8.78) recorded the maximum value and C_2 (0.08) the minimum value.

4.4.5 Reducing sugars (g glucose $100g^{-1}$)

The reducing sugar content of ripe fruits is presented in Table 20. Statistical analysis revealed a significant difference among the different treatments. T_6 (9.68) was found to show the highest value followed by T_{13} (8.47) ad T_8 (8.03). C_1 and C_2 recorded values of 2.76 and 2.70 respectively.

Table 19 Effect of different growth regulators on leaf proline content (μ moles g^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturati on stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.27	0.98	1.00	0.66	5.20	1.62 (326.31)
T_2	IAA	20	0.20	0.02	0.19	0.61	0.16	0.23
T_3	IAA	30	0.07	0.04	0.21	0.73	0.42	0.29
T_4	IAA	40	0.03	0.05	0.34	0.55	0.59	0.31
T_5	NAA	10	0.20	0.01	0.04	0.14	1.06	0.29
T_6	NAA	20	0.02	0.03	0.04	0.40	2.75	0.64 (68.42)
T_7	NAA	30	0.20	0.16	0.05	0.68	4.17	1.05 (176.31)
T_8	NAA	40	0.08	0.50	0.03	0.37	4.94	1.18 (210.52)
T_9	Tria-contanol	1	0.11	0.11	0.45	0.02	2.56	0.65 (71.05)
T_{10}	Tria-contanol	2	0.38	0.03	0.33	0.12	8.78	1.92 (405.26)
T_{11}	Tria-contanol	3	0.16	0.45	0.63	0.19	3.01	0.88 (131.57)
T_{12}	Tria-contanol	4	0.01	0.36	0.48	0.49	1.75	0.61 (60.52)
T_{13}	GA	10	0.26	0.00	0.05	0.12	0.48	0.18
T_{14}	GA	20	0.20	0.31	0.12	0.39	2.72	0.74 (94.73)
T_{15}	GA	30	0.04	0.09	0.18	0.66	0.36	0.26
T_{16}	GA	40	0.10	2.02	0.65	0.28	3.95	1.40 (268.42)
C_1	Control	Water spray	0.11	0.34	0.19	0.32	0.96	0.38
C_2	Control	No spray	0.18	0.23	0.88	0.31	0.08	0.33
	Mean		0.14	0.31	0.32	0.39	2.44	
	F value		9.27**	2419.41**	15658.48**	26.37**	515439.40**	
	CD		0.09	0.01	0.01	0.20	0.01	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

Table 20 Effect of different growth regulators on reducing sugars, carotenoids and capsaicin content of fruits

Treat-ment	Growth regulator	Concen-tration (ppm)	Reducing sugars (g glucose 100 g^{-1})	Carotenoids (mg 100 g^{-1})	Capsaicin content (µg g^{-1})
T_1	IAA	10	2.19	1.36	67.52
T_2	IAA	20	5.10	2.35	64.05
T_3	IAA	30	5.18	1.40	61.34
T_4	IAA	40	4.21	2.69	55.13
T_5	NAA	10	6.96	0.84	61.65
T_6	NAA	20	9.68	1.31	49.71
T_7	NAA	30	4.99	0.36	51.62
T_8	NAA	40	8.03	1.12	59.11
T_9	Tria-contanol	1	2.67	1.36	51.30
T_{10}	Tria-contanol	2	2.89	1.00	41.57
T_{11}	Tria-contanol	3	3.81	0.84	48.43
T_{12}	Tria-contanol	4	3.08	1.84	48.11
T_{13}	GA	10	8.47	2.12	59.90
T_{14}	GA	20	5.69	2.24	51.50
T_{15}	GA	30	3.93	1.08	66.24
T_{16}	GA	40	5.05	0.80	60.06
C_1	Control	Water spray	2.76	0.40	47.32
C_2	Control	No spray	2.70	0.88	45.25
	Mean		4.85	1.33	54.46
	F value		65.10**	10.08**	3.59**
	CD		0.77	0.88	12.67

** Significant at 0.01 level

4.4.6 Carotenoids (mg 100 g^{-1})

The data on carotenoid content of red ripe fruits of chilli is presented in Table 20. T_4 (2.69) recorded the highest carotenoid content followed by T_2 (2.35) and T_{14} (2.24). T_7 (0.36) recorded the lowest value and this value was observed to be lower than C_1 (0.40) and C_2 (0.88).

4.4.7 Capsaicin content (μ gram $gram^{-1}$)

The capsaicin content of ripe fruits is presented in Table 20. Statistical analysis revealed significant difference among the different treatments. T_1 (67.52) was observed to be the best treatment with a 43.44 per cent increase over C_1 (47.32). T_{15} (66.24) and T_2 (64.05) were on par with T_1. T_{10} and T_{14} both with a value of 41.57 recorded the lowest value.

4.5 Yield parameters

4.5.1 Total fresh weight (g $plant^{-1}$)

Data on fresh weight per plant in five stages of crop growth is presented in Table 21. An increase in fresh weight of plants was observed from S_1 to S_4 stage and then a decrease is seen in the S_5 stage. T_2 (66.11) recorded the highest value followed by T_5 (60.09). T_3 (24.70) recorded the lowest value.

Statistical analysis revealed a significant difference among the treatments in all the five stages. In S_1 stage, T_6 (6.27) recorded the maximum fresh weight and T_1 (1.13) the minimum. T_{10} (14.34) recorded the maximum value and T_8 (5.32) the minimum value in S_2 stage. T_{13} (14.13)

Table 21 Effect of different growth regulators on total fresh weight (g plant^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturation stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	1.13	7.87	9.18	127.00	56.00	40.23 (16.77)
T_2	IAA	20	2.41	5.63	13.51	197.67	111.33	66.11 (91.90)
T_3	IAA	30	3.51	11.05	15.68	116.00	81.67	24.70
T_4	IAA	40	5.16	9.28	21.39	144.00	49.08	45.78 (32.88)
T_5	NAA	10	2.23	11.23	15.25	180.00	91.75	60.09 (74.42)
T_6	NAA	20	6.27	10.24	13.14	160.00	42.17	47.36 (37.47)
T_7	NAA	30	1.70	11.17	11.90	54.25	96.33	35.07 (1.79)
T_8	NAA	40	2.46	5.32	17.16	66.67	93.67	37.05 (7.54)
T_9	Tria-contanol	1	2.41	9.64	18.83	82.00	66.83	35.94 (4.32)
T_{10}	Tria-contanol	2	2.18	14.34	22.15	174.33	71.33	56.86 (65.05)
T_{11}	Tria-contanol	3	2.89	7.12	25.65	99.67	120.67	51.20 (48.62)
T_{12}	Tria-contanol	4	3.02	10.47	17.23	130.00	112.50	54.64 (58.60)
T_{13}	GA	10	3.72	14.13	22.01	54.67	86.67	36.24 (5.19)
T_{14}	GA	20	3.98	6.81	8.92	133.67	123.70	55.40 (60.81)
T_{15}	GA	30	4.40	6.67	16.97	148.00	59.33	47.07 (36.63)
T_{16}	GA	40	3.22	5.70	13.57	137.00	99.75	51.84 (50.47)
C_1	Control	Water spray	3.31	5.95	28.01	67.00	68.00	34.45
C_2	Control	No spray	3.42	5.41	7.15	67.33	64.33	29.52
	Mean		3.19	8.77	16.53	118.84	82.89	
	F value		26.40**	28.27**	75.59**	1243.25**	98.90**	
	CD		0.67	1.53	1.84	3.61	6.82	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

was on par with T_{10}. In S_3 stage, the values ranged from 28.01 (C_1) to 7.15 (C_2). T_2 (197.67) recorded the maximum fresh weight and T_7 (54.25) the minimum fresh weight in S_4 stage. The highest value in S_5 stage was recorded in T_{14} (123.70) followed by T_{11} (120.67) and the lowest value in T_6 (42.17).

4.5.2 Total dry weight (g plant^{-1})

Data on total dry weight per plant is presented in Table 22. T_{11} (13.22) recorded the highest dry weight followed by T_{16} (12.87) and C_2 (5.75) recorded the lowest dry weight per plant.

The difference between the treatments were observed to be statistically significant. In S_1 stage, T_6 (0.93) recorded the maximum value and T_1(0.12) the minimum. T_{10} (3.83) and C_2 (1.11) recorded the maximum and minimum dry weight respectively in the S_2 stage. The values ranged from 8.69 (T_{15}) to 2.40 (C_2) in the S_3 stage. In S_4 stage, the highest dry weight per plant was observed in T_{10}(32.03) and the lowest in T_9 (9.05). In S_5 stage, the values ranged from 40.80 (T_{11}) to 8.19 (T_3).

4.5.3 Total number of fruits per plant

Data on number of fruits per plant is presented in Table 23. T_1 (48.83) showed the maximum value with a 54.23 per cent increase over C_1 (31.66). T_2 (46.83), T_9 (44.16) and T_3 (42.16) were on par with T_1. T_7 (21.33) showed the minimum number of fruits per plant and this was observed to be lower than C_1 (31.66) and C_2 (36.0).

Table 22 Effect of different growth regulators on total dry weight (g plant^{-1})

Treat-ment	Growth regulators	Concen-tration (ppm)	Vegetative stage (S_1)	Flower initiation stage (S_2)	Peak flowering stage (S_3)	Maturati on stage (S_4)	Ripening stage (S_5)	Mean
T_1	IAA	10	0.12	2.72	5.90	19.06	13.24	8.02
T_2	IAA	20	0.46	1.73	4.27	20.82	30.08	11.47 (10.60)
T_3	IAA	30	0.52	2.95	6.13	15.20	8.19	6.59
T_4	IAA	40	0.75	2.12	4.32	25.97	13.89	9.41
T_5	NAA	10	0.28	2.16	8.03	27.05	25.25	12.55 (21.02)
T_6	NAA	20	0.93	1.71	6.61	22.16	18.25	9.93
T_7	NAA	30	0.26	2.10	2.80	12.85	22.98	8.19
T_8	NAA	40	0.73	1.43	5.85	12.56	21.43	8.40
T_9	Tria-contanol	1	0.42	2.09	3.41	9.05	16.03	6.20
T_{10}	Tria-contanol	2	0.19	3.83	6.78	32.03	18.18	12.20 (17.64)
T_{11}	Tria-contanol	3	0.40	2.68	5.77	16.46	40.80	13.22 (27.48)
T_{12}	Tria-contanol	4	0.55	2.51	4.15	17.39	22.29	9.37
T_{13}	GA	10	0.55	3.00	5.51	18.93	21.16	9.83
T_{14}	GA	20	0.54	1.27	3.41	20.71	31.73	11.53 (11.18)
T_{15}	GA	30	0.41	1.24	8.69	10.92	15.48	7.39
T_{16}	GA	40	0.31	1.90	6.27	29.74	26.14	12.87 (24.10)
C_1	Control	Water spray	0.45	2.07	5.02	14.24	30.11	10.37
C_2	Control	No spray	0.42	1.11	2.40	10.87	13.99	5.75
	Mean		0.46	2.14	5.29	18.66	21.62	
	F value		1229.95**	1372.42**	498.84**	832.75**	10.97**	
	CD		0.02	0.05	0.22	0.65	6.79	

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

4.5.4 Total weight of fruits per plant (g)

Data on weight of fruits per plant is presented in Table 23. Statistical analysis revealed a significant difference among the treatments. T_2 (183.66) showed the highest value with a 42.67 per cent increase over C_1 (128.73). T_9 (179.77), T_4 (164.99).T_1 (163.81) and T_{10} (162.82) were on par with T_2. T_{16}(76.28) showed the lowest value while C_2 recorded a value of 119.06.

4.5.5 Fruit length (cm)

Data on fruit length is presented in Table 23. The difference between the treatments was observed to be statistically significant. T_{10}(7.87) recorded the maximum fruit length and showed 25.31 per cent increase over C_1 (6.28). T_{14}(7.76), T_{15} (7.68), T_6 (7.67), T_{13}(7.62), T_2 (7.40) and T_{16} (7.00) were on par with T_{10}. T_{12} (3.68) recorded the minimum fruit length.

4.5.6 Fruit breadth (cm)

Data on fruit breadth is presented in Table 23. Statistical analysis revealed no significant difference among the treatments. The maximum fruit breadth was recorded by T_8(1.76) and the minimum by T_{16} (1.15). The control values were C_1 (1.42) and C_2 (1.46).

4.5.7 Colour of fruit at ripening

The colour of fruits at ripening showed no visual difference among the treatments. In general, the colour of fruit at ripening was orangish red.

Table 23 Effect of different growth regulators on yield parameters

Treatment	Growth regulator	Concent-ration (ppm)	Number of fruits per plant	Total weight of fruits per plant (g)	Fruit length (cm)	Fruit breadth (cm)	1000 seed weight (g)	Germination percentage of seeds	Harvest index
T_1	IAA	10	48.83 (54.23)	163.81 (27.25)	6.16	1.50 (5.63)	3.78 (14.54)	60.00 (15.94)	0.74 (23.33)
T_2	IAA	20	46.83 (47.91)	183.66 (42.67)	7.40 (17.83)	1.22	2.73	61.25 (18.35)	0.62 (3.33)
T_3	IAA	30	42.16 (33.16)	140.36 (9.03)	5.74	1.20	3.09	32.66	0.63 (5.00)
T_4	IAA	40	37.16 (17.37)	164.99 (28.16)	5.66	1.47 (3.52)	4.62 (40.00)	42.83	0.77 (28.33)
T_5	NAA	10	29.50	117.41	6.57 (4.61)	1.58 (11.26)	3.56 (7.87)	56.00 (8.21)	0.56
T_6	NAA	20	27.33	138.20 (7.35)	7.67 (22.13)	1.35	3.79 (14.84)	62.50 (20.77)	0.73 (21.66)
T_7	NAA	30	21.33	82.79	5.31	1.21	3.85 (16.67)	82.33 (59.09)	0.46
T_8	NAA	40	25.33	99.96	6.36 (1.27)	1.76 (23.94)	3.49 (5.75)	72.56 (40.21)	0.60
T_9	Triacontanol	1	44.16 (39.48)	179.77 (39.64)	6.28	1.30	2.74	67.33 (30.10)	0.72 (20.00)
T_{10}	Triacontanol	2	38.50 (21.60)	162.82 (26.48)	7.87 (25.31)	1.43 (0.70)	2.75	59.33 (14.64)	0.70 (16.66)
T_{11}	Triacontanol	3	26.33	161.18 (25.20)	5.62	1.37	3.54 (7.27)	87.16 (68.42)	0.58
T_{12}	Triacontanol	4	31.33	90.44	3.68	1.30	3.43 (3.93)	62.16 (20.11)	0.45
T_{13}	GA	10	40.00 (26.34)	134.20 (4.24)	7.62 (21.33)	1.43 (0.70)	1.99	73.50 (42.02)	0.60
T_{14}	GA	20	32.50 (2.65)	114.65	7.76 (23.56)	1.26	4.02 (21.81)	77.83 (50.39)	0.48
T_{15}	GA	30	25.50	85.49	7.68 (22.29)	1.44 (1.40)	2.39	65.00 (25.60)	0.59
T_{16}	GA	40	26.00	76.28	7.00 (11.46)	1.15	2.32	58.75 (13.52)	0.43
C_1	Control	Water spray	31.66	128.73	6.28	1.42	3.30	51.75	0.60
C_2	Control	No spray	36.00	119.06	5.76	1.46	3.44	60.55	0.64
Mean			33.91	130.29	6.46	1.38	3.26	62.97	0.60
F value			8.01**	13.35**	10.25**	1.60	10.26**	9.22**	19.52**
CD			7.98	26.15	0.96	-	0.58	12.72	0.07

** Significant at 0.01 level

( ) Indicates percentage increase over C_1

4.5.8 Thousand seed weight (g)

Data on thousand seed weight is presented in Table 23. The difference among the treatments were statistically significant. T_4 (4.62) recorded the maximum value with a 40 per cent increase over C_1(3.30). T_4 was followed by T_{14} (4.02). C_2 (3.44) showed a higher value than T_{13} (1.99) which recorded the lowest value.

