INFLUENCE OF PLANT GROWTH REGULATORS ON GROWTH, PHYSIOLOGY AND YIELD IN CUCUMBER (*Cucumis sativus* L.)

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1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important and popular vegetable crops belonging to the family Cucurbitaceae. It is grown mainly for its fruits, both in India and abroad. Worldwide, cucumbers are extensively grown for fresh market and China leads in production followed by India. In India, cucumber is cultivated extensively in the states of Karnataka, Tamil Nadu, Uttar Pradesh, AndraPradesh, Kerala and Maharashtra. In the world during 2008, cucumber was cultivated on an area of 17.92 lakh ha with a production of 30.50 lakh tons and an average yield of 17021 kg/ha. While in India, it was cultivated on an area of 17800 ha with a production of 2.09 lakh tons and an average productivity of 11750 kg/ha. The Indian yields are 13.3 percent less than the world's average (Anon., 2008)

The fruits are highly nutritive and have very high water content and very low calories. The fruit is used as a vegetable or salad. It is rich in minerals, thiamine, niacin and vitamin C. (0.38 g, 0.3 mg, 0.2 mg and 78 mg, respectively per 100 g of edible fruit). Fruits consist about 80 percent of edible portion which contains 95% water, 0.7% protein, 0.1% fat, 3.4% carbohydrates, 0.4% fiber and 0.4% ash (Aykroyd, 1963).

It is an ideal summer crop chiefly grown for its edible tender fruits preferred as salad ingredient, pickles, dessert fruit and as a cooked vegetable. Its high water content makes it diuretic. Cucumber has a cleansing action within the body by removing accumulated pockets of old waste material and chemical toxins. It also helps in the treatment of arthritis, since it helps eliminate uric acid. Its low calorie makes it perfect food for diet. Its juice is also nourishing for our skin and hair, has the reputation of being rejuvenator and makes one feel and look young. Cucumber also has the power to relax and alleviate the sunburn's pain. Cucumber is a women's friend when they are on a diet but also for its cosmetic properties.

Plant growth regulators (PGRs) are organic compounds, other than nutrients that modify plant physiological processes. PGRs, called biostimulants or bioinhibitors act inside plant cells to stimulate or inhibit specific enzymes or enzyme systems and thus regulate plant metabolism. They normally are active in low concentrations in plants. About sixty plant regulators are commercially being used and several of them have reached considerable importance in crop production. Growth regulators include both growth promoters and retardants which have shown to modify the canopy structure and other yield attributes.

The importance of plant growth regulators was first recognized in the 1930s. Since that time, natural and synthetic compounds that alter function, shape and size of crop plants have been discovered. Today, specific plant growth regulators are used to modify crop growth rate and growth pattern during the various stages of development from germination through harvest and post harvest. Growth regulating chemicals that have positive influences on crops can be of value. The final test, however, is that harvested yields must be increased or crop quality enhanced for plant growth regulators to be profitable.

Plant growth regulators are known to have great potential to increase the productivity of vegetables. The potentialities of growth promoters and growth retardants can be best used to maximize the yield of several vegetable crops. The response of plant or plant parts to growth regulators varies due to fluctuations in endogenous hormonal levels of the plant and the manner in which the natural growth regulators interact with the applied growth regulators.

Though the plant growth regulators have great potentialities to influence plant growth and morphogenesis, its application and actual assessments etc. have to be judiciously planned in terms of optimal concentrations, stage of application, species specificity, seasons, etc. which constitute the major impediments in PGRs applicability. In view of their wide spectrum effectiveness on every aspect of plant growth, even a modest increase of 10-15 percent could bring about an increment in the gross annual productivity by 10-15 million tons.

With this background, the present investigation was aimed to find out the suitable plant growth regulators for increasing the yield potential and quality in cucumber with the following objectives:

1. To find out the influence of plant growth regulators (PGRs) on growth and development in cucumber.
2. To find out the influence of plant growth regulators (PGRs) on physiological parameters and productivity potential in cucumber.
3. To find out the influence of plant growth regulators (PGRs) on quality in cucumber.

2. REVIEW OF LITERATURE

The role of plant growth regulators in various physiological and biological processes in plants is well known, which enables a rapid change in the phenotype of the plant. Growth regulators are known to affect seed germination, vegetative growth, flowering, fruit set, seed development, fruit ripening and yield. Further, the physio-chemical quality of the crop is also influenced by growth regulators.

There is a great deal of experimental evidence in the literature showing that endogenous growth substances are involved in many processes which lead to growth and development. Plants have also been shown to respond to exogenous application of plant growth regulators. Considering their role in plants, plant growth regulators have been designated as magic chemicals which bring about as unprecedented growth and help in removing and circumventing many of the barriers imposed by genetics and environment. Crop yield is a complex heritable character influenced by many morphological and physiological characters of plant interacting with environment. An attempt has been made to present the impact of plant growth regulators on plant growth and development vis-à-vis physiological, biochemical and yield parameters. The literature on the use of growth regulators in cucumber is meager and hence the work on other closely related vegetable crops and also on other fruit crops and their effects on morphological, physiological, biochemical parameters and yield attributes are considered.

2.1 Morphological characters

2.1.1 Vine length

The experiment conducted by Krishnamoorthy and Sandooja (1981) revealed that the application of GA_3 increased the stem growth and the effect was more at higher concentrations. According to Mangal *et al*. (1981), the application of CCC at 250 ppm showed significant increase in plant height compared CCC at 500 ppm in bittergourd. Application of CCC at 100 ppm and ethrel (250 ppm) spray proved equally effective in the elongation of main axis in musk melon (Sidhu *et al.,* (1982).

The application of GA_3 at 25 ppm and NAA at (50 ppm) stimulated the elongation of main vine length in summer squash. Similarly, the application of GA_3 (25 ppm) at 2-4 true leaf stage resulted in the more vine length as compared to control in bittergourd (Arora *et al*. 1982 and 1985). It was noticed that the application of NAA at 2 and 4 true leaf stages increased the main vine length of the vine in watermelon cv, Sugar Baby (Shinde *et al,*. 1994).

Arun *et al.* (1982) reported that the application of GA_3 @ 200 ppm resulted in maximum plant height followed by seed soaking with GA_3 @15 ppm in brinjal cv Pusa Purple Long. According to Ram Asrey *et al.* (2001), the application of GA_3 at 500 ppm increased the length the vine in muskmelon.

2.1.2 Number of leaves

Das and Swain (1977) reported that nitrogen and growth regulators increased leaf numbers as well as leaf area in pumpkin when the crop was sprayed with planofix (100 ppm), ethrel (200 ppm) and alar (200 ppm) at 10 and 20 days after planting. Whereas, Singh *et al*. (1991) reported that the foliar application of mixtalol (30 ml/10 l) increased the number of leaves per plant significantly in bottlegourd. Seed soaking with 550 ppm GA_3 for 12 hrs increased the number of leaves per plant in muskmelon (Ram Asrey *et al.* 2001). Ertan *et al.,* (2008) reported that Shoot diameter and leaf number per plant increased with salicylic acid treatments in cucumber grown under salt stress.

2.1.3 Number of flowers

El- Kholy and Hafez (1982) in their experiment with snake cucumber obtained more number of male flowers by the application of gibberellic acid at 100 mg/l. Significantly

increased number of male flowers and reduced number of female flowers was recorded by Patil *et al.,* (1984) with the application of gibberellic acid at 225 ppm in cucumber. Banerjee *et al.,* (1992) reported that both GA_3 and ethrel in lower concentrations promoted female flower production as well as fruit setting and development.

According to Mangal *et al.,* (1981), higher concentration of cycocel (250-500 ppm) resulted in early female flower appearance when growth regulators were applied at fourth true leaf stage in bittergourd cv. KH-8. Aisha *et al.,* (2006) found that in *Cucumis sativus* L. and *Momordica charantia* L. the application of GA_3 at 400 ppm caused precocious flowering, increasing the number of pistillate and staminate flowers in both the plants.

Sedghi *et al.,*(2008) reported that in medicinal pumpkin, the number of female flowers per plant was positively affected by both naphthalene acetic acid (NAA) and GA_3 treatments. Iranbakhsh and Ebadi., (2008) recorded the appearance of more male flowers when the combination of IAA 100 ppm and GA3 500 ppm was used in cucumber in green house.