4.5.9 Germination percentage of seeds (per cent)

Data on germination percentage of seeds is presented in Table 23. Statistical analysis revealed significant difference among the treatments. T_{11} (87.16) recorded the highest percentage of germination with 68.42 per cent increase over C_1 (51.75). T_7 (82.33) and T_{14} (77.83) were on par with T_{11}. T_3 (32.66) recorded the lowest value while C_2 recorded a value of 60.55.

4.5.10 Harvest index

Data on harvest index is presented in Table 23. The difference among the treatments were statistically significant. The harvest index ranged from 0.77(T_4) to 0.43 (T_{16}). T_1 (0.74), T_6(0.73), T_9 (0.72) and T_{10} (0.70) were on par with T_4. The control values observed were 0.60(C_1) and 0.64(C_2).

4.6 Biotic factors

4.6.1 Reaction towards pests and diseases

From visual observations, it was inferred that the treatments T_1, T_3, T_9, T_{12}, T_{13} and T_{15} showed low level of leaf curl disease compared to a

higher level of infection in T_{11} and T_{16}. C_1 and C_2 showed medium level of leaf curl disease.

In general, the incidence of colletotrichum fruit rot was less among the different treatments.

The infestation of mites in leaves was high in T_{16} compared to medium infestations in T_3, T_6, C_1 and C_2. All other treatments showed low level of mite infestations.

4.7 Economics of cultivation

Data on economics of cultivation is presented in Table 24. The data revealed that among the treatments, T_9 was the most remunerative followed by T_2, T_{10} and T_{11} in terms of net return. Benefit cost ratio was also the highest (1.51) under T_9. T_{10}, T_2, T_{11}, T_1, T_6, C_1 and C_2 also showed a benefit cost ratio more than one. T_3, T_4, T_5, T_7, T_8, T_{12}, T_{13}, T_{14}, T_{15}, and T_{16} recorded negative values for net return and registered benefit cost ratio less than one.

4.8 Correlation studies

Simple correlations of crop characters with fruit yield was worked out and is presented in Table 25.

The fruit yield of chilli was found to be significantly and positively correlated with number of fruits per plant, harvest index and root- shoot ratio. Plant height, fruit length, fruit breadth, thousand seed weight and dry weight per plant, CGR, LA, LAI, SLW, NAR, LAR and RGR recorded non significant correlation with fruit yield.

Table 24 Economics of chilli cultivation

Treat-ment	Growth regulators	Concen-tration (ppm)	Total cost ha^{-1} (Rs)	Gross return ha^{-1} (Rs)	Net return ha^{-1} (Rs)	Benefit - cost ratio
T_1	IAA	10	75586.50	97079.00	21492.50	1.28
T_2	IAA	20	81125.92	108836.16	27710.24	1.34
T_3	IAA	30	238176.50	83176.77	-154999.73	0.34
T_4	IAA	40	294301.50	97778.34	-196523.16	0.33
T_5	NAA	10	70354.50	69756.69	-597.81	0.99
T_6	NAA	20	70791.41	81896.76	11105.35	1.15
T_7	NAA	30	83178.50	49061.02	-34117.48	0.58
T_8	NAA	40	87602.50	59235.89	-28366.61	0.67
T_9	Tria-contanol	1	70459.50	106530.98	36071.48	1.51
T_{10}	Tria-contanol	2	71012.50	96486.98	25474.48	1.35
T_{11}	Tria-contanol	3	71566.50	95514.62	23948.12	1.33
T_{12}	Tria-contanol	4	73226.50	53600.30	-19626.20	0.73
T_{13}	GA	10	84946.50	79526.38	-5420.12	0.93
T_{14}	GA	20	99614.26	67941.13	-31673.13	0.68
T_{15}	GA	30	515466.50	50661.03	-464805.47	0.09
T_{16}	GA	40	663986.50	45203.22	-618783.28	0.06
C_1	Control	Water spray	69906.50	75692.28	5785.78	1.08
C_2	Control	No spray	69251.50	70554.47	1302.97	1.01

Cost of IAA - Rs. 355 per 5 g
Cost of NAA - Rs. 140 per 25 g
Cost of Triacontanol - Rs. 35 per 100 ml
Cost of GA - Rs. 188 g^{-1}
Wage rate of ordinary labourer - Rs. 140 day^{-1}
Wager rate of skilled labourer (for spraying) - Rs. 145 day^{-1}
Cost of chilli - Rs. 12 kg^{-1}

Table 25 Simple correlation studies of crop characters with fruit yield

Sl. No.	Character	Fruit yield
1.	Plant height	0.0996^{NS}
2.	Number of fruits per plant	0.6610**
3.	Fruit length	0.2266 ^{NS}
4.	Fruit breadth	-0.0333 ^{NS}
5.	Thousand seed weight	0.0730 ^{NS}
6.	Dry weight per plant	-0.0984 ^{NS}
7.	Harvest index	0.7530**
8.	Crop growth rate	0.1493 ^{NS}
9.	Leaf area	-0.0949 ^{NS}
10.	Leaf area index	-0.1316 ^{NS}
11.	Specific leaf weight	0.2360 ^{NS}
12.	Net assimilation rate	-0.2602 ^{NS}
13.	Relative growth rate	0.0762 ^{NS}
14.	Leaf area ratio	-0.2032 ^{NS}
15.	Root-shoot ratio	0.460**

** Significant at 0.01 level
NS Non-significant

Discussion

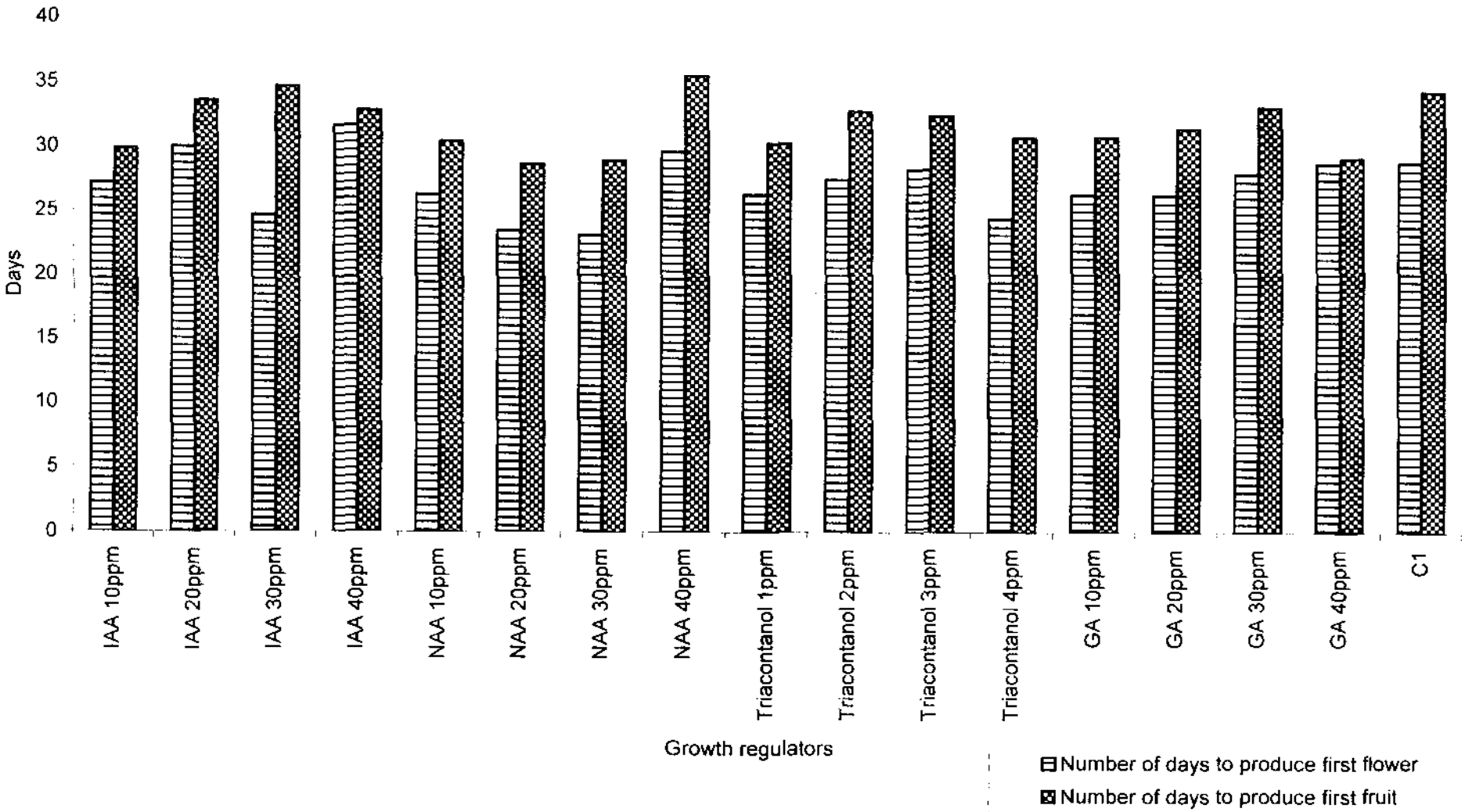
5. DISCUSSION

Chilli *(Capsicum annuum* L.) is a very important spice cum vegetable crop which forms an indispensable adjunct in the diet of both rich and poor all over the world. Economically chilli is a good choice for income generation among the farming sector. The control of flower and fruit drop, a major limitation in enhancing chilli production is highly desired. The enormous variation which can be brought about by the judicious application of growth regulators emphasizes the significance of their discovery and its use in crop production. The use of growth regulators in preventing flower and fruit drop has been widely reported by Negi and Singh (1956) in cotton, Jagirdar and Choudry (1967) in mango, Mukherji and Roy (1966) in tomato and Warade and Singh (1977) in chillies. The main emphasis of the present investigation was to study the effect of growth regulators viz. IAA, NAA, Triacontanol and GA in reducing flower and fruit drop in chilli var. Jwalasakhi and also to know their effect on various plant characters. The results of the investigation presented in the previous chapter provided information on the effect of these growth regulators on morphological, growth, physiological, biochemical and yield attributes. A critical discussion with the background material available from the literature is presented in the following pages to fulfill the objectives mentioned earlier.

5. 1 Morphological parameters

Earliness in flowering and fruiting is an indication of early transformation of plants to reproductive phase. Among the growth regulators

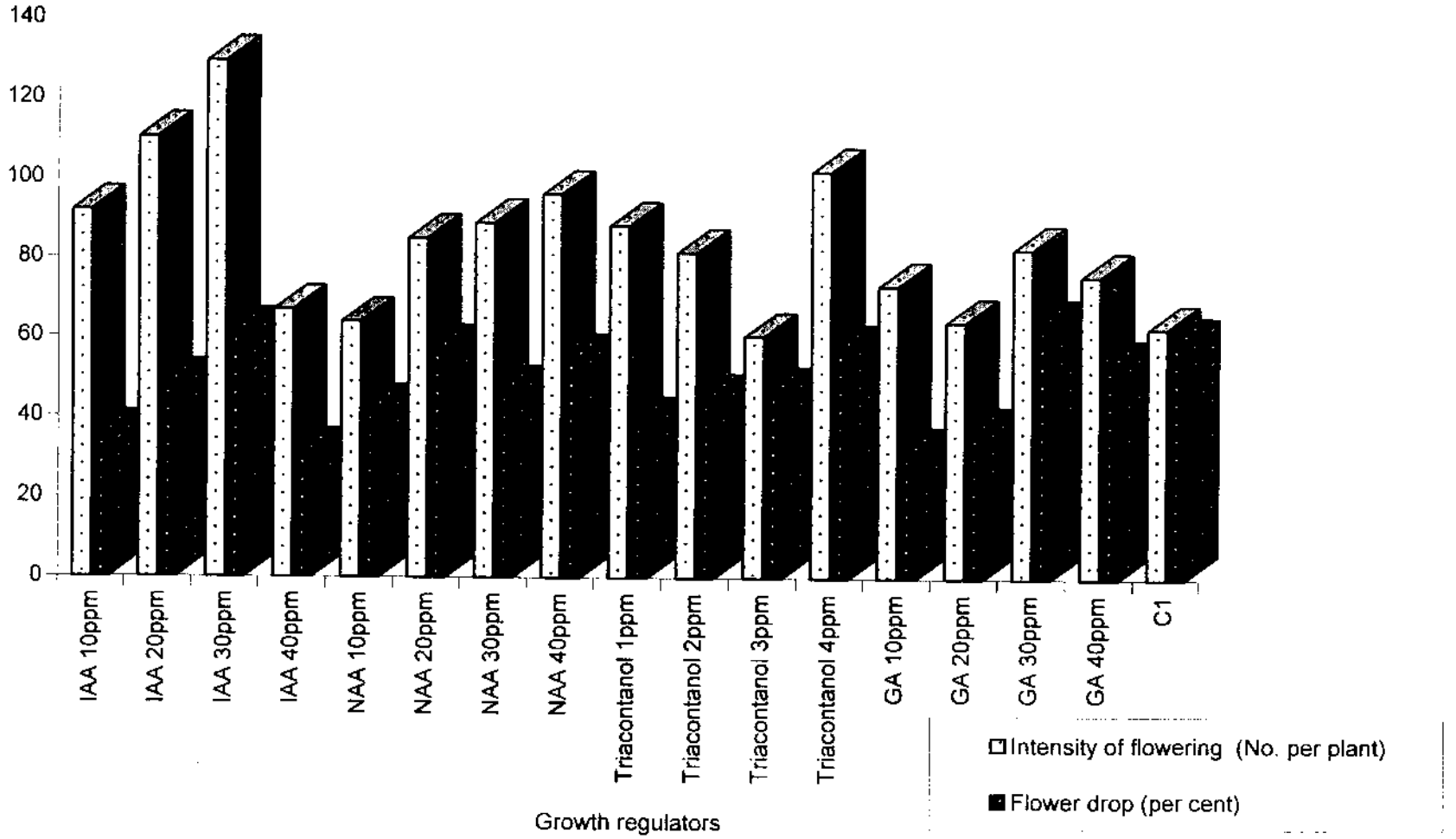
Fig. 2 Effect of different growth regulators on flower and fruit initiation