2.1.4 Fruit set

Wittwer and Buckovac (1965) reported that the application of GA_3 succeeded in promoting fruit set without pollination in watermelon. According to Gopalkrishnan and Choudhary (1978), foliar application of GA_3 at 25 and 50 ppm increased percent fruit set. Rajpal Singh *et al.* (2001) also reported that the foliar application of NAA at 10 and 20 ppm in ber cv. Umran significantly increased fruit set over control. The highest percent (84.51) fruit set per plant was obtained when GA_3 was applied at 70 ppm. The lowest (63.41) was obtained with GA_3 (20 ppm) in bittergourd (Dostogir *et al.,* 2006)

2.2 Phenological characters

2.2.1 Days to flower initiation

Application of CCC at 250 and 500 ppm recorded minimum number of days for the appearance of female flowers (48.4 to 49.5), which was about 13 days earlier to untreated control (Mangal *et al.,*1981). Effect of different concentrations of cycocel on growth and yield of cucumber was studied by Sadiq *et al.,* (1990) who reported lowest number of days to flowering and maturity due to the application of CCC 500 ppm. Cycocel when sprayed to cucumber cultivar, Marketer at different concentrations (300,400 and 500 ppm) resulted in significantly lesser number of days to flowering and maturity with increasing concentrations (Abdul Wahid *et al.,* 1993).

Arora *et al.* (1982) reported that the application of ethrel at 100 and 250 ppm was most effective in inducing early as well as increased number of female flowers than the male flowers in summer squash. The Application of plant growth regulator MH at 150 mg/l showed earliest appearance of first staminate and pistillate flowers. Whereas, NAA at 50 mg/l delayed the appearance of first staminate and pistillate flowers in cucurbitaceous crops (Arora *et al.*1985). The application of NAA (50 ppm) produced the first male flower earlier (43 days) and was significantly superior to all other treatments in bittergourd (Gedam *et al.,* 1998)

Pankaj *et al.* (2005) studied the effect of plant growth regulators in bottlegourd and recorded substantial variation in the number of days for first male and female flowers over control and the application of CCC at 200 ppm exhibited significantly lower values (50.94 days) for male flowers and 58.8 days for female flowers as against the control. Application of NAA at 50 ppm delayed the appearance of first male flower (48 days) than female flower (45.04) as compared to control in bittergourd (Marbhal *et al.,* 2005). Similarly, the application of GA_3 at 85 ppm showed significant influence on days to first male flower (34.7) in bittergourd. The earliest (30.63 days) was obtained in control (Dostogir *et al.,* 2006)

2.2.2 Days to fruit set

Splittstoesser (1970) recorded delayed fruit set and maturity by the application of gibberellic acid in pumpkin. In the green house cucumber, at two to three leaf stage, spraying

of gibberellins at 2000 ppm delayed the yield of marketable fruits (Churata musca and Awad, 1974).

Dostogir *et al.,* (2006) studied the effect of GA_3 on flowering and fruit development in bittergourd and reported that the application of GA_3 at 25 and 40 ppm reduced the number of days to fruit set.

2.2.3 Days to fruit maturity

Mishra *et al.* (1972) revealed that the application of GA_3 (10 ppm) at 21 days after sowing and again a week later resulted in earliness of fruit maturity in bottlegourd. Similarly, foliar application of GA_3 (25 ppm) at two and four true leaf stages of plant growth resulted in earliness of fruit maturity in watermelon cv. Fuken (Arora *et al.,* 1988). Similarly, the application of NAA at 50 ppm showed the earliest fruit maturity (19.3 days) in bittergourd (Gedam *et al.,* 1998). In muskmelon, the seed soaking with GA 400 ppm solution for 24 hours showed the fruit maturity followed by GA_3 at 450 ppm (Ram Asrey *et al.,* 2001).

Marbhal *et al.,* (2005) studied the effect of growth regulators and picking sequence on seed yield in bittergourd and reported that the number of days required to pick the mature fruits from flowering significantly influenced by growth regulator treatments. It was also noticed that number of days was reduced by ethephon treatment (33.8 days) as compared to control (39.2 days) and also there was a slight reduction with NAA treatments (37.3 days).

2.2.4 Fruit characteristics

Singh *et al.,*(1975) reported the improvement in fruit size by the application of gibberellic acid at 10, 25 and 50 ppm in summer squash. GA_3 and GA_{4+7} applied to ovaries of developing autumn and winter green house cucumber flowers increased the average weight fruit by 3 and 5 times heavier respectively than fruits from untreated control (Ogawa and Aoki, 1977).

Yasuyoshi and Yoshiyuki (1995) opined that the application on NAA (150 ppm) at 2 and 4 true leaf stages increased the average fruit weight and also the combined effect of both hand pollination and cytokinin increased the fruit weight in watermelon. The foliar application of NAA (50 ppm) and boron (4 ppm) recorded an increase in fruit diameter and fruit weight in bittergourd (Gedam *et al.,* 1998).

The maximum average length (6.0 cm) and average diameter (5.7 cm) was observed in squash melon with the application of 20 ppm and 10 ppm triacontanol (Mahajan and Sharma, 2000). Ram Asrey *et al.,* (2001) studied seed soaking with 400 ppm GA solution for 12 hours and showed increase in fruit weight in muskmelon.

The foliar application of GA_3 (5, 10, 20 ppm) and MH (50,100, 200 ppm) at 2,4 and 6 leaf stages resulted in increased fruit diameter of summer cucumber; whereas, GA_3 was inferior to MH (Rafeekar *et al.,* 2002). The foliar application of NAA at 50 ppm showed increase in fruit weight by 34 percent, as compared to 100 ppm of MH (19%) and 13% with 50 ppm ethephon (Marbhal *et al.,* 2005). The application of GA_3 at 40 ppm showed the maximum fruit diameter and fruit weight and it was lowest with GA_3 (85 ppm) in bittergourd (Dostogir *et al.,* 2006).

2.3 Bichemical characters

Treating the apex of the main stem and the side shoots of cucumber plants five times with 0.002 percent GA increased the reducing sugar and total sugar contents of the fruits (Tagmazjan, 1968). Ahmed *et al.* (1985) found that spraying of cycocel (500 ppm) at 21 days after planting in potato produced the higher amount of chlorophyll ‘a’ and ‘b’. Similarly, increase in chlorophyll content was found with the application of CCC and mepiquat chloride in seed tuber potato over control (Ganiger, 1992 and Gasti 1994). Application of ethrel at 400 ppm showed increase in reducing sugars (3.13 g/100 g fresh wt) and total sugars (3.43 g/100 g fresh wt.) as compared to GA in cucumber cv. Belgaum (Vadigeri *et al.,* 2001). Whereas, foliar application of GA_3 to tomato increased the sugar content in fruits (Adhlakha and Verma

1984). While, Siddareddy (1988) noted that the foliar application of mixalol (1-2 ppm) increased the contents of reducing, non reducing, total sugars and protein content in potato tubers.

Bourbouloux *et al,*(1998) studied in leaf discs of beet (*Beta vulgaris*) and found out that the increase in sugar and ammino acid intake as a result of tissue ageing was inhibited to a large extent by external SA administration (10-200 µM).

GA_3 has been reported to prevent chlorophyll degradation in *Zantedeschia* leaves (Janowska and Jerzy, 2003). Archana Singh and Pramod K. Singh (2008) reported that Salicylic acid (SA) treatments at lower concentrations (50 µM) showed significant increase in chlorophyll content and total non-structural carbohydrate (TNC). However, higher concentrations have inhibitory effects. Further, salicylic acid increases nitrate assimilation through the induction of nitrate reductase activity and accumulation of total nitrogen in isolated cucumber cotyledons

Songul Chanakci and Omer Munzuroglu (2009) reported that salicylic acid exert a chlorophyll (a & b) loss delaying effect on leaf discs taken from radish cotyledons, while there was no such effect on leaf segments of barley.

2.4 Yield and yield components

Yield is the ultimate economic product of the crop which is determined mainly by fruit weight and number of fruits per plant. Most of the yield components show a direct influence on fruit yield. Under good crop management conditions, the highest yield levels could be obtained through improved package of practices, which includes the use of plant growth regulators.

2.4.1 Fruit yield

The total fruit yield per ha increased with the application of GA_3 (10 ppm) at 21 and 28 days after sowing in bottlegourd (Mishra *et al.,* 1972). The application of GA_3 (10 ppm) at 2, 4 and 6 leaf stages increased the fruit yield per hactre in muskmelon (Randhawa and Kirtisingh, 1973)

Gopalkrishnan and Choudhary (1978) studied the effect of plant growth regulators on fruit set and development in watermelon and found out that the application of GA_3 (25 ppm) increased the fruit weight, fruit number and yield per ha. The foliar application of CCC (250 and 500ppm) at 4 leaf stage and second at 15 days of first spray in bittergourd recorded highest yield followed by spraying of ascorbic acid (25 ppm), ethrel (250 ppm) and boron @ 1 ppm (Mangal *et al.,*1981).

Sidhu *et al.* (1981) reported that the foliar application of GA_3 (10 ppm) and NAA (100 ppm) at two and four true leaf stages increased the fruit yield per ha by increasing the average fruit weight per plant in squash melon. The highest fruit yield per ha was recorded with the application of ethrel (500 ppm) in comparison to other treatments in muskmelon (Sidhu *et al*., 1982). The application of MH (150 ppm) in summer squash significantly enhanced fruit yield followed by 25 ppm GA (Arora *et al.,* 1982). Foliar spray of MH (150 ppm) at 2 and 4 true leaf stages at 7 days interval recorded highest total yield (376.3 q/ha) by number and weight in bottle gourd (Arora *et al.,* 1985). Similar results have been reported by Pandey and Singh (1973) in bottlegourd but are contrary to the earlier findings of Randhawa and Kirtisingh (1973) who noticed the maximum yield of muskmelon with the application of NAA (25 ppm).

Gedam *et al.* (1998) reported that a significant increase in fruit yield per plant and per ha was due to the application of NAA (50 ppm) as compared to other treatments in bitter gourd. The application of ethrel (400 ppm) in cucumber cv. Poinsette was found to be superior with respect to yield with maximum number of fruits per plant (12.65) and yield (25.83 t/ha) than Belgaum Local (Vadigeri *et al.,* 2001).

Seed soaking with GA_3 (400 ppm) for 24 hours increased the number of fruits and yield in muskmelon (Ram Asrey *et al.,* 2001). Maximum number of fruits and yield per ha were observed in the order of ethrel > MH>NAA>GA_3 and optimum concentration was 100 ppm ethrel in summer cucumber (Rafeekar *et al.,* 2002).

Marbhal *et al.,* (2005) reported that the maximum fruit yield was observed by spraying of NAA (50 ppm) which was higher than control. Dostogir Hossain *et al.,* (2006) reported that the application of GA_3 at 25 ppm recorded maximum number of fruits per plants (15.8). Similarly, application of GA_3 at 20 ppm recorded maximum yield compared to other treatments in bittergourd (Geeta, 2008).

Table 1. Monthly meteorological data during crop growth period (2009-10) and the average of 59 years (1950-2009) at Main Agricultural Research Station, UAS, Dharwad

Months	Rainfall (mm)		Temperature (^{o}C)				Relative humidity (%)	
	2009-10	1950-2009	Mean maximum		Mean minimum		2009-10	1950-2009
			2009-10	1950-2009	2009-10	1950-2009		
April	52.8	39.0	36.5	36.0	21.1	20.1	81.0	78.0
May	91.6	68.0	35.5	34.4	21.5	20.9	84.0	75.6
June	144.8	107.9	30.3	28.8	20.9	21.7	77.0	86.4
July	256.8	136.7	26.0	28.7	20.9	20.9	88.0	89.2
August	72.2	155.8	28.1	26.9	20.6	20.1	80.0	88.7
September	229.0	133.6	28.5	28.2	20.7	19.9	83.0	86.8
October	141.0	93.6	29.3	30.2	18.8	18.7	65.0	79.7
November	46.0	52.6	28.6	29.7	18.0	15.9	69.0	73.7
December	76.4	2.6	28.8	28.9	15.4	13.2	66.0	69.3
January	0.8	0.05	28.2	29.7	15.5	13.9	63.0	64.9
February	0.4	0.5	32.4	32.2	17.3	16.5	50.0	54.5
March	Trace	15.6	35.6	33.7	20.3	19.7	49.0	64.5
Total	1272.6	806.2						

3. MATERIAL AND METHODS

A filed experiment was conducted at Main Agricultural Research Station, University Agricultural Sciences, Dharwad during *rabi*/summer with an objective to find out the effect of plant growth regulators on growth, physiological parameters, yield and quality in cucumber (*Cucumis Sativus*) cv. Belgaum Local. The details of the materials used and the methods followed in the investigation are described in this chapter.

3.1 Experimental site

A field experiment was laid out in Plot No.125 of E block on medium black soils at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, which is situated at 15° 12'N latitude and 70° 07' E longitude with an altitude of 678 m above mean sea level.

3.2 Weather data during the crop growth period

The data on weather parameters such as rainfall (mm), mean maximum and minimum temperature (°C) and relative humidity (%) recorded at Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during the experimental year and the mean of the last 59 years (1950-2009) are presented in Table 1.

The mean annual rainfall for the past 59 years was 806.2 mm and the maximum rainfall was received in the month of August (155.8 mm) followed by July (136.7 mm). The total rainfall during 2009-10 was 1272.6 mm and a maximum of 256.8 mm was received in July followed by September (229.0 mm). The mean maximum temperature ranged from 36.5 °C (April) to 26 °C (August) during year 2009. The months of April, May and June were hottest. While the mean maximum temperature during past 59 years indicated that, it was maximum in April (36°C) followed by May (34.4°C). The minimum temperature ranged from 15.4 (December) to 21.5°C (May) during the 2009-10. The average of last 59 years indicated that the mean minimum temperature was maximum during June (21.7°C) and minimum during December (13.2°C). The relative humidity ranged from 49 (March) to 88 per cent (July) during 2009-10, while it ranged from 54.5 per cent (February) to 88.7 per cent (August) during the last 59 year. The climatic conditions are very much favourable for the crop growth and development during kharif 2009-10. The incidence of pest and diseases was not severe; the crop stand was good and healthy.

3.3 Soil and its characteristics

The soil of experimental site was medium black clay loam soil. Composite soil samples were collected from the experimental site and analyzed for various physical and chemical properties. The details along with methods employed are presented in Table 2.

3.4 Experimental details

The experiment was carried in *rabi*/summer 2009 and the details of the experiment are listed below.

3.4.1 Treatment details

The experiment consists of nine treatments having two growth promoters, a retardant and salicylic acid each in two concentrations and a control, the detail of which is indicated below. Plant growth regulators were applied at 20 DAS in cucumber cv. Belgaum Local. The salient features of plant growth regulators used in the experiment are given in Table 3.

Treatments

T_1 – Foliar application of GA_3 (50 ppm) at pre flowering

T_2 – Foliar application of GA_3 (100 ppm) at pre flowering

T_3 – Foliar application of NAA (50 ppm) at pre flowering

T_4 – Foliar application of NAA (100 ppm) at pre flowering

T_5 – Foliar application of CCC (250 ppm) at pre flowering

T_6 – Foliar application of CCC (500 ppm) at pre flowering

T_7 – Foliar application of salicyclic acid (500 ppm) at pre flowering

T_8 – Foliar application of salicyclic acid (1000 ppm) at pre flowering

T_9 – Control

Variety : Belgaum Local

3.4.2 Design and layout

The experiment was laid out in randomized block design with three replications. The plan of layout of the experiment is given Figure..

Plot size : 6.0 m x 4.5 m = 27.0 m^2

Spacing : Between rows = 2.0 m within rows = 0.75 m

Replications : Three

3.4.3 Description of the cultivar used in the experiment

It is a locally adopted cultivar, less spreading nature, the vines are smooth without spiny hairs, fruits are long with light green colour and have excellent quality.

3.5 Cultural practices

3.5.1 Land preparation

After the harvest of previous crop, the land was ploughed and harrowed twice followed by planking to bring the soil to a fine tilth. The farm yard manure was applied at the rate of 25 tons/ha prior to sowing.

3.5.2 Sowing/ dibbling

Two to three seeds were hand dibbled 2-3 cm deep. Later, gap filling and tinning were done to retain two plants per hill.

3.5.3 Fertilizer application

Fertilizers were applied following ring method of application at the rate of 125:75:75 kg NPK per hectare in the form of urea, single super phosphate and muriate of potash, respectively.