used, NAA 30 ppm was most effective in producing the earliest flowers (23.17 days) whereas control (water spray) took 28.84 days to initiate flowering (Fig.2). This result is in accordance with the findings of Chhonkar and Singh (1959), Singh (1995) in tomato and Warade and Singh (1977) in chillies. According to Usha (1988), NAA acts through fundamental processes like nucleic acid synthesis, enzyme synthesis and activation. Florigen or flowering hormone synthesized under the influence of auxins induced the production of flower primordia in *Calendula officinalis* (Raghava and Singh, 1970). Triacontanol and GA treated plants also induced earliness compared to control (water spray). Earliness induced by triacontanol might be due to increased synthesis of cytokinin in the roots and their simultaneous translocation to the buds, thereby triggering the metabolic processes and narrowing carbon-nitrogen ratio (Ries, 1985). All the growth regulators in the present study showed earliness in fruiting compared to control (water spray) except IAA 30 ppm and NAA 40 ppm (Fig. 2).

The flower production was increased by the different growth regulators tried. The plants treated with IAA 30 ppm produced the maximum number of 129.50 flowers per plant (Fig. 3). This represented over 100 per cent higher value than control (water spray). IAA 20 ppm and Triacontanol 4 ppm also produced more number of flowers per plant. Osborne (1963) opined that auxins delayed senescence through maintenance of RNA synthesis and increased synthesis of carbohydrates thus resulting in large number of flowers. Similar results have been reported by Jayanandam *et al.* (1976) in chillies and Oenofeghara (1981) in tomato. Henry and Gordon (1980) in peas and Umajyothy and Shanmughavelu (1985) in brinjal have reported increase

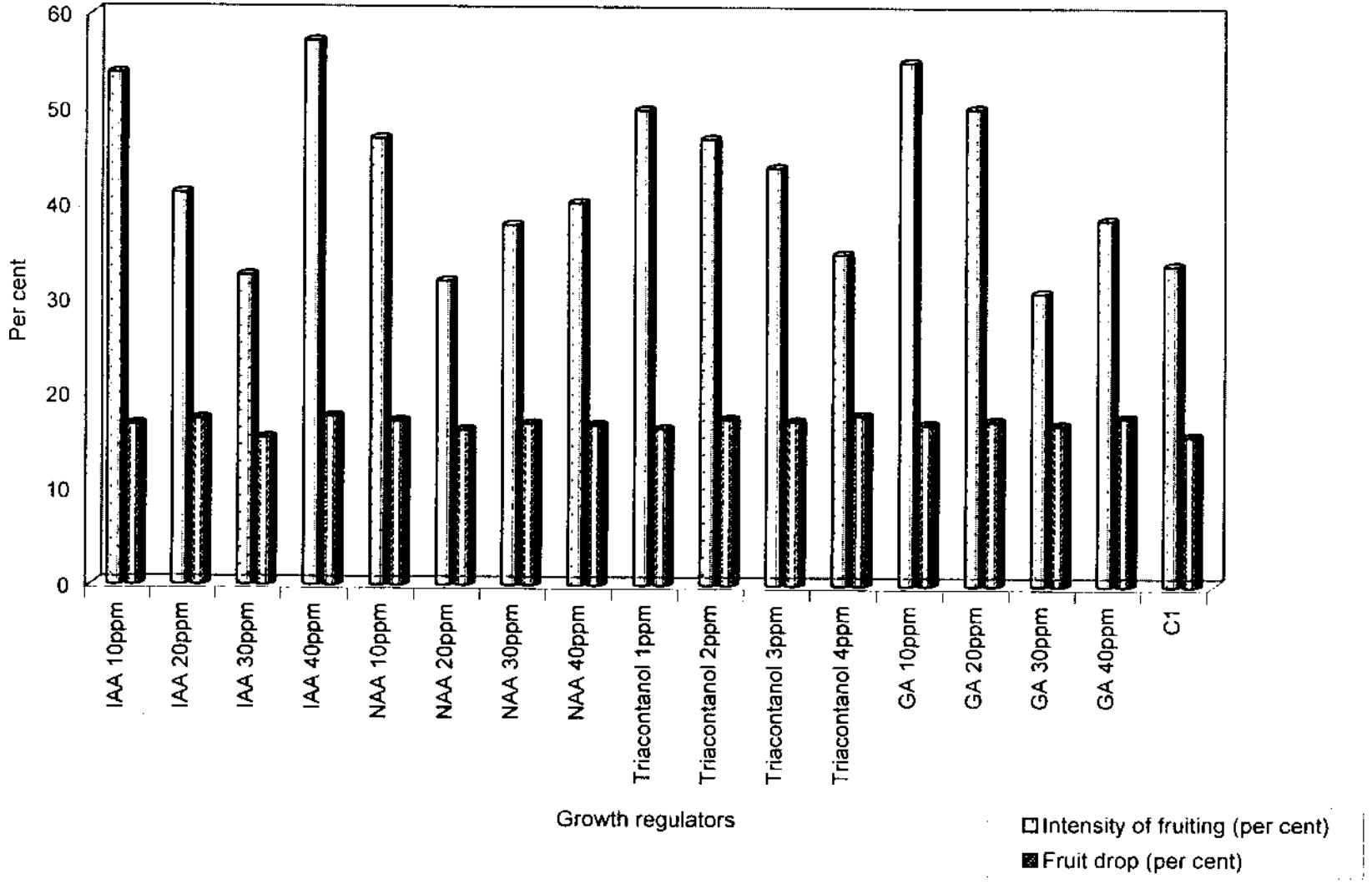
Fig. 3 Effect of different growth regulators on flowering and flower drop



in flower production due to Triacontanol application. Enhanced flowers may be due to higher peroxidase level and auxin breakdown in triacontanol treated plants as reported by Henry and Gordon (1980) in peas. Rajamani *et al.* (1990) have attributed the induction of more flowers in chillies by triacontanol treatment to the increase in photosynthetic efficiency and increased translocation of sugar to the points of axillary bud narrowing the carbon-nitrogen ratio.

An improvement in fruit set was observed with the application of growth regulators. This is a consequence of the effect of these chemicals to stimulate more number of ovaries and prevention of their subsequent abscission. Addicot and Lynch (1955) attributed the exhaustion of growth substances as the immediate cause of flower drop. In the present study, IAA 40 ppm was observed to be most effective in the producing the minimum flower drop of 30.94 per cent (Fig. 3) and maximum fruit set of 57.22 per cent (Fig.4). This accounted for about 48.06 per cent decrease in flower drop and 69.18 per cent increase in fruit set compared to control. Similar result was obtained with IAA in chilli var. NP-46-A by Patil and Ballal (1980). Leopold (1964) proved that auxins are the agents which stimulate ovaries to develop. At the time of anther dehiscence, auxin level of the flower falls off rapidly, but once the pollination and fertilization occurs, the auxin level of the flower is restored and the flower is not shed (Nitsch, 1952). External application of auxins in the present study might have supplemented the low level of auxins, leading to increased fruit set. All the other treatments except IAA 30 ppm and GA 30 ppm showed a better performance in reducing flower drop and increasing fruit set. The increased fruit set observed due to the

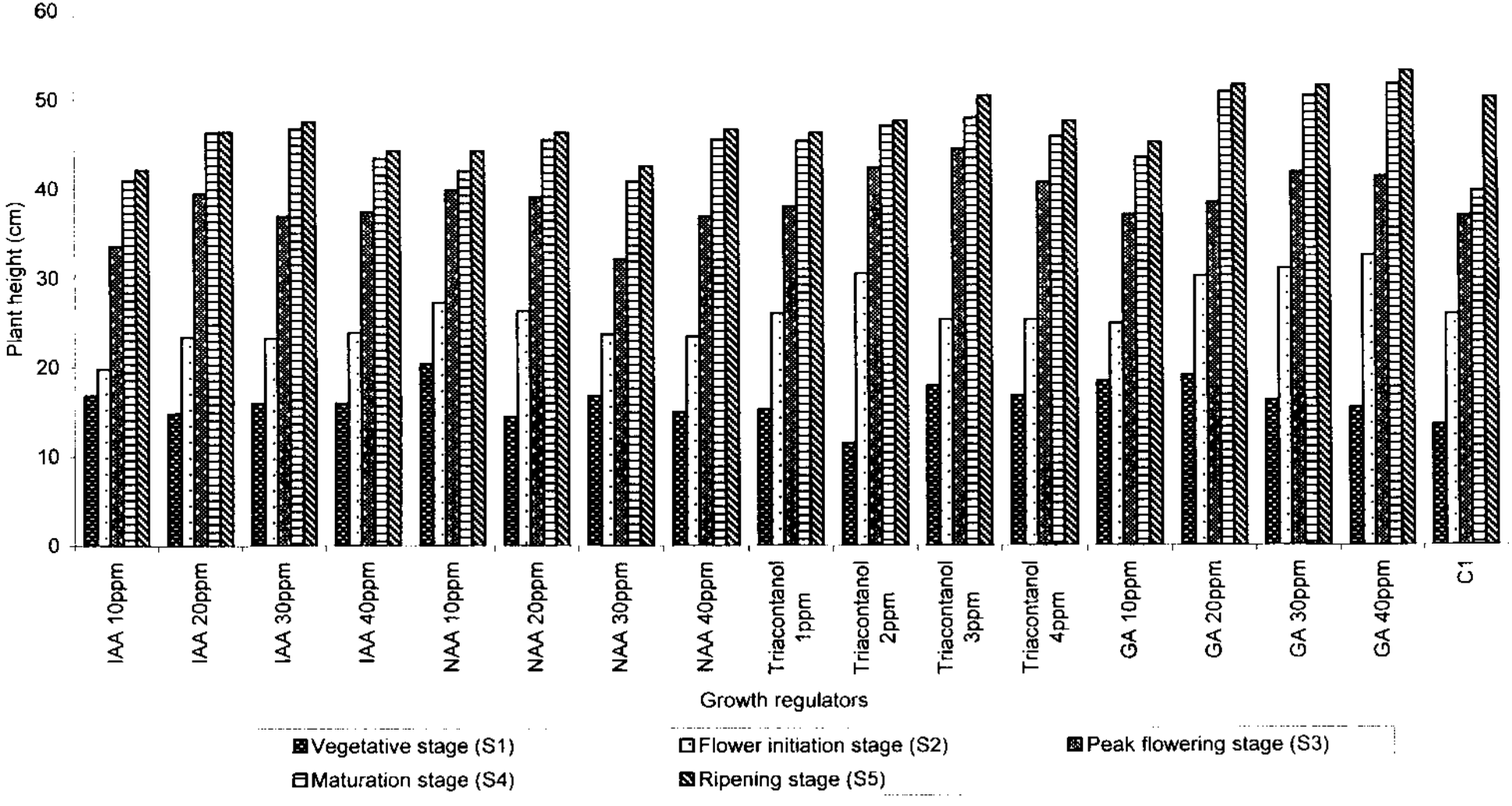
Fig. 4 Effect of different growth regulators on fruiting and fruit drop



application of triacontanol was through the stimulation of ovaries to develop and thus protecting the natural auxins from enzymatic destruction (Henry and Gordon, 1980). This increased content of native auxins might have prevented flower abscission and enhanced the fruit set. Hua *et al.* (1985) opined that triacontanol application in citrus inhibited cellulase and pectinase activities before the start of abscission and again during abscission thereby increasing fruit set and reducing flower drop. El-Asdoudi (1993b) reported a fruit set of 61.2-63.3 per cent by foliar sprays of GA_3 in *Capsicum annuum* var. California Wonder. As such in the present study, none of the growth regulators showed a better performance compared to control in preventing fruit drop (Fig. 4). But the performance of IAA 30 ppm was relatively better in preventing fruit drop.