3.5.4 After care

The hills were watered daily with rosehead can until two true leaf stage of seedling and latter the plots were irrigated at critical stages of crop growth depending on the weather and soil conditions.

3.5.5 Plant protection and intercultural operations

Three hand weedings were done to overcome the weed problem. One intercultural operation was done by the use of hoe to keep the soil porous and free of weeds. The crop was sprayed with endosulphan @ 2.0 ml to avoid the attack of snakegourd semilooper.

Table 2. Physical and chemical properties of the soil in the experimental site

Sl. No.	Properties	Value obtained	Method employed
I	Physical properties		
1	Coarse sand (%)	6.28	International pipette method (Piper, 1966)
2	Fine sand (%)	14.27	International pipette method (Piper, 1966)
3	Silt (%)	27.52	International pipette method (Piper, 1966)
4	Clay (%)	51.99	International pipette method (Piper, 1966)
5	Bulk density (g/cc)	1.33	Core sample method
II	Chemical properties		
1	Soil pH (1:2.5 Soil: Water)	7.60	pH meter (Piper, 1966)
2	Electrical Conductivity (dS/m)	0.28	Conductivity bridge (Jackson, 1967)
3	Organic carbon (%)	0.52	Walkely and Black Wet oxidation method (Jackson, 1967)
4	Available Nitrogen (kg/ha)	221.0	Modified Kjeldahl method (Jackson, 1967)
5	Available Phosphorous (kg/ha)	32.4	Olsen’s method (Jackson, 1967)
6	Available Potassium (kg/ha)	318.7	Flame photometer (Jackson, 1967)

Table 3. Salient features of plant growth regulators used in the experiment

Sl. No	Common name/ Trade name	Chemical group	Chemical name	Physiological effects and uses
1	Gibberellins (GA_3)	Gibberelins	Gibberelic acid	Growth promoter, stimulates cell division, elongation, cell wall plasticity and permeability of cell membranes, RNA synthesis, induction of hydrolytic enzymes and increases plant height, increased mobilization and translocation of reserve food material.
2	1-Napthalene acetic acid	Auxin	1-Napthalene acetic acid	Growth promoter, stimulates cell division, cell elongation, elongation of shoot, photosynthesis, RNA synthesis, membrane permeability to water uptake, prevents abscission and leaves, flowers and fruits, enhances leaf area index, leaf chlorophyll content, and increased yield in fruit crops.
2	Cycocel/Lihocin	Chlormequat	2-chloroethyl-trimethyl-ammonium chloride	Anti-gibberelin, inhibits cell elongation, increase chlorophyll synthesis and root development, improves sturdiness, prevents lodging, increase yield, control vegetative growth giving more compact plants.
3	Salicylic acid	Phenolics	Salicylic acid	Regulates thermogenesis, defense response to pathogen attack, ethylene synthesis and fruit ripening, regulates plant responses to abiotic stresses, role in signal transduction pathway leading to systemic acquired resistance (SAR) against a broad spectrum of pathogens.

Plate.1. General view of cucumber experimental plot

Plate.2. Flowering stage of cucumber

LEGEND

Variety : Belagavi Local

Treatments:

T_1 – Foliar application of GA_3 (50 ppm) at pre flowering

T_2 – Foliar application of GA_3 (100 ppm) at pre flowering

T_3 – Foliar application of NAA (50 ppm) at pre flowering

T_4 – Foliar application of NAA (100 ppm) at pre flowering

T_5 – Foliar application of CCC (250 ppm) at pre flowering

T_6 – Foliar application of CCC (500 ppm) at pre flowering

T_7 – Foliar application of salicyclic acid (500 ppm) at pre flowering

T_8 – Foliar application of salicyclic acid (1000 ppm) at pre flowering

T_9 – Control

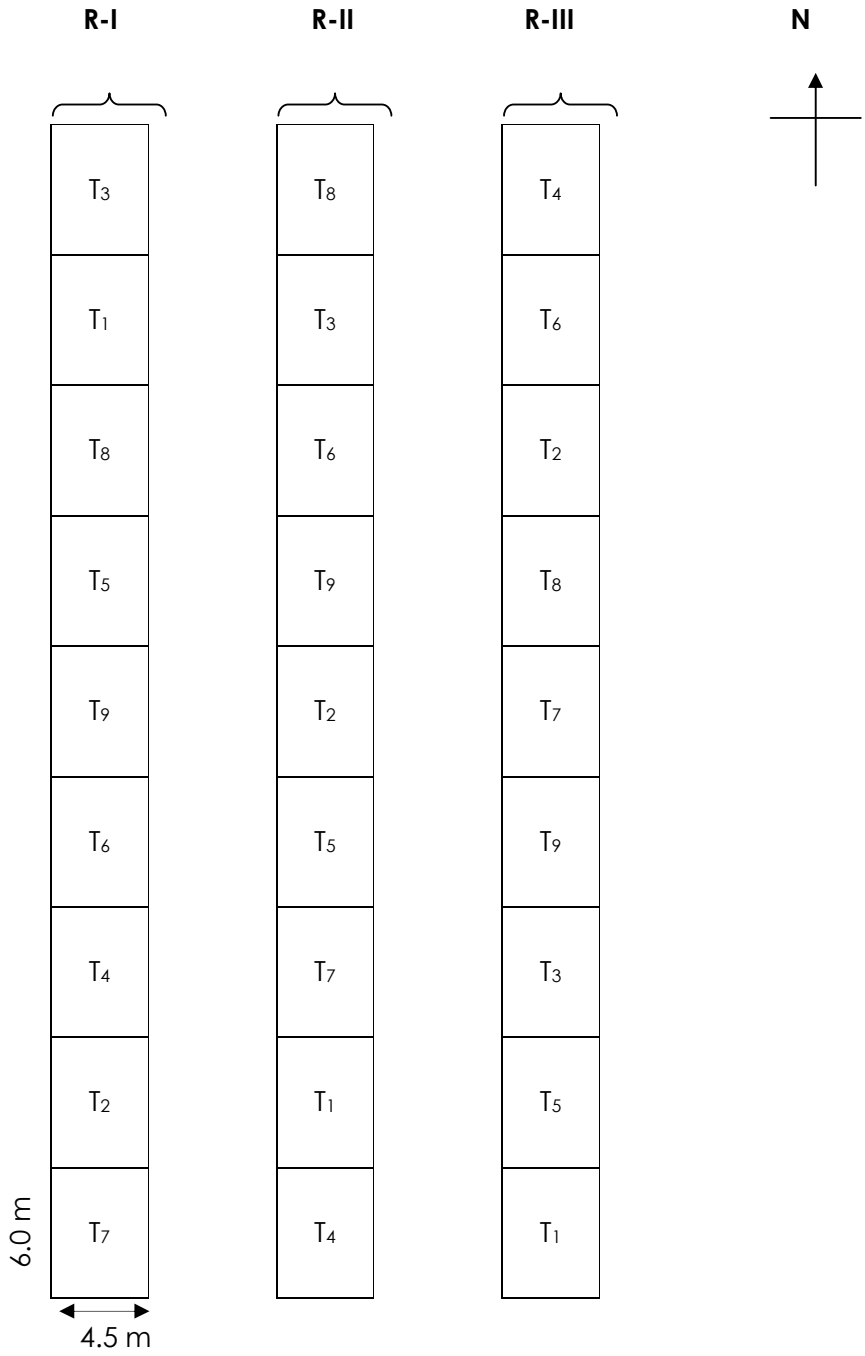

Fig. 1: Plan of layout of the experiment

3.5.6 Harvesting

Harvesting was done based on the marketable maturity indices (appearance). The harvesting was done by hand pickings at regular intervals from 55 DAS onwards. In all, five pickings were done.

3.6 Collection of experimental data

Three plants were tagged randomly in each treatment for recording the observations on the following parameters.

3.6.1 Morphological characters

3.6.1.1 Vine length

The vine length was measured from the cotyledonary node upto the growing tip and the means were worked from three plants which were selected at random in each treatment and expressed in centimeters.

3.6.1.2 Number of leaves per plant

Total number of green leaves was estimated by counting the individual leaf from top to bottom of the plant and the mean value of three plants selected at random in each treatment was expressed as number of leaves per plant.

3.6.1.3 Number of flowers per plant

The total number of flowers produced was counted from three plants selected at random in each treatment and the mean was worked out.

3.6.1.4 Fruit set (%)

Fruit set percent was calculated from the number of fruits to the number of female flowers produced per plant as follows:

$$\text{Fruit set (\%)} = \frac{\text{No. of fruits/ plant}}{\text{No. of female flowers / plant}} \times 100$$

3.6.2 Phenological characters

3.6.2.1 Days to first flower initiation

The number of days required by the plant from the date of sowing to the date of opening of first male and female flower was recorded.

3.6.2.2 Days to fruit set

The number of days required from the date of sowing to fruit set was measured.

3.6.2.3 Days to fruit maturity

The number of days required to harvest the first marketable fruit when they attain a tender and edible maturity from the date of sowing was recorded.

3.6.3 Growth and growth parameters

3.6.3.1 Total dry matter production per plant (g)

Three randomly selected plants from each treatment were uprooted and separated into leaf and stem, and then they were chopped into small pieces to enable drying. They were oven dried at 80 ^{o}C to a constant weight and then oven dry weight of stem along with leaf was recorded and expressed as gram per plant. The observations were recorded at 40, 55 and 70 DAS. The observations for fruit were recorded at 55 and 70 DAS.

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

Leaf area per plant was worked out by leaf disc method (Vivekanandan *et al*., 1972) on dry weight basis. Thirty leaf discs having a known diameter (1 cm^2) were collected randomly from fully expanded leaves throughout the plant canopy by avoiding midrib of the leaf. The discs thus collected and rest of the leaves was oven dried separately at 80^0C for 72 hours. The dry weight of leaf discs and rest of the leaves was recorded and leaf area was computed and expressed in cm^2 per plant

3.6.3.3 Leaf area index

The leaf area index (LAI) is the ratio of leaf area per plant to the land area occupied by the plant and was calculated by using the formula as suggested by Sestak *et al*. (1971).

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by a plant } (cm^2)}$$

3.6.3.4 Leaf area ratio ($cm^2\ g^{-1}$)

Leaf area ratio (LAR) is the ratio of leaf area to the total dry matter which was calculated by using the formula given below and expressed as $cm^2\ g^{-1}$

$$LAR\ (cm^2\ g^{-1})) = \frac{\text{Leaf area } (cm^2)}{\text{Total dry matter (g)}}$$

3.6.3.5 Absolute growth rate (g day^{-1})

Absolute growth rate (AGR) is the dry matter production per unit time (g day^{-1}), which was calculated by using formula given by Radford (1967).

$$AGR\ (g\ day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where

W_1 = Dry matter of the plant (g) at time t_1

W_2 = Dry matter of the plant (g) at time t_2

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

Relative growth rate (RGR) is the rate of increase in the dry weight per unit dry weight already accumulated and was calculated by using the formula of Blackman (1919).

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

Where,

W_1 = Dry matter of the plant (g) at time t_1

W_2 = Dry matter of the plant (g) at time t_2

3.6.3.7 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate (CGR) is the ratio of dry matter production per unit ground area per unit time, which was calculated by adopting the formula given by Watson (1956) and expressed as g m^{-2} day^{-1}.

$$CGR\ (g\ m^{-2}\ day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where,

W_1 = Dry matter of the plant (g) at time t_1

W_2 = Dry matter of the plant (g) at time t_2

A = Unit land area occupied by the plant (m^2)

3.6.3.8 Net assimilation rate (g m^{-2} day)

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time, which was calculated by the formula as adopted by Gregory (1926) and expressed as g m^{-2} day^{-1} .

$$NAR\ (g\ m^{-2}\ day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$$

Where,

A_1 and W_1 = leaf area (m^2) and dry weight of the plant (g) at time t_1

A_2 and W_2 = leaf area (m^2) and dry weight of the plant (g) at time t_2

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

The Specific leaf weight (SLW) indicates the average leaf thickness and was determined by the method suggested by Radford (1967) and expressed as g m^{-2}.

$$SLW\ (g\ m^{-2}) = \frac{\text{Leaf dry weight per plant (g)}}{\text{Leaf area per plant } (m^2)}$$

3.6.3.10 Leaf area duration (days)

Leaf area duration (LAD) is nothing but relation of potential green leaf area for a particular period and was worked out by the formula as suggested by Power *et al*. (1967).

$$LAD\ (days) = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where,

L_1 = LAI at time t_1

L_2 = LAI at time t_2

3.6.3.11 Biomass duration (g days)

The biomass duration (BMD) was calculated by using the following formula of Sestak *et al*. (1971).

$$BMD\ (g\ days) = \frac{TDM_1 + TDM_2}{2} \times (t_2 - t_1)$$

Where,

TDM_1 = total dry matter (g) at t_1

TDM_2 = total dry matter (g) at t_2

3.6.3.2 Fruit characters

3.6.3.2.1 Fruit length

Measurement of length was recorded form stalk end to floral end with the help of linear scale.

3.6.3.2.2 Fruit diameter

Fruit diameter was taken at three different places i.e., stalk end, middle end and floral end with the help of vernier calipers and average diameter was calculated.

3.6.3.2.3 Fresh fruit weight

Three random fruits collected from each treatment were collected and their fresh weights were recorded.

3.6.3.2.4 Dry fruit weight

Marketable fruits harvested for reading fruit weight were cut in four halves and were oven dried at 80^0C until constant weight was recorded and the dry weight was determined.

3.6.4 Biochemical parameters

3.6.4.1 Chlorophyll content

Shoaf and Lium (1976) devised an improved method of extraction of chlorophyll by using dimethyl sulfoxide (DMSO). Fully opened third leaf from the distal end of the vine was selected and brought from the field in ice box. The fresh leaves were gently washed in water to remove dirt and were blotted gently with tissue paper to remove water. The fresh leaf tissue was cut into small pieces avoiding the midrib and veins. 250 mg was weighed and incubated in 7.0 ml of DMSO at 65^oC for 30 minutes. At the end of the incubation period, supernatant was decanted discarding the leaf tissue. The volume was made upto 10 ml with DMSO. The absorbance of the extract was measured at 645 and 663 nm in spectrophotometer (Spectro UV-VIS dual beam UVS-2700, Labomed Inc., USA) using DMSO as blank.

Total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were calculated by using the formulae as given below and expressed in mg/g fresh weight.

$$\text{Chlorophyll 'a'} = (12.7 \times A663) - (2.69 \times A645) \times \frac{V}{1000 \times a \times w}$$

$$\text{Chlorophyll 'b'} = (22.9 \times A645) - (4.68 \times A663) \times \frac{V}{1000 \times a \times w}$$

Total Chlorophyll = Chlorophyll 'a' + Chlorophyll 'b'

Where,

A = Absorbance at specific wavelength (645 and 663nm)

V = Final volume of chlorophyll extract (10 ml)

W = Fresh weight of the sample (0.25 g)

A = Path length of light (1 cm)

3.6.4.2 Nitrate reductase activity (nmol NO_2 g fr.wt.$^{-1}$hr^{-1})

The nitrate reductase activity (NRA) *in vivo* was estimated following the method of Saradhambal *et al.* (1978). Leaves were cut into small round discs and their fresh weight was determined. These discs were floated in petri dish having 0.1 M KNO_3 under bright light for one hour for complete stomatal opening. The discs were transferred to 25 ml flasks containing 5.0 ml of solution having 0.1 M phosphate buffer (pH 7.5), 0.02 M KNO_3, propanol (5%) and two drops of chloromphenicol (0.5 mg/ml) and incubated at 30°C for 30 minutes in dark. The reaction was stopped by adding 0.1 ml of zinc acetate (1.0 M) and 1.0 ml of ethanol (70%). The contents were centrifuged at 3000 g for 10 minutes and the supernatant was collected, to which, 1.0 ml of sulphanilamide (1%) and 1.0 ml of NNEDA (0.02%) were added and incubated at room temperature for 20 minutes. The total volume in the test tubes was 9.0 ml. The absorbance of pink colour developed at the end of incubation was measured at 540 nm in spectrophotometer (Spectro UV-VIS dual beam UVS-2700, Labomed Inc., USA). The activity of nitrate reductase was determined from a standard curve of KNO_2 (Fig. 2) and expressed as nmol NO_2 formed per g fresh weight per hour.