Studies on the effect of growth regulators revealed a significant difference in plant height only in the flower initiation stage (Fig. 5). This may be the result of the first foliar spray at pre-flowering stage. In the other stages, not much difference was noted among the growth regulators. GA 40 ppm showed the maximum plant height (38.93 cm) with a 16.94 per cent increase over control. GA at 20 and 30 ppm and Triacontanol at 3 ppm also showed considerable increase in plant height. The effectiveness of GA in increasing plant height has been reported by Nanjappa (1965), El-Asdoudi (1993b) in chillies, Irullappan and Muthukrishnan (1974) and Tomar and Ramagery (1997) in tomato. External application of gibberellins caused an increase in both cell elongation and cell division of the internodes resulting in an increase in cell length and cell number and thus the height of the plants. The cell elongation by gibberellins is brought about by the mechanical

Fig. 5 Effect of different growth regulators on plant height (cm)

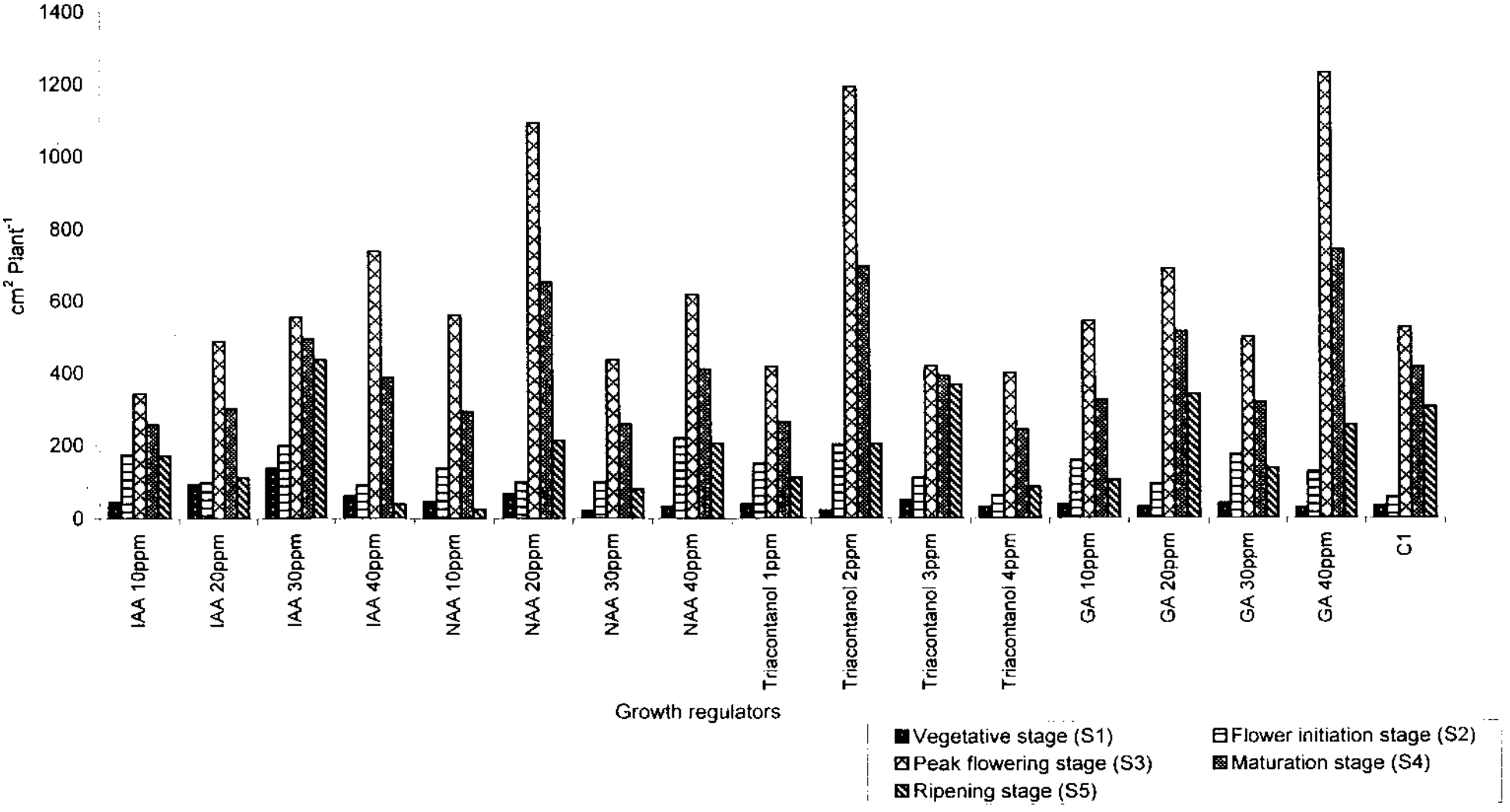


extensibility of cell wall and stress relaxation of walls of living cells (Taiz and Zeiger, 1998). Ries (1985) suggested that triggering of enzymes and secondary messengers by triacontanol resulted in increased plant growth. Thus it may have brought an increase in plant height. The works of Usha (1988) in chilli, Phookan *et al.* (1991) and Sharma (1995) in tomato supports the results obtained.

5.2 Growth parameters

Leaf as a major source in manufacturing photoassimilates forms one of the major components of the above ground mass. The leaf area develops at an exponential rate in annuals (Gardner *et al.*, 1985). The leaf area progressively increased upto the flowering stage and then declined (Fig. 6). This trend might be due to the partitioning of assimilates after flowering wherein most of them are directed to the formation of the reproductive sink (Nazar, 1989). Senescence of older leaves and malformations of leaves due to leaf curl and crinkling might have also contributed to the decrease in leaf area at the later stages. The plants treated with GA 40 ppm showed the maximum leaf area (478.04 cm^2 $plant^{-1}$) which is 78.57 per cent higher than control. Triacontanol 2 ppm showed about 73.76 per cent greater leaf area compared to control. Stowe and Yamaki (1959), Abdulkhader and Madhava Rao (1983) in grape vine have also reported similar results. Anu (1997) and Salvi (1997) reported that in anthurium the application of GA increased the production of lateral branches and enhanced their growth too. The increased production of branches will naturally lead to more number of leaves per plant. Chhonkar (1957) in tomato and Mehrotra *et al.* (1970) in chilli have reported increased

Fig. 6 Effect of different growth regulators on leaf area



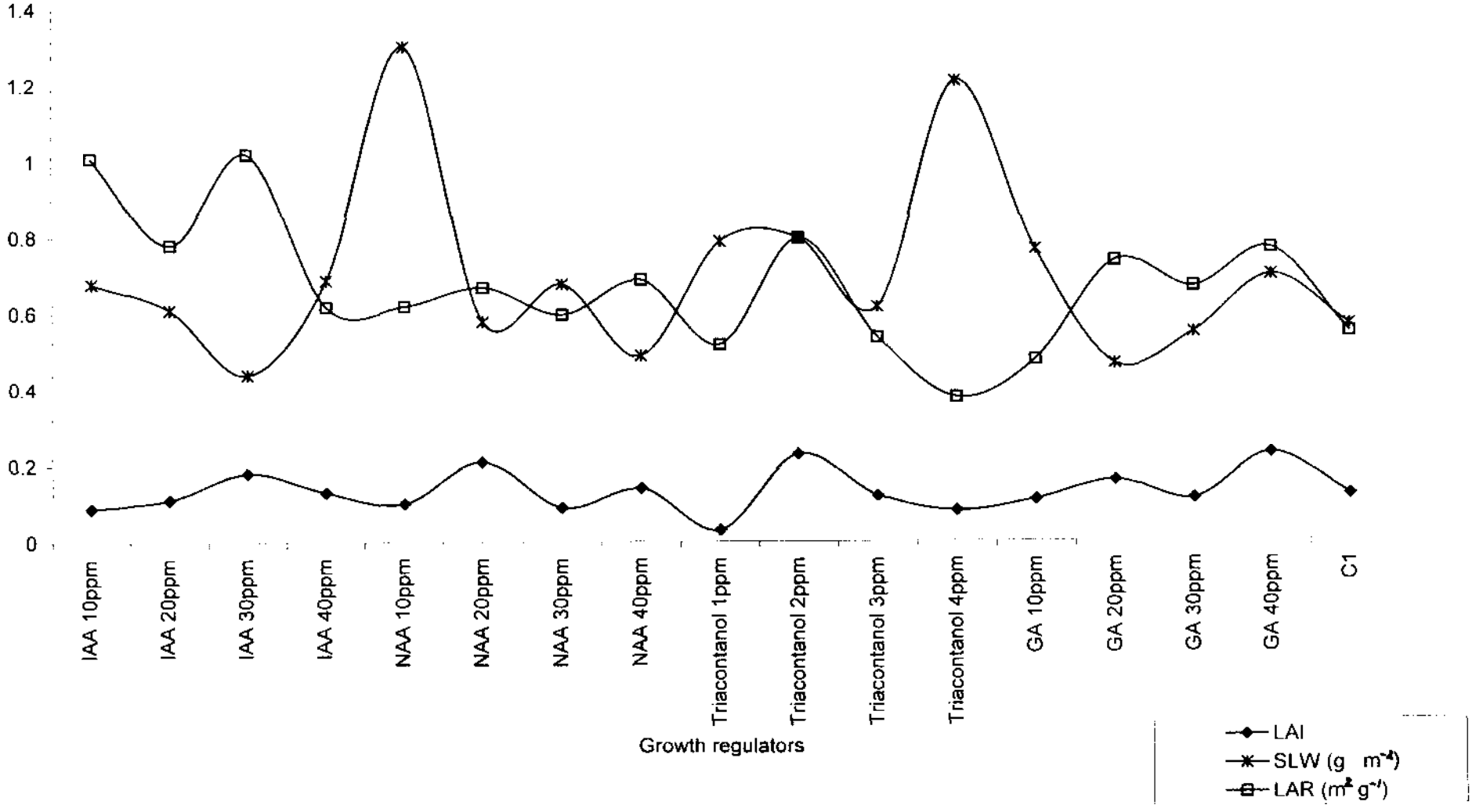
vegetative growth by GA_3 application. Triacontanol application in tea increased the leaf production by delaying senescence of leaves and also by mobilizing increased uptake of nutrients (Raman, 1981). This is also supported by the reports of Gunashekaran (1982) in tomato and Pocock (1979) in sugarbeet.

The results of leaf area index (LAI) also showed a similar trend as that of leaf area. Significant difference was observed among the treatments by growth regulator application. A gradual increase in LAI was observed till peak flowering stage and thereafter a decline was seen. GA 40 ppm and Triacontanol 2 ppm recorded the highest LAI of 0.23 (Fig. 7). In the present study, LAI increased with increase in leaf area and thus showed a similar trend as that of leaf area.

Specific leaf weight (SLW) indicates accumulation of photosynthates with in a specific area. Growth regulators produced significant difference in SLW. The ripening stage recorded the highest SLW value. Plants sprayed with NAA 10ppm showed the maximum value of 1.30 g m^{-2} (Fig.7). Triacontanol sprays also enhanced SLW. Warade and Singh (1977) have stated that in chillies the high yield of NAA treated plants may be attributed to the fact that they are physiologically more active to build sufficient food reserves. Moreover auxins are known to delay the senescence of the leaves. Longevity of leaves favours sustained photosynthetic activity and thus an increased SLW.

In the present study, fluctuating values of leaf area ratio (LAR) was noted in the different stages. IAA 30 ppm showed the maximum LAR (1.02

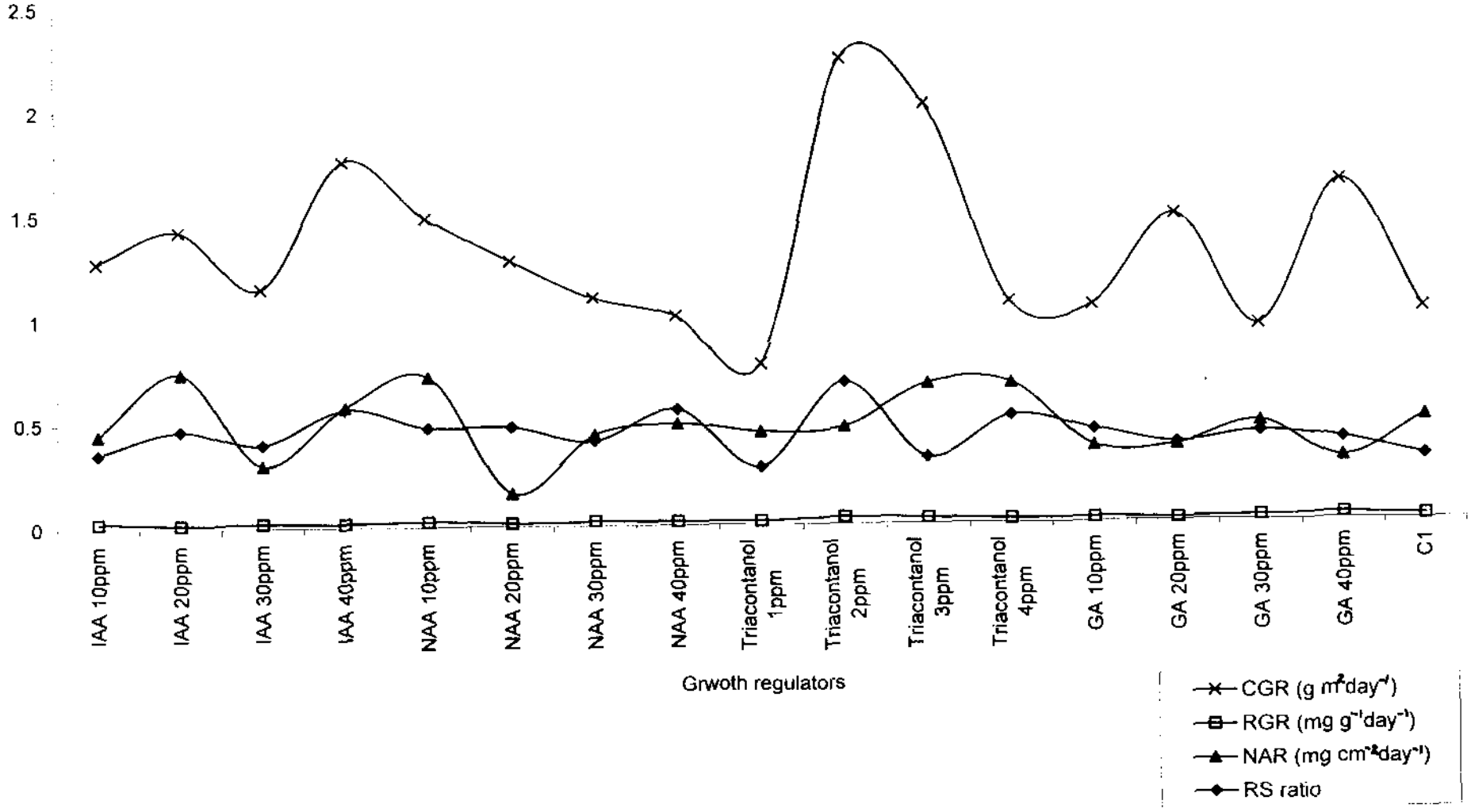
Fig. 7 Effect of different growth regulators on LAI, SLW and LAR



m^2 g^{-1}) with a 85.09 per cent increase over control (Fig. 7). All the other treatments except GA 10 ppm and Triacontanol sprays showed better performance than control. In Eddoe Taro (*Colocasia esculenta* var. antiquorum L.), the leaf area per total plant dry weight i.e., LAR was maximum at the first month and drastically decreased at the end of fifth month (Chowdhury *et al.*, 2000). They also reported that LAI had a significant positive correlation with LAR. High LAR in the vegetative stage must be due to low plant dry weight.