3.6.4.3 Estimation of reducing sugars

Reducing sugar content in fresh leaves and freshly harvested samples at the time of harvest was estimated by Nelson method (1941).

Sample extraction

1. Leaves were cut in small pieces and 1.0 g of fresh plant sample was weighted and immersed in 10 ml of boiling ethanol and allowed to boil for 5-10 minutes on a steam bath.
2. The contents were cooled and the tissue was crushed thoroughly in a pestle and motar and filtered through cheese cloth.
3. The extraction procedure was repeated to ensure the complete removal of alcohol soluble substances.
4. Both the extracts were pooled and filtered through Whatman No. 41 filter paper. The volume of the extract was reduced by evaporating on hot water bath to represent 5-10 ml of the extract for every gram of tissue.
5. The extract was dried on hot water bath and this was used for estimating sugar content.

Reagents

Alkaline copper reagent

Solution A: 2.5 g of anhydrous sodium carbonate, 2.0 g of sodium bicarbonate, 2.5 g of potassium sodium tartarate and 20 g of anhydrous sodium sulphate were dissolved in 80 ml of water and the volume was made up to 100 ml.

Solution B: 15 g of copper sulphate was dissolved in a small volume of distilled water and one drop of sulphuric acid was added and the volume was made up to 100 ml

96.0 ml of solution A and 4.0 ml of solution B was mixed just before use.

Arsenmolybdate reagent: 2.5 g of ammonium molybdate was dissolved in 4.0 ml of water to which, 2.5 ml of sulphuric acid was added and mixed well then, 0.3 g of disodium hydrogen arsenate was added.

Procedure : 0.4 ml of sample aliquot was pipetted out in a test tube. Similarly, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of working standard solutions was pipetted out into different test tubes. The volume was made up to 1.0 ml with distilled water. Blank was maintained taking 1.0 ml of distilled water in a separate tube. 1.0 ml of alkaline copper reagent was added to each tube and placed in a boiling water bath for 20 minutes. The tubes were then cooled under running tap and 1.0 ml of arsenomolybdate reagent was added to each tube with regular stirring to get blue colour. Finally, the volume was made up to 10 ml with distilled water and the absorbance was measured at 510 nm in spectrophotometer.

Standard curve : 100 mg of glucose was dissolved in a little quantity of water and the volume was made up to 100 ml to get a stock solution. 10 ml of stock solution was diluted in 100 ml of distilled water to get a working standard of 100 mg/ml concentration. The other procedure followed was similar to that used for plant samples.

3.6.4.4 Estimation of total sugars by anthrone method

Anthrone reagent

0.2 mg of anthrone was dissolved in 100 ml of concentrated sulphuric acid. Fresh solution was prepared just before use.

Procedure

One ml of aliquot was taken in a test tube. The volume was made up to 2.5 ml with distilled water. All the test tubes were kept in ice bath, to which, 5.0 ml of anthrone reagent was added slowly. Contents were stirred gently with a glass rod and heated on boiling water bath exactly for 7.5 minutes and cooled immediately on ice bath. After cooling, the absorbance of the solutions were measured at 630 nm against the blank in a spectrophotometer and the sugar content was calculated from the standard curve.

Non reducing sugars

Non reducing sugars were estimated by subtracting the reducing sugar from the total sugar content of the sample.

3.6.5 Yield and yield components

3.6.5.1 Fruit yield

The total fruit yield was calculated both on t/ha and kg/plant. It was calculated by multiplying net plot yield per hectare by total yield per vine of three randomly labeled plants.

3.6.5.2 Number of fruits per plant

The number of fruits harvested at each picking from the tagged plants was recorded and the total number was calculated summing from all the harvests. The average per plant was then worked out.

3.6.6 Disease scoring

The disease incidence was recorded by randomly selecting five plants per plot and severity was recorded by using the following 0-5 scale.

Grade	Percent disease severity
0	No disease
1	1-10
2	11-25
3	26-50
4	51-75
5	>75

Percent disease index (PDI) was calculated by using following formula proposed by Wheeler (1969).

$$\text{Percent Disease Index (PDI)} = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of leaves observed X Maximum grade}} \times 100$$

3.7 Statistical analysis

Fisher's method of analysis of variance was applied for the analysis and interpretation of the experimental data as suggested by Panse and Sukhatme (1967). The level of significance used in 'F' and't' test was P = 0.5. Critical difference (C.D) values were calculated at 5 per cent level, wherever 'F' test was significant.

4. EXPERIMENTAL RESULTS

A field experiment was conducted during *rabi*/summer, 2009 to study the influence of different plant growth regulators *viz*., GA_3 (50 and 100 ppm), NAA (50 and 100 ppm), CCC (250 and 500 ppm) and salicyclic acid (500 and 1000 ppm) as foliar spray on growth, development, physiology, quality and yield in cucumber (*Cucumis sativus* L.) at Main Agriculture Research Station, University of Agricultural Sciences, Dharwad. The results obtained from the investigation are presented in this chapter.

4.1 Morphological characters

4.1.1 Vine length (cm)

The data on vine length presented in Table 4 indicated significant differences between the treatments at all the stages except 40 DAS. The vine length almost doubled between 40 and 55 DAS and increased progressively thereafter. At 55 DAS, the vine length was significantly higher (139.3) with the treatment of gibberellic acid (50 ppm) followed by gibberellic acid (100 ppm). The lowest vine length (126.0 cm) was recorded in cycocel (500 ppm) followed by CCC (250 ppm) which did not differ significantly among themselves. Among the treatments, gibberellic acid (50 ppm) recorded significantly higher vine length (220.4 cm) over all the treatments even at 70 DAS. Significantly lower vine length (197.4) was recorded in cycocel (500 ppm)as compared to control.

4.1.2 Number of leaves

In general, the number of leaves increased from 40 to 55 DAS, irrespective of the treatments, it differed significantly between the treatments at all the stages except 40 DAS (Table 5).

At 55 DAS, the number of leaves was maximum (63.0) in gibberellic acid (50 ppm) followed by gibberellic acid (100 ppm) and naphthalene acetic acid (50 ppm) and was significantly superior over control. Significantly lower number of leaves was recorded in control (57.0) compared to all other treatments. At 70 DAS, gibberellic acid (50 ppm) recorded significantly higher number of leaves (155.8) over all the treatments. Significantly lower number of leaves was recorded in control. However, the treatments gibberellic acid (100 ppm), naphthalene acetic acid (50 ppm and 100 ppm) was at par with each other.

4.1.3 Days to flower initiation

The data with respect to days to flower initiation indicated significant differences between the treatments (Table 6). Days to first male and female flower initiation was found to be influenced significantly due to different growth regulators. CCC (500 ppm) delayed the appearance of male flowers (30.1) whereas GA_3 (100 ppm) produced first male flowers as early as 25.7 DAS. However, less number of days (40.8) was required to initiate first female flower with CCC (500 ppm) followed by GA_3 (50 ppm). The maximum number of days for first female flower initiation (44.7) was recorded in control.

4.1.4 Number of female flowers per plant

The data on number of female flowers per plant presented in Table 7 indicated significant differences between the treatments. Among the treatments, the number of female flowers was found to be maximum (10.8) with CCC (500 ppm) followed by naphthalene acetic acid (100 ppm) which were on par with each other. The minimum number of female flowers (10.2) was recorded in salicyclic acid (1000 ppm) compared to all other treatments. However, the number of female flowers in control (10.0) was lower than salicyclic acid (1000 ppm).