Dry matter accumulation per unit of land area per unit of time or crop growth rate (CGR) is the most meaningful growth analysis (Gardner *et al.*, 1985). CGR of different treatments increased up to peak flowering stage when maximum leaf area was achieved. Similar trend was observed by Nazar (1989) in groundnut. Relative growth rate (RGR) was highest in the vegetative stage and declined towards the maturation stage. Triacontanol at 2ppm was observed to show the highest CGR and RGR value of 2.24 g $m^{-2}day^{-1}$ and 0.033 mg g^{-1} day^{-1} respectively (Fig. 8). Increase in CGR may be responsible for the increase in RGR. Net assimilation rate (NAR) is often used to express the rate at which dry matter is produced and is defined as the net assimilation per unit area. In the present investigation, most of the treatments showed high NAR at the vegetative stage. But in some cases, an increasing trend is seen till the maturation stage. Chowdhury *et al.* (2000) reported highest NAR in Eddoe Taro cultivars initially followed by a decline towards the end of fifth month. As the crop grows, LAI increases, more and more leaves becomes shaded, thus showing a decrease in NAR at the later

Fig. 8 Effect of different growth regulators on CGR, RGR, NAR and RS ratio



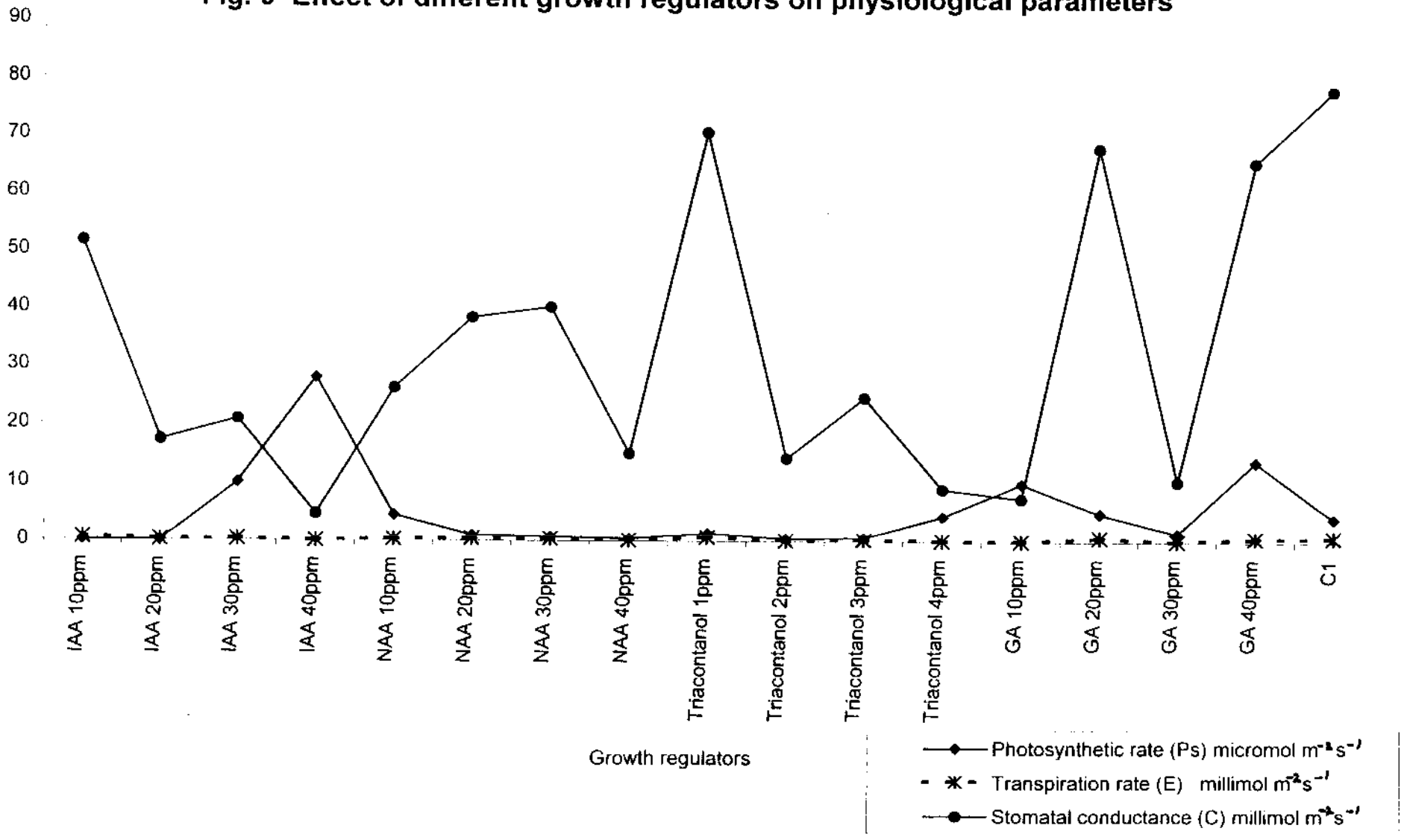
stages (Gardner *et al.*, 1985). The results revealed that the plants treated with IAA 20 ppm showed the highest NAR (0.75 mg cm^{-2} day^{-1}) followed by NAA 10 ppm (0.73 mg cm^{-2} day^{-1}) (Fig. 8). NAA treatment in capsicum cv. Bruinsma Wonder increased the dry matter accumulation by higher photosynthesis (Zhang *et al.*, 1985). Beringer (1978) stated that the growth and yield of a crop is based on cell division, cell enlargement and the differentiation into assimilating, transporting and storage tissues. The role of auxins in inducing cell division and cell enlargement is well known.

The growth regulators produced significant effect on root-shoot ratio. Triacontanol 2 ppm produced the highest root-shoot ratio of 0.69 (Fig. 8). GA sprays in general showed lower root-shoot ratio which was contrary to the findings of Lou and Kato (1988) in brinjal and El-Asdoudi (1993a) in chilli var. California Wonder.

5.3 Physiological parameters

The application of growth regulators produced significant effect on the physiological parameters studied viz. photosynthetic rate, transpiration rate and stomatal conductance. The highest photosynthetic rate of 28.09 micromol m^{-2} s^{-1} was shown in plants treated with IAA 40 ppm (Fig. 9). Similar results have been obtained by Zhang *et al.* (1985) in chilli and Sharma and Singh (1990) in lemon. Exogenous application of IAA to potato stolons enhanced the photosynthetic rate (Puzina *et al.*,1998). Narwadkar and AnserWadekar (1989) also reported similar results in mango. GA 40 ppm treatment also showed higher photosynthetic rate. With regard to transpiration rate, GA 20 ppm showed the highest value (0.74 millimol $m^{-2}s^{-1}$) which was 2.77 per cent

Fig. 9 Effect of different growth regulators on physiological parameters

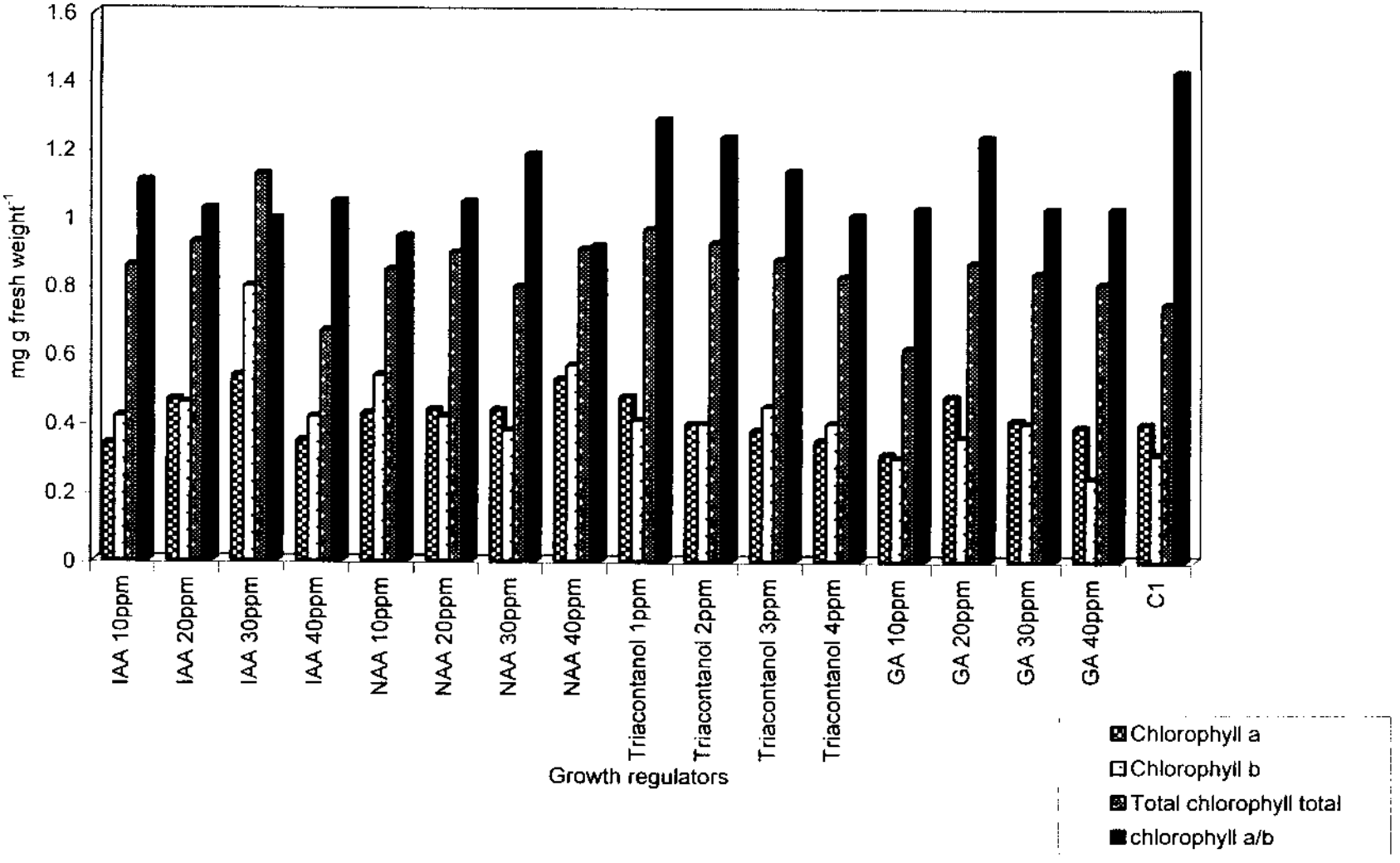


higher than control (Fig.9). Triacontanol 1 ppm also enhanced the transpiration rate of plants. IAA 40 ppm recorded the lowest transpiration rate. Stomatal conductance indicates how open or closed the stomatas are. The plants in control showed the highest stomatal conductance (78.0 milli mol $m^{-2}s^{-1}$) followed by Triacontanol 1 ppm with a value of 70.63 milli mol m^{-2} s^{-1} (Fig.9). Higher stomatal conductance increases CO_2 diffusion into the leaf and favours high photosynthetic rate.

5.4 Biochemical parameters

The data on photosynthetic pigments indicated an increase till the peak flowering stage followed by a decline in later stages. Nazar (1989) has reported a similar trend in ground nut. Significant variation was produced by the growth regulators in chlorophyll-b content and total chlorophyll content in all the stages. In vegetative stage, no significant difference among growth regulators was noted with respect to chlorophyll-a and chlorophyll a/b ratio. Foliar sprays of IAA 30 ppm showed the highest content of chlorophyll-a, chlorophyll-b and total chlorophyll with values of 0.54, 0.80 and 1.13 mg g fresh $weight^{-1}$ respectively (Fig.10). GA 10 ppm recorded the lowest chlorophyll-a content (0.31 mg g fresh $weight^{-1}$) and total chlorophyll content (0.62 mg g fresh $weight^{-1}$) whereas GA 40 ppm showed the lowest chlorophyll-b value (0.24 mg g fresh $weight^{-1}$). Chandra and Shivaraj (1972) reported that in chillies, GA treated plants showed chlorosis and a higher iron content compared to control plants. Increase in the uptake of iron may be present in unavailable form for chlorophyll synthesis. Omar *et al.* (1988) in *Vicia faba*

Fig. 10 Effect of different growth regulators on photosynthetic pigments

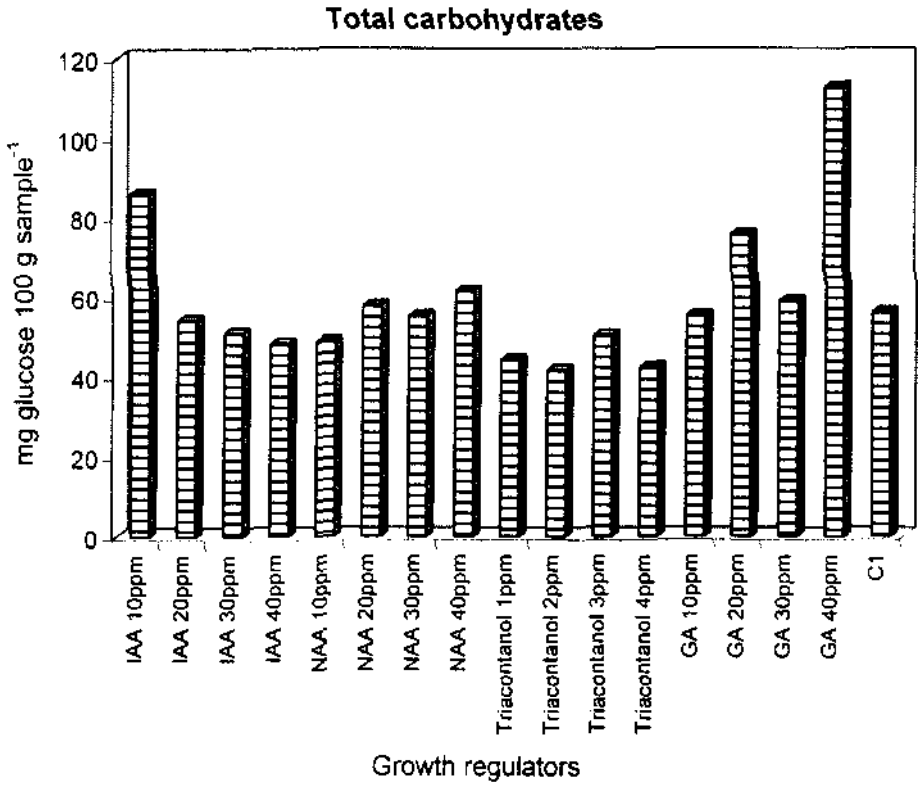


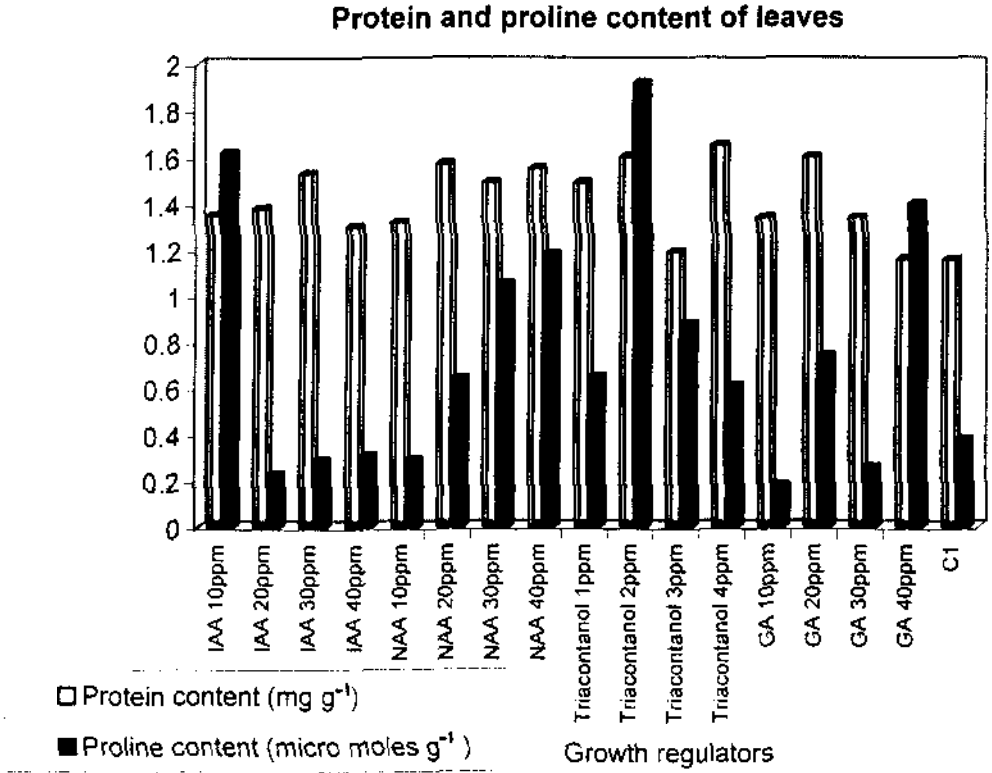
and Mosquera and Mendez (1994) in chillies also reported similar results. The role of auxins in increasing photosynthetic pigments can be supported by the reports of Chandra and Sivaraj (1972) in chillies and Shaddad and El-Tayeb (1990) in maize and cowpea. The control showed the highest chlorophyll a/b ratio (1.43) followed by Triacontanol 1ppm with a value of 1.29 (Fig. 10). The lowest chlorophyll a/b ratio was observed in NAA 40 ppm treated plants (0.92).

The protein content of plants is considered as a better index for assessing the status of plants for its growth and development. Nearly 50 per cent of total soluble protein extract in plants was accounted for RuBP carboxylase (Ellis, 1976). Therefore he stated that the estimation of soluble protein can be a better measure of RuBP carboxylase enzyme as well as the ultimate photosynthetic efficiency. The protein content of leaves increased from vegetative stage to maturation stage. Foliar sprays of Triacontanol 4 ppm showed the highest leaf protein content (1.65 mg g^{-1}) (Fig. 11). This was 42.24 per cent higher than control. Triacontanol 2 ppm and GA 20 ppm also showed higher values for protein content. The works of Sidda Reddy (1988) in potato and Subbiah *et al.* (1989) in tomato emphasized the role of triacontanol in improving the protein content.

A steady increase in carbohydrate content of leaves was observed from vegetative stage to peak flowering stage and thereafter a decline was seen. This may be attributed to the transport of assimilates to the reproductive sink at the later stages of crop growth. The plants treated with GA 40 ppm recorded the highest carbohydrate content of 112.50 mg glucose 100g $sample^{-1}$ (Fig. 11). This result is contrary to the findings of Chrungoo and Farooq

Fig. 11 Effect of different growth regulators on protein, carbohydrate and proline content of leaves



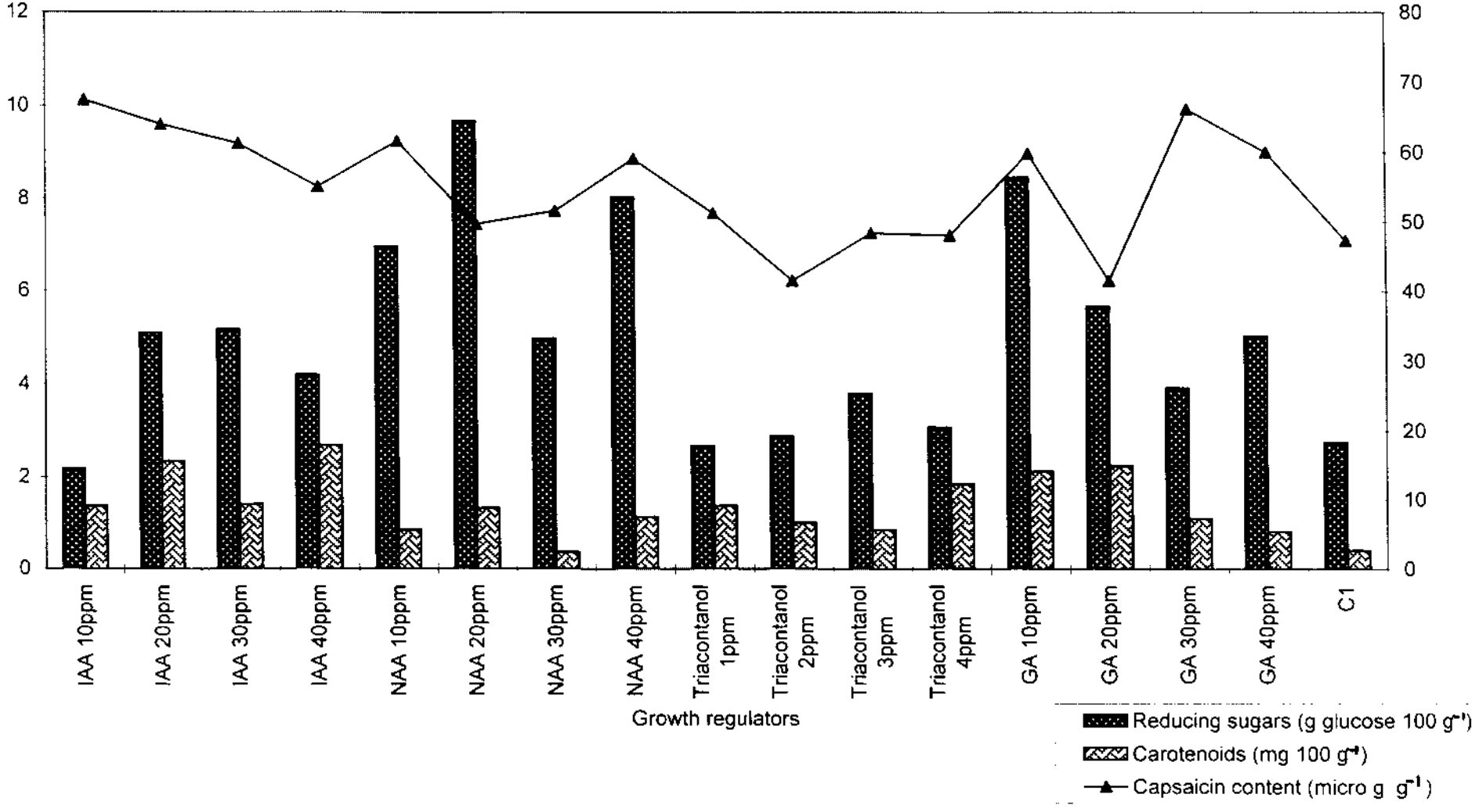


(1989) and Belakbir *et al.* (1996) in chillies. IAA 10 ppm, GA 20 ppm and NAA 40 ppm also considerably enhanced the carbohydrate content of leaves. The works of Chandra and Sivaraj (1972), Patil *et al.* (1985) in chillies supports the role of auxins in enhancing the carbohydrate content.

The accumulation of free amino acids is a characteristic mechanism of defence against wilting (Palfi *et al.*, 1974). Leaf proline content estimated as a biochemical index shows the ability of a plant to withstand stress. The proline content of leaves varied in different stages though a higher value was seen in the ripening stage. This should have been the response to stress at the later stages of the crop. During peak flowering stage also, the proline content was higher. Among the growth regulators, foliar sprays of Triacontanol 2 ppm showed the highest proline content of 1.92 μ moles g^{-1} (Fig. 11). IAA 10 ppm, GA 40 ppm, NAA 40 ppm and NAA 30 ppm sprays also recorded high proline values in their leaves.

Growth regulators revealed significant difference with respect to the biochemical constitution of the fruits viz. reducing sugars, carotenoids and capsaicin contents. NAA sprays of plants enhanced reducing sugar content of the fruits. The results revealed NAA 20 ppm to be the best with a value of 9.68 g glucose $100g^{-1}$. NAA 40 ppm and GA 10 ppm also showed higher values. An increase in reducing sugar content of fruits by NAA treatment has been reported by Bal *et al.* (1988) in Ber, Chrungoo and Farooq (1989), Phookan *et al.* (1991) and Gabr *et al.* (1984) in tomato. As the fruits ripened, chlorophyll pigments disappeared and the concentration of carotenoids was increased. IAA 40 ppm recorded the highest carotenoid content (2.69 mg 100 g^{-1}) in ripe fruits (Fig. 12). The performance of IAA and GA both at 20ppm

Fig. 12 Effect of different growth regulators on reducing sugars, carotenoids and capsaicin content of fruits

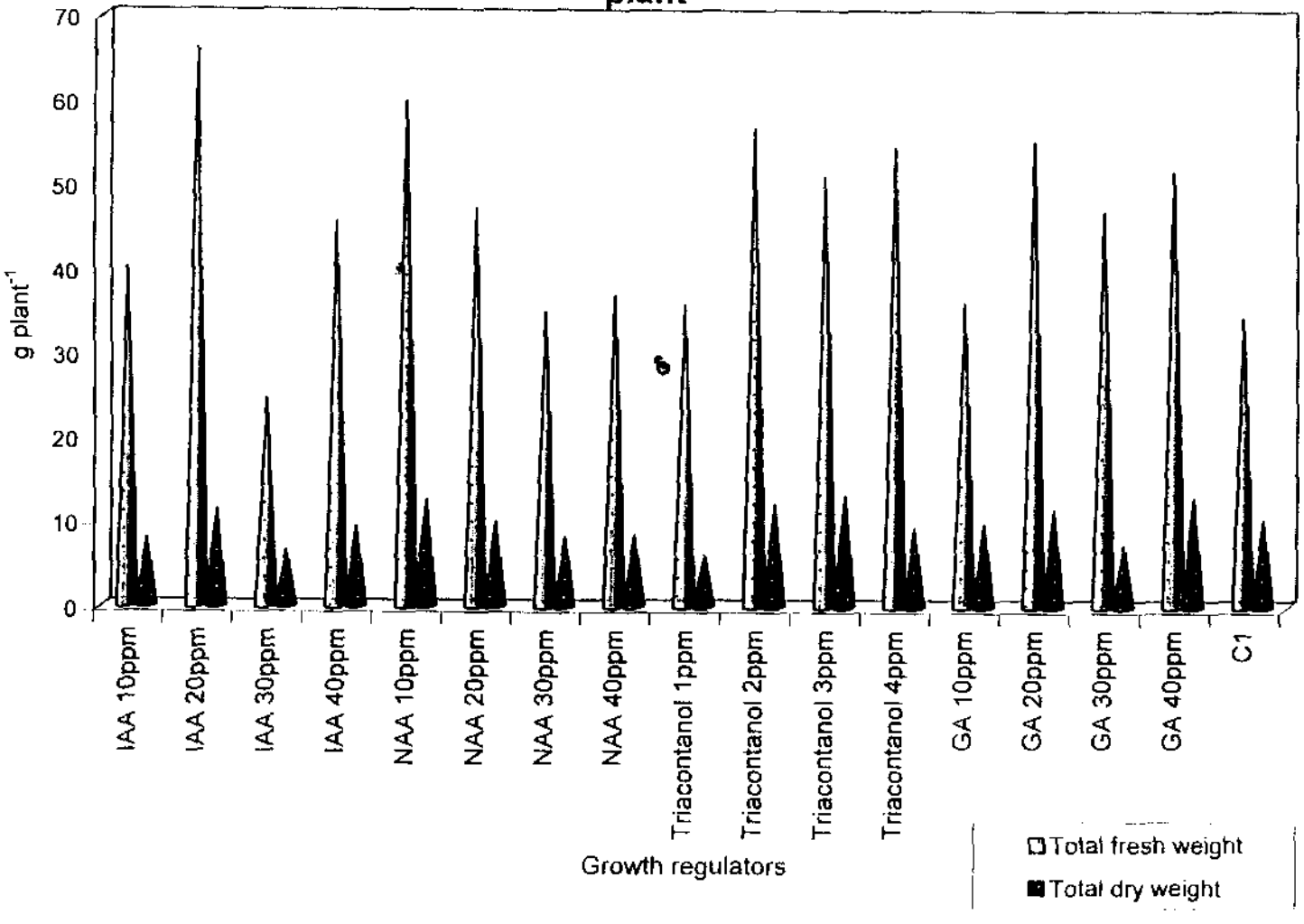


were also better. IAA and GA_3 both were found to increase the carotenoid content in maize and cowpea (Shaddad and El-Tayeb, 1990). Capsaicin is the pungent principle present in chillies. The capsaicin content in IAA 10 ppm treated plants showed the highest value (67.52 μ gram $gram^{-1}$) with 43.44 per cent increase over control (Fig. 12). GA 30 ppm and IAA 20 ppm also recorded higher values. This is in accordance with the reports of Patil *et al.* (1985) in chillies. Capsaicin content increases with increasing maturity (El-said, 1996).