4.1.5 Fruit set (%)

The data on percent fruit set presented in Table 7 indicated significant differences between the treatments. Among the treatments, the percent fruit set was maximum (82.9) with gibberellic acid (50 ppm) and it was significantly superior over rest of the treatments. The

Table 4. Influence of plant growth regulators on vine length (cm) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	79.8	139.3	220.4
T_2 - GA_3 (100 ppm)	77.9	133.3	208.3
T_3 - NAA (50 ppm)	72.7	132.2	208.9
T_4 - NAA (100 ppm)	76.7	132.5	210.8
T_5 - CCC (250 ppm)	71.6	127.3	200.4
T_6 - CCC (500 ppm)	69.6	126.0	197.4
T_7 - Salicylic acid (500 ppm)	74.4	131.3	207.2
T_8 - Salicylic acid (1000 ppm)	74.6	130.6	206.7
T_9 - Control	73.4	129.4	204.0
Mean	75.0	131.3	207.8
S.Em±	3.6	2.34	3.74
CD (5%)	NS	7.03	11.23

T_1

T_2

T_3

T_4

T_5

T_6

T_7

T_8

T_9

Plate.3 Influence of plant growth regulator on vine length in cucumber

Table 5. Influence of plant growth regulators on number of leaves at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	42.7	63.0	155.8
T_2 - GA_3 (100 ppm)	42.9	59.7	152.3
T_3 - NAA (50 ppm)	42.4	61.4	148.1
T_4 - NAA (100 ppm)	42.8	58.3	151.7
T_5 - CCC (250 ppm)	41.8	57.6	143.6
T_6 - CCC (500 ppm)	42.3	57.2	142.2
T_7 - Salicylic acid (500 ppm)	40.8	58.0	147.8
T_8 - Salicylic acid (1000 ppm)	41.6	60.6	145.5
T_9 - Control	40.7	57.0	141.3
Mean	42.0	59.4	147.7
S.Em±	1.23	2.14	1.52
CD (5%)	NS	6.42	4.58

minimum percent fruit set (71.0) was recorded control which was significantly lower than rest of the treatments.

4.2 Physiological parameters

4.2.1 Total dry matter production per plant (g/plant)

The total dry weight increased from 40 to 70 DAS in all the treatments (Table 8). The maximum total dry weight was noticed at 70 DAS with all the growth regulator treatments.

At 55 DAS, gibberellic acid (50 ppm) recorded significantly higher total dry weight (59.2) followed by cycocel (250 and 500 ppm) which did not differ significantly with each other. The rest of the treatments showed a significant increase in total dry weight and they were on par with each other. The minimum total dry weight was recorded in control which was significantly lower than all the treatments. A similar trend was noticed at 70 DAS with gibberellic acid (50 ppm) showing the highest total dry matter (63.8) followed by cycocel (500 and 250 ppm). The minimum total dry matter (56.3) was recorded in control which was significantly lower over all other treatments.

4.2.2 Leaf area (dm^2 $plant^{-1}$)

The data on leaf area presented in Table 9 indicated significant differences between the treatments. Among the treatments, at 55 DAS, the leaf area was significantly superior (57.37) in gibberellic acid (50 ppm) over all the treatments. The treatments, gibberellic acid (100 ppm), naphthalene acetic acid (50 ppm and 100 ppm), salicylic acid (500 ppm) were on par with each other. The lowest leaf area (43.72) was recorded in cycocel (500 ppm) which was significantly lower compared to all other treatments. At 70 DAS, gibberellic acid (50 ppm) continued to produce significantly higher leaf area (61.26) compared to all other treatments. Similarly, the treatments, gibberellic acid (100 ppm), naphthalene acetic acid (50 ppm and 100 ppm) and salicylic acids were found to be on par with each other; while cycocel recorded minimum (47.10) leaf area.

4.2.3 Leaf area index (LAI)

The data on LAI, presented in Table 10 indicated that it increased from 40 to 70 DAS. It followed a similar trend as that of leaf area.

4.2.4 Leaf area ratio (LAR, dm^2 g^{-1})

The LAR presented in Table 11 indicated significant differences due to influence of growth regulators. In general, the LAR decreased from 40 DAS to harvest.

At 40 DAS, the LAR values indicated significant differences among the treatments. The maximum LAR (1.63) was recorded in naphthalene acetic acid (50 ppm) followed by gibberellic acid (100 ppm) and they were on par with each other. The lowest LAR was recorded in cycocel (500 ppm) followed by cycocel (250 ppm) which was lower than control.

At 55 DAS, naphthalene acetic acid (50 ppm) recorded maximum LAR (0.98) followed by gibberellic acid (50 ppm) and naphthalene acetic acid (50 ppm) and they were on par with each other. The minimum LAR (0.74) was recorded in cycocel which was significantly lower over all other treatments.

4.2.5 Absolute growth rate (AGR, g day^{-1})

The AGR decreased with an advancement in the crop growth. The AGR indicated in Table 12 was maximum at 40 DAS and it reduced at 55 DAS.

At 40-55 DAS, AGR was maximum (2.56) in gibberellic acid (50 ppm), which was on par with cycocel (250 and 500 ppm) and significantly higher over, control. Minimum AGR was recorded in control which was significantly over all other treatments. However, rest of the treatments performed to be on par with each other.

Table 6. Influence of plant growth regulators on days to first male flower initiation, female flower initiation and fruit set in cucumber

Treatments	Days to first male flower	Days to first female flower	Days to fruit set
T_1 - GA_3 (50 ppm)	27.4	34.6	41.6
T_2 - GA_3 (100 ppm)	25.7	35.7	42.5
T_3 - NAA (50 ppm)	29.7	32.8	43.2
T_4 - NAA (100 ppm)	29.8	33.4	42.5
T_5 - CCC (250 ppm)	30.0	33.5	41.8
T_6 - CCC (500 ppm)	30.1	33.3	40.8
T_7 - Salicylic acid (500 ppm)	30.0	34.6	44.2
T_8 - Salicylic acid (1000 ppm)	30.1	34.8	44.6
T_9 - Control	30.3	36.3	44.7
Mean	29.2	34.4	42.9
S.Em±	0.05	0.34	0.64
CD (5%)	1.50	1.03	1.94

Table 7. Influence of plant growth regulators on number of female flowers per plant and percent fruit set at 55 DAS in cucumber

Treatments	Number of female flowers	Fruit set (%)
T_1 - GA_3 (50 ppm)	10.5	82.9
T_2 - GA_3 (100 ppm)	10.4	76.0
T_3 - NAA (50 ppm)	10.5	73.3
T_4 - NAA (100 ppm)	10.7	78.5
T_5 - CCC (250 ppm)	10.6	79.2
T_6 - CCC (500 ppm)	10.8	79.6
T_7 - Salicylic acid (500 ppm)	10.2	74.5
T_8 - Salicylic acid (1000 ppm)	10.2	73.5
T_9 - Control	10.0	71.0
Mean	10.4	76.5
S.Em±	0.12	1.59
CD (5%)	0.36	4.78

Table 8. Influence of plant growth regulators on total dry weight (g plant^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	20.8	59.2	63.8
T_2 - GA_3 (100 ppm)	19.3	57.4	61.7
T_3 - NAA (50 ppm)	18.4	56.4	60.8
T_4 - NAA (100 ppm)	20.4	57.1	61.4
T_5 - CCC (250 ppm)	20.8	58.9	63.4
T_6 - CCC (500 ppm)	20.6	59.0	63.5
T_7 - Salicylic acid (500 ppm)	18.1	56.5	60.1
T_8 - Salicylic acid (1000 ppm)	18.0	55.5	57.9
T_9 - Control	17.8	54.5	56.3
Mean	19.4	57.2	60.9
S.Em±	0.76	1.12	0.48
CD (5%)	2.28	3.35	1.45

Table 9. Influence of plant growth regulators on leaf area (dm^2 plant^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	31.53	57.37	61.26
T_2 - GA_3 (100 ppm)	30.98	53.32	55.13
T_3 - NAA (50 ppm)	29.60	54.84	57.51
T_4 - NAA (100 ppm)	29.38	55.74	58.26
T_5 - CCC (250 ppm)	28.21	45.64	48.56
T_6 - CCC (500 ppm)	27.56	43.72	47.10
T_7 - Salicylic acid (500 ppm)	28.83	52.18	55.68
T_8 - Salicylic acid (1000 ppm)	27.65	49.63	52.65
T_9 - Control	27.26	47.82	51.40
Mean	28.90	51.14	54.17
S.Em±	0.29	0.09	0.39
CD (5%)	0.87	0.06	1.18

Table 10. Influence of plant growth regulators on leaf area index (LAI) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	0.210	0.382	0.408
T_2 - GA_3 (100 ppm)	0.207	0.356	0.368
T_3 - NAA (50 ppm)	0.197	0.366	0.383
T_4 - NAA (100 ppm)	0.196	0.372	0.388
T_5 - CCC (250 ppm)	0.188	0.304	0.324
T_6 - CCC (500 ppm)	0.184	0.292	0.314
T_7 - Salicylic acid (500 ppm)	0.192	0.348	0.371
T_8 - Salicylic acid (1000 ppm)	0.184	0.331	0.351
T_9 - Control	0.182	0.319	0.343
Mean	0.193	0.341	0.361
S.Em±	0.001	0.002	0.002
CD (5%)	0.005	0.008	0.007