5.5 *Yield parameters*

Wareing and Patric (1975) considered high dry matter production as an important prerequisite for greater yield in crop plants. Dry matter accumulation increases with the age (Watson, 1971). An increase in fresh weight was noted from vegetative stage to maturation stage and after which a decline was seen. This may be due to senescence and water loss in later stages of the crop growth. IAA 20 ppm recorded the highest fresh weight (66.11 g $plant^{-1}$) followed by NAA 10 ppm (60.09 g $plant^{-1}$) (Fig.13). The percentage increase over control was 91.90 and 74.42 respectively. Auxins maintain the rate of RNA synthesis and thereby delay the senescence of leaves. Initiation of lateral roots and adventitious roots is stimulated by high auxin levels. Auxins stimulate the cells to divide and hence result in more growth and increased fresh weight and cell elongation (Taiz and Zeiger, 1998). IAA increases fresh weight probably by increasing water use efficiency in maize and cowpea (Shaddad and El-Tayeb, 1990). NAA 40 ppm resulted in greatest increase in plant height along with shoot and root fresh weight in

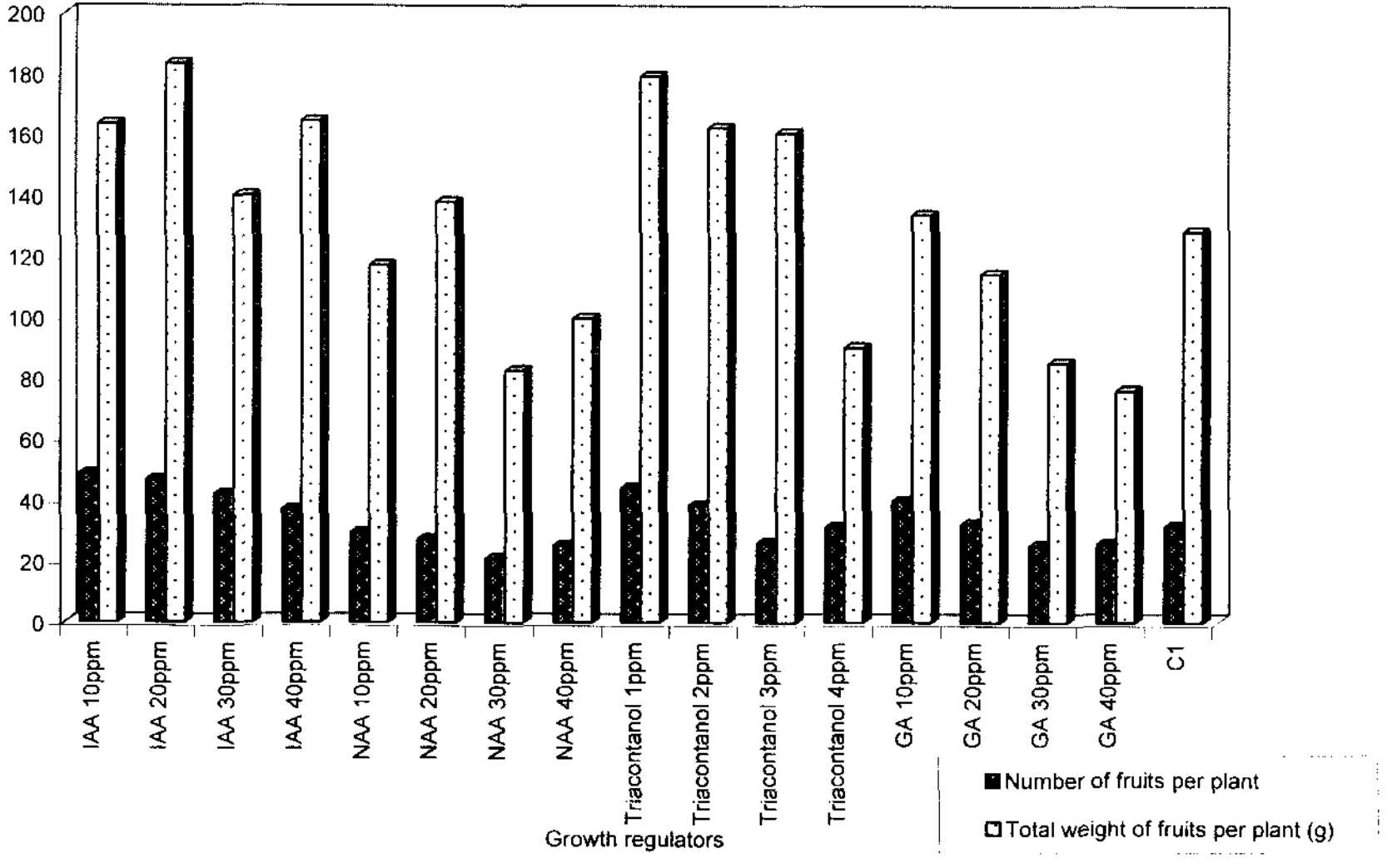
Fig. 13 Effect of different growth regulators on total fresh weight and dry weight per plant



chillies (Singh *et al.*, 1993). In case of dry weight per plant, it was observed to increase until the ripening stage. Growth regulators showed significant variation in increasing the dry weight per plant. Foliar sprays of triacontanol 3 ppm showed the highest dry weight of 13.22 g plant^{-1} followed by GA 40 ppm (12.87 g plant^{-1}) (Fig.13). Increase in dry weight of plants by triacontanol treatment in tomato has been reported by Eriksen *et al.* (1981).

Number of fruits per plant is a principal yield attribute showing high positive correlation with yield. The results revealed that the plants given foliar sprays of IAA 10 ppm recorded the highest number of fruits per plant (48.83) with a 54.23 per cent increase over control (Fig. 14). IAA 20 ppm, IAA 30 ppm and Triacontanol 1 ppm also produced more number of fruits per plant. This must be related to the rise in carbohydrate content which in turn increased the number of fruits harvested per picking. Niranjana *et al.* (1999) and Mamat *et al.* (1983) in tobasco pepper got similar results. Growth regulators produced significant difference in the yield of fruits also. IAA 20 ppm recorded the highest yield (183.66 g plant $^{-1}$) with a 42.67 per cent increase over control (Fig. 14). IAA at other concentrations and Triacontanol at 1, 2 and 3 ppm also showed a better performance than control in enhancing yield The auxin directed translocation of nutrients and photoassimilates as reported by Krishnamurthy (1981) should have been responsible for the increased yield. Singh (1999) reported that the induction of early flowering and fruiting and maximum number of fruits to be the reasons for the increase in yield by IAA treatment. The yield increase by application of triacontanol was due to increase in both number of fruits as well as fruit weight. This can be attributed to increased uptake of nutrients, enhanced photosynthesis and

Fig. 14 Effect of different growth regulators on yield characters



more translocation of sugars and other metabolites (Umajyothy and Shanmughavelu, 1985). Shukla and Prabhakar (1989) in tomato, Pandita *et al.*(1991) in bhindi, Sharma (1995) in tomato and Thakur *et al.*(1999) in bell pepper also got similar results. Harvest index is the ratio of economic yield to biological yield. A higher harvest index indicates greater yield of a crop. Fruit yield displayed significant positive association with harvest index in chillies (Vijayalakshmi *et al.*, 1988). IAA 40 ppm showed the highest harvest index of 0.77 (Fig. 14). IAA 10 ppm, NAA 20 ppm, Triacontanol at 1 and 2 ppm also showed a higher harvest index.

In chillies yield displayed significant and positive association with fruit length (Rani *et al.*, 1996). Fruit diameter and number of fruits per plant exhibited antagonistic indirect effects with each other (Kaul and Sharma, 1989). Application of growth regulators produced significant difference in the length of fruits. The fruits of plants treated with Triacontanol 2 ppm recorded the maximum fruit length (7.87 cm) (Plate 4) showing a 25.31 per cent increase over control. GA at all the concentrations (Plate 5), IAA 20 ppm and NAA 20 ppm also showed an increase in length of pods compared to control (Plate 2 and 3). Vijayalakshmi *et al.* (1988) noticed negative correlation of fruit length with fruit girth in chillies. The maximum fruit breadth was observed in NAA 40 ppm (1.76 cm) while GA 40 ppm showed the minimum fruit breadth of 1.15 cm. This result is in accordance with the findings of Maurya and Lal (1987) in chilli, Mukherji and Roy (1966) in tomato and Doddamani and Panchal (1989) in chilli.

Plate 2 Effect of IAA on fruit size

Plate 3 Effect of NAA on fruit size


IAA
CONTROL
10 ppm
30 ppm
C1
20 ppm
40 ppm
C2


NAA
CONTROL
10 ppm
30 ppm
C1
20 ppm
40 ppm
C2

Plate 4 Effect of triacontanol on fruit size

Plate 5 Effect of GA on fruit size


TRIACONTANOL
CONTROL
1 ppm
3 ppm
C1
2 ppm
4 ppm
C2


GA
CONTROL
10 ppm
30 ppm
C1
20 ppm
40 ppm
C2

The chlorophyll pigments of fruits disappeared at the later stages and the colour changed to orange red. Not much difference was produced by the growth regulators in the colour of fruits at the ripening stage.

The results of the study indicated significant difference being produced by the growth regulators with respect to thousand seed weight. IAA 40 ppm recorded the highest value (4.62 g) with a 40 per cent increase over control. GA 20 ppm also showed higher thousand seed weight (4.02 g). Singh and Lal (1995) reported a higher seed yield in chilli by auxin treatment. The role of growth regulators in the germination percentage of seeds was significant. The highest germination percentage of 87.16 was seen in plants treated with Triacontanol 3 ppm. NAA 30 ppm and GA 20 ppm also showed an enhanced germination percentage. Niranjana *et al.* (1999) reported significant increase in germination in maize, rice and sunflower by triacontanol treatment. In chilli, GA was more effective in stimulating germination while auxin application did not alter it (Watkins and Cantliffe, 1983). GA application stimulates the production of numerous hydrolases notably alpha-amylase by aluerone grains and thus the germination. Similar result was reported by Vijayaraghavan (1999) in bhendi. The works of Hariharan and Unnikrishnan (1985) and Singh and Lal (1995) showed the role of NAA in enhancing germination in chilli.

5.6 Biotic factors

In general the incidence of pests and diseases was less in most of the crop stages. Bhatt and Verma (1958) reported that NAA application to virus infected tomato plants resulted in the disappearance of the symptoms. Auxins sprayed on diseased plants corrected the internal auxin imbalance rather than

inhibiting virus multiplication (Reddy and Yaraguntaiah, 1981). The role of GA in reversing the leaf curl symptoms are well reported by Nariani (1963), Lal and Singh (1961) in chillies and Reddy and Yaraguntiah (1981) in tomato. Triacontanol application reduced the leaf curl incidence due to insect repellant property of vipul in chilli var. KAU cluster (Usha, 1988). Though the incidence of pests and diseases were less, the growth regulator treated plants showed a better performance than control with respect to leaf curl, colletotrichum fruit rot and mite infestation.

5.7 Economics of cultivation

The role of growth regulators in enhancing the yield of crops has been well reported. The plants treatment with Triacontanol 1 ppm was found to be the most remunerative. It was observed that an additional investment of Rs. 1210 per hectare resulted in a 51 per cent extra yield over control and thus a greater income. This can be attributed to the role of triacontanol in enhancing the yield as reported by Umajyothi and Shanmugavelu (1985) in brinjal and Sharma (1995) in tomato along with the low cost of the growth regulator (Rs. 35 100 ml^{-1}). The benefit cost ratio was also high (1.51). A high benefit cost ratio indicates the economic feasibility of the growth regulator triacontanol.

Summary

6. SUMMARY

The present investigation "Effect of growth regulators in reducing flower and fruit drop in chilli (*Capsicum annuum* L.)" was conducted at the Department of Plant Physiology, College of Agriculture, Vellayani during December 1999 to March 2000. The aim of the investigation was to study the effect of IAA, NAA, Triacontanol and GA in reducing flower and fruit drop in chilli var. Jwalasakhi and also to know their effect on various plant characters. IAA, NAA and GA were used at concentrations of 10, 20, 30 and 40 ppm while Triacontanol was used at 1, 2, 3 and 4 ppm . Two controls were also provided, one with distilled water spray and the other with no spray. The experimental design was randomized block design with three replications. Two foliar sprays of growth regulator were given, one at 20 days after transplanting and the other at 40 days after transplanting .Observations were taken at five stages of crop growth viz. vegetative stage, flower initiation stage, peak flowering stage, maturation stage and ripening stage. The salient findings of the investigation are summarized here.

- Growth regulators produced significant difference with respect to earliness in flowering whereas no significant difference was observed in days to produce first fruit. Foliar sprays of NAA 30 ppm produced the earliest flowers in 23.17 days. Triacontanol and GA sprays also induced earliness compared to control (water spray).

- The flower production was maximum in plants sprayed with IAA 30 ppm (129.50 flowers per plant) which is over hundred per cent more than control (water spray). IAA 20 ppm and Triacontanol 4 ppm also produced more number of flowers per plant. With regard to flower and fruit drop, the growth regulators produced significant difference. The plants sprayed with IAA 40 ppm was most effective in producing the minimum flower drop of 30.94 per cent and maximum fruit set of 57.22 per cent. This accounted for 48.06 per cent decrease in flower drop and 69.18 per cent increase in fruit set compared to control (water spray.) Thus the findings indicate the effectiveness of growth regulators in reducing the flower drop and increasing the fruit set.

- The effect of growth regulators in enhancing the plant height was significant only in the flower initiation stage. GA 40 ppm recorded the maximum height of 38.93 cm showing a 16.94 per cent increase over control.

- Leaf area progressively increased up to peak flowering stage and thereafter declined. Maximum leaf area of 478.04 cm^2 $plant^{-1}$ was seen in plants treated with GA 40 ppm. Triacontanol 2 ppm also enhanced the leaf area. Similar trend was seen with leaf area index (LAI) where GA 40 ppm recorded a value of 0.23. Specific Leaf Weight (SLW) was highest at the ripening stage. NAA 10 ppm showed the highest value of 1.30 g m^{-2} . Triacontanol treatment also increased the SLW values. IAA 30 ppm recorded the maximum leaf area ratio of 1.08 m^2 g^{-1} with a 85.09 per cent increase over control.

- Crop growth rate values of different treatments increased up to peak flowering stage when maximum leaf area was achieved. Relative growth rate was highest in the vegetative stage and it declined towards the ripening stage. Application of Triacontanol 2 ppm to the plants produced the highest crop growth rate and relative growth rate of 2.24 g m^{-2} day^{-1} and 0.033 mg g^{-1} day^{-1} respectively. IAA 20 ppm showed the highest net assimilation rate of 0.75 mg cm^{-2} day^{-1} followed by NAA 10 ppm (0.73 mg cm^{-2} day^{-1}).

- The growth regulators produced significant difference with respect to root-shoot ratio. Triacontanol 2 ppm produced the highest root-shoot ratio of 0.69.

- Photosynthetic rate, transpiration rate and stomatal conductance of the leaves was recorded 30 days after transplanting. These parameters were significantly influenced by the growth regulators. Foliar sprays of IAA 40 ppm showed the highest photosynthetic rate (28.09 μ mol m^{-2} s^{-1}). GA 40 ppm also enhanced the photosynthetic rate. With regard to transpiration rate, GA 20 ppm showed the highest value (0.74 milli mole m^{-2} s^{-1}) and IAA 40 ppm recorded the lowest value (0.09 milli mole m^{-2} s^{-1}). The performance of Triacontanol 1 ppm was on par with GA 20ppm. Stomatal conductance was highest in control plants (78 milli mole m^{-2} s^{-1}) followed by triacontanol 1 ppm (70.9 milli mole m^{-2} s^{-1}).

- An increase in photosynthetic pigments was seen till the peak flowering stage followed by a decline in the later stages. Significant difference was observed by the application of growth regulators with regard to chlorophyll-b content and total chlorophyll content in all the stages. In vegetative stage, no significant difference was seen with respect to chlorophyll-a content and chlorophyll a/b ratio. IAA 30 ppm showed the highest chlorophyll-a content (0.54 mg g fresh weight^{-1}), chlorophyll-b content (0.80 mg g fresh weight^{-1}) and total chlorophyll content of 1.13 mg g fresh weight $^{-1}$. The control showed the highest chlorophyll a/b ratio of 1.42 followed by Triacontanol 1ppm (1.29).

- The protein content of leaves increased from vegetative stage to maturation stage. The highest protein content (1.65 mg g^{-1}) was recorded in plants given foliar sprays of Triacontanol 4 ppm. This was 42.24 per cent higher than control.

- Growth regulators produced much variation in the carbohydrate content of leaves. A steady increase in carbohydrate content was observed from vegetative stage to peak flowering stage and further a decline was seen. GA 40ppm recorded highest carbohydrate content of 112.50 mg g^{-1}. IAA 10 ppm, GA 20 ppm and NAA 40 ppm also increased the carbohydrate content of leaves.

- The proline content of leaves varied in the different stages, but a comparatively higher value was been in the ripening stage. Triacontanol 2 ppm showed the highest proline content (1.92 μ moles g^{-1}).

IAA 10 ppm, GA 40 ppm, NAA 40ppm and NAA 30 ppm also recorded high proline content in their leaves.

- Growth regulators revealed significant difference with respect to biochemical constitution of fruits viz. reducing sugar content, carotenoids and capsaicin content. NAA treatment of plants considerably enhanced the reducing sugar content. NAA 20 ppm recorded the highest value (9.68 g glucose $100g^{-1}$) IAA 40 ppm recorded the highest carotenoid content of 2.69 mg 100 g^{-1} in ripe fruits. IAA and GA both at 20 ppm also showed a higher value. Plants treated with IAA 10 ppm recorded the highest capsaicin content of 67.52 μ gram $gram^{-1}$ with a 43.44 per cent increase over control. IAA 20 ppm and NAA 10 ppm also showed higher capsaicin content.
- An increase in fresh weight of plants was noted from vegetative stage to maturation stage after which a decline is seen. The dry weight of plants increased till the ripening stage. IAA 20 ppm recorded the highest fresh weight (66.11 g plant $^{-1}$) followed by NAA 10 ppm (60.09 g plant $^{-1}$). Triacontanol 3 ppm recorded the highest dry weight (13.22 g $plant^{-1}$) followed by GA at 40 ppm (12.87 g plant $^{-1}$).
- Application of growth regulators produced significant difference with respect the number of fruits per plant and weight of fruits per plant. IAA 10 ppm recorded the highest number of fruits per plant (48.83) with a 54.23 per cent increase over control. IAA 20 ppm, IAA 30 ppm and Triacontanol 1ppm also produced more number of fruits per plant. IAA 20 ppm showed the maximum per plant yield (183.66 g $plant^{-1}$)

which was 42.67 per cent higher than control (water spray). IAA at other concentrations and Triacontanol at 1,2 and 3 ppm also showed higher per plant yield compared to control (water spray)

- Significant difference was noticed in harvest index by growth regulator application. IAA 40 ppm showed the harvest index of 0.77. IAA 10 ppm, NAA 20 ppm, Triacontanol at 1ppm and 2 ppm also showed a higher harvest index.

- Fruit length was significantly influenced by the application of growth regulators. Foliar sprays of Triacontanol 2 ppm recorded the maximum fruit length (7.87 cm) which was 25.31 per cent higher than control. GA at all the four concentrations, IAA 20 ppm and NAA 20 ppm also showed better fruit length compared to control. No significant difference was observed with respect to fruit breadth. NAA 40 ppm recorded the maximum fruit breadth (1.76 cm) whereas GA 40 ppm showed the minimum fruit breadth (1.15cm)

- The growth regulators had no significant role in influencing the colour of fruits at ripening . The highest thousand seed weight (4.62g) was produced by foliar sprays of IAA 40ppm. GA 20 ppm also enhanced the thousand seed weight.

- The percentage germination of seeds was also influenced by the growth regulators. Triacontanol 3ppm showed the highest germination percentage of 87.16. NAA 30 ppm, GA 20 ppm and GA 10 ppm also increased the germination percentage of seeds.

- Though the incidence of pests and diseases was less in all the crop stages, the plants sprayed with the growth regulators had lesser incidence of leaf curl, colletotricum fruit rot and mite infestation compared to control.
- Correlation studies showed that the fruit yield was significantly and positively correlated with the number of fruits per plant, harvest index and root shoot ratio.
- A comparison of the economics of cultivation revealed Triacontanol 1 ppm to be the most remunerative. It was observed that an additional investment of Rs. 1210 per hectare resulted in 51 percent extra yield over control and thus a greater benefit-cost ratio (1.51).

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* Originals not seen

Appendices

APPENDIX - I

Soil characteristics of the experimental field

	Particulars	Content
1.	**Mechanical composition (per cent)**	
a)	Coarse sand	16.70
b)	Fine sand	31.30
c)	Silt	25.50
d)	Clay	19.20
2.	**Physical properties**	
a)	Bulk density (g cc^{-1})	1.33
b)	Water holding capacity (per cent)	20.03
c)	Porosity (per cent)	30.65
3.	**Chemical properties**	
a)	Available Nitrogen (Kg ha^{-1})	282.24
b)	Available Phosphorus (Kg ha^{-1})	40.56
c)	Available Potassium (Kg ha^{-1})	160.35
d)	Organic Carbon (per cent)	1.28
e)	Soil reaction (p^H)	4.80

APPENDIX - II

Weather data for the cropping period – December 1999 to March 2000 at Instructional Farm, College of Agriculture, Vellayani

Date (Weekly Average)	Temperature ^{0}C		Relative Humidity (%)	Wind velocity (km/h)	Rainfall (mm)	Sunshine hours	Soil temperature – 5 cm (^{0}C)
	Maximum	Minimum					
Dec.1 to Dec. 6	30.08	22.50	82.21	2.85	0.88	4.42	30.60
Dec.7 to Dec. 14	31.47	21.94	79.21	2.42	0.00	3.59	30.48
Dec.15 to Dec. 21	30.47	21.68	78.07	3.14	0.00	4.87	26.84
Dec.22 to Dec. 28	30.74	21.32	77.00	3.00	0.05	4.08	31.22
Dec.29 to Jan. 4	30.85	20.78	78.14	3.42	0.00	4.99	31.99
Jan. 5 to Jan. 11	30.97	23.14	78.78	2.42	1.07	3.85	32.10
Jan. 12 to Jan. 18	30.91	22.47	79.07	2.85	0.24	5.14	32.25
Jan. 19 to Jan. 25	30.45	20.35	78.07	2.85	0.00	6.91	32.69
Jan. 26 to Feb. 1	31.40	20.87	75.57	3.28	0.00	7.22	34.72
Feb. 2 to Feb. 8	30.52	22.67	79.57	3.00	14.02	5.93	32.69
Feb. 9 to Feb. 15	30.94	22.38	77.92	3.57	0.37	8.94	33.59
Feb. 16 to Feb. 22	30.85	22.55	76.57	3.14	0.00	8.48	34.23
Feb.23 to Feb.29	31.05	29.74	78.00	2.71	0.20	6.80	34.58
Mar.1 to Mar.7	31.52	22.75	77.78	3.28	0.17	7.88	35.52
Mar.8 to Mar.14	32.00	23.94	76.42	3.42	0.68	9.20	36.38
Mar.15 to Mar.21	31.84	23.31	76.42	2.85	0.48	9.72	37.19
Mar.22 to Mar.28	32.45	23.20	75.42	3.28	0.00	9.01	37.00
Mar.29 to Mar.31	32.60	24.43	78.00	3.66	0.00	9.10	38.10

EFFECT OF GROWTH REGULATORS ON FLOWER AND FRUIT DROP IN CHILLI (*Capsicum annuum* L.)

By

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ABSTRACT OF THE THESIS
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ABSTRACT

Investigations were carried out at the Department of Plant Physiology, College of Agriculture, Vellayani during December 1999 to March 2000 to find the effect of growth regulators viz. IAA, NAA, Triacontanol and GA in controlling flower and fruit drop in chilli var. Jwalasakhi. IAA, NAA and GA were used at concentrations of 10, 20, 30 and 40 ppm while Triacontanol was used at 1,2, 3 and 4 ppm. Two controls were also provided, one with distilled water spray and the other with no spray. Two sprays of growth regulators were given, one at 20 days after transplanting and the other at 40 days after transplanting. The effect of these growth regulators on morphological, growth, physiological, biochemical and yield parameters were also studied.

The growth regulators produced considerable variation with respect to intensity of flowering, flower drop, fruit set and fruit drop. The flower production was increased upto 45.5 per cent with IAA 30 ppm. IAA 40 ppm was most effective in reducing the flower drop by 48.06 per cent increasing the fruit set by 69.18 per cent when compared to control (water spray). NAA 30 ppm induced earliness in flowering (23.17 days) and GA at 40 ppm showed the maximum plant height (38.93 cm).

The plants treated with GA 40 ppm showed the maximum leaf area (478.04 cm^2 $plant^{-1}$) and leaf area index (0.23). NAA 20 ppm recorded the highest specific leaf weight (1.30 g m^{-2})and IAA 30 ppm, the maximum leaf area ratio (1.08 m^{-2} g^{-1}). The plants sprayed with Triacontanol 2 ppm showed

the highest crop growth rate (2.24 g m^{-2} day^{-1}), relative growth rate (0.033 mg g^{-1} day^{-1}) and root-shoot ratio (0.69). Highest net assimilation rate (0.75 mg cm^{-2} day^{-1}) was seen in plants sprayed with IAA 20 ppm.

Significant influence of growth regulators was observed in the physiological and biochemical parameters studied. The highest photosynthetic rate (28.09 μ mol m^{-2} s^{-1}) was seen in plants sprayed with IAA 40 ppm. GA 20 ppm recorded the highest transpiration rate (0.74 milli mole m^{-2} s^{-1}). Stomatal conductance was maximum (78.0 milli mole m^{-2} s^{-1}) in control plants followed by Triacontanol 1 ppm with a value of 70.9 milli mole m^{-2} s^{-1}. IAA 30 ppm had a significant role in increasing the photosynthetic pigments viz., chlorophyll-a content (0.54 mg g fresh $weight^{-1}$), chlorophyll-b content (0.80 mg g fresh $weight^{-1}$) and total chlorophyll content (1.13 mg g fresh $weight^{-1}$). Foliar sprays of Triacontanol 4 ppm produced the highest protein content (1.65 mg g^{-1}) in leaves and GA 40 ppm recorded the highest carbohydrate content (112.50 mg g^{-1}). The proline content of leaves was more in Triacontanol 2 ppm sprays. The highest reducing sugar content (9.68 g glucose 100 g^{-1})of ripe fruits was seen in NAA 20 ppm, carotenoid content of 2.69 mg 100 g^{-1} in IAA 40 ppm sprays and the capsaicin content of 67.52 μ gram $gram^{-1}$ was recorded in IAA 10 ppm treated plants.

Significant effect of growth regulators was seen in the yield parameters also. The maximum fresh weight (66.11g $plant^{-1}$) and fruit yield (183.66g $plant^{-1}$) was seen in IAA 20 ppm sprays. The fruit yield was 42.6 per cent when compared to control. Triacontanol 3 ppm recorded the highest dry

weight (13.22g plant^{-1}) and germination percentage (87.16) of seeds. The number of fruits per plant (48.83), thousand seed weight (4.62 g) and harvest index (0.77) was maximum in foliar sprays of IAA 40 ppm. The maximum fruit length (7.87cm) was recorded in Triacontanol 2 ppm while NAA 40 ppm showed the maximum breadth (1.76 cm) of the fruits.

Correlation studies indicated significant positive association of fruit yield with number of fruits per plant, harvest index and root shoot ratio. In terms of net income and benefit-cost ratio, foliar sprays of Triacontanol 1 ppm was the most remunerative. An additional expenditure of Rs. 1210 per hectare towards the growth regulator showed 51 per cent more yield over control and thus a greater benefit-cost ratio (1.51).