Table 11. Influence of plant growth regulators on leaf area ratio (LAR, $dm^2\ g^{-1}$) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	1.52	0.97	0.96
T_2 - GA_3 (100 ppm)	1.61	0.93	0.89
T_3 - NAA (50 ppm)	1.63	0.97	0.95
T_4 - NAA (100 ppm)	1.46	0.98	0.95
T_5 - CCC (250 ppm)	1.36	0.78	0.77
T_6 - CCC (500 ppm)	1.34	0.74	0.74
T_7 - Salicylic acid (500 ppm)	1.60	0.92	0.93
T_8 - Salicylic acid (1000 ppm)	1.54	0.90	0.91
T_9 - Control	1.53	0.88	0.91
Mean	1.51	0.89	0.88
S.Em±	0.06	0.02	0.01
CD (5%)	0.18	0.05	0.03

At 55-70 DAS, a similar trend was recorded with gibberellic acid (50 ppm) showing maximum AGR followed by cycocel (250 and 500 ppm) and they did not differ significantly with each other. While, it was minimum in control.

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

The data on relative growth rate indicated that there was a decrease in RGR as growth advanced (Table 13) and maximum RGR was noticed at 40-55 DAS. The treatment salicyclic acid (1000 ppm) recorded significantly higher RGR (0.3302) over naphthalene acetic acid (100 ppm). However, it was on par with rest of the treatments. At 55-70 DAS, naphthalene acetic acid (50 ppm) recorded significantly higher RGR over control. Salicyclic acid (500 and 1000 ppm) was on par with each other however, it was significantly higher over control.

4.2.7 Crop growth rate (CGR, g m^{-2} day^{-1})

The data on crop growth rate (CGR) revealed that there was decline in CGR with advancement in crop growth (Table 14). At 40-55 DAS, gibberellic acid (50 ppm) and salicyclic acid (500 ppm) recorded the maximum CGR compared to all other treatments. Significantly lowest CGR was recorded with naphthalene acetic acid (100 ppm) and control as compared to all other treatments. The rest of the treatments showed no significant differences and were on par with each other. At 55-70 DAS, among the treatments, gibberellic acid (50 ppm) recorded the highest CGR and the lowest (0.16) was recorded in salicyclic acid (500 ppm). However, control showed the lowest CGR.

4.2.8 Net assimilation rate (g m^{-2} day)

The data on net assimilation rate (Table 15) indicated significant differences due to different growth regulators. In general, NAR values decreased continuously from 40-55 DAS to 55-70 DAS.

At 40-55 DAS, maximum NRA was recorded with cycocel (500 ppm) compared all other treatments. However, it was found to be on par with cycocel (250 ppm); whereas, the lowest NRA was recorded in control. At 55-70 DAS, cycocel (250 ppm) recorded significantly higher NRA compared to all other treatments. Among the treatments, the lowest NRA was recorded in salicyclic acid (1000 ppm). However, the control recorded lower NAR compared to salicyclic acid (1000 ppm).

4.2.9 Specific leaf weight (SLW, g m^{-2})

The data on SLW indicated that the values increased with the age of the crop (Table 16).

At 40 DAS, gibberellic acid (50 ppm) showed significantly higher value (9.03) compared to all other treatments followed by cycocel (500 ppm) and naphthalene acetic acid (100 ppm) which were on par with each other. The minimum value was recorded in control which was significantly lower compared to all other treatments. At 55 DAS, cycocel (250 ppm) recorded higher SLW (19.62) followed by gibberellic acid (50 ppm) which did not differ significantly with each other; while control recorded the lowest (12.20) value followed by salicyclic acid (500 ppm). However, no significant differences were observed between the treatments, naphthalene acetic acid (50 ppm), salicyclic acid (500 ppm) and salicyclic acid (1000 ppm). At 70 DAS, cycocel (500 ppm) recorded the highest SLW followed by cycocel (250 ppm) which did not differ significantly with each other. However, control continued to show the minimum SLW as compared to all other treatments.

4.2.10 Leaf area duration (LAD, days)

The data on leaf area duration presented in Table 17 indicated significant differences among the treatments. The leaf area duration values increased from 40-55 DAS to 55-70 DAS.

Table 12. Influence of plant growth regulators on absolute growth rate (AGR, g day^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	2.56	0.31
T_2 - GA_3 (100 ppm)	2.54	0.29
T_3 - NAA (50 ppm)	2.53	0.29
T_4 - NAA (100 ppm)	2.45	0.28
T_5 - CCC (250 ppm)	2.54	0.30
T_6 - CCC (500 ppm)	2.56	0.30
T_7 - Salicylic acid (500 ppm)	2.56	0.24
T_8 - Salicylic acid (1000 ppm)	2.50	0.16
T_9 - Control	2.44	0.12
Mean	2.52	0.25
S.Em±	0.10	0.08
CD (5%)	NS	0.26

Table 13. Influence of plant growth regulators on relative growth rate (RGR, g g^{-1} day^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	0.03032	0.00218
T_2 - GA_3 (100 ppm)	0.03152	0.00209
T_3 - NAA (50 ppm)	0.03256	0.00219
T_4 - NAA (100 ppm)	0.02992	0.00207
T_5 - CCC (250 ppm)	0.03017	0.00217
T_6 - CCC (500 ppm)	0.03040	0.00216
T_7 - Salicylic acid (500 ppm)	0.03302	0.00180
T_8 - Salicylic acid (1000 ppm)	0.03261	0.00121
T_9 - Control	0.03233	0.00094
Mean	0.03143	0.00187
S.Em±	0.0014	0.00060
CD (5%)	NS	0.0019

Table 14. Influence of plant growth regulators on crop growth rate (CGR, g m^{-2} day^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	1.71	0.21
T_2 - GA_3 (100 ppm)	1.69	0.19
T_3 - NAA (50 ppm)	1.69	0.20
T_4 - NAA (100 ppm)	1.63	0.19
T_5 - CCC (250 ppm)	1.69	0.20
T_6 - CCC (500 ppm)	1.70	0.20
T_7 - Salicylic acid (500 ppm)	1.71	0.16
T_8 - Salicylic acid (1000 ppm)	1.67	0.10
T_9 - Control	1.63	0.08
Mean	1.68	0.17
S.Em±	0.06	0.06
CD (5%)	NS	0.17

Table 15. Influence of plant growth regulators on net assimilation rate (NAR, g m^{-2} day^{-1}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	2.575	0.226
T_2 - GA_3 (100 ppm)	2.677	0.229
T_3 - NAA (50 ppm)	2.687	0.226
T_4 - NAA (100 ppm)	2.580	0.214
T_5 - CCC (250 ppm)	3.050	0.276
T_6 - CCC (500 ppm)	3.172	0.290
T_7 - Salicylic acid (500 ppm)	2.830	0.193
T_8 - Salicylic acid (1000 ppm)	2.891	0.132
T_9 - Control	2.899	0.105
Mean	2.818	0.210
S.Em±	0.119	0.078
CD (5%)	0.356	0.234

Table 16. Influence of plant growth regulators on specific leaf weight (SLW, g m^{-2}) at different growth stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	9.03	18.51	21.69
T_2 - GA_3 (100 ppm)	7.41	15.61	20.93
T_3 - NAA (50 ppm)	7.34	12.98	20.24
T_4 - NAA (100 ppm)	8.34	15.98	17.11
T_5 - CCC (250 ppm)	7.56	19.62	23.84
T_6 - CCC (500 ppm)	8.30	17.13	24.89
T_7 - Salicylic acid (500 ppm)	6.37	12.57	19.13
T_8 - Salicylic acid (1000 ppm)	5.70	12.93	17.69
T_9 - Control	5.29	12.20	14.80
Mean	7.26	15.30	20.04
S.Em±	0.59	0.81	1.33
CD (5%)	1.78	2.42	4.00

The LAD at 40-55 DAS was maximum (4.45) in gibberellic acid (50 ppm) followed by naphthalene acetic acid (100 ppm) while, the lowest LAD was recorded in cycocel (500 ppm and 250 ppm) as compared all other treatments.

At 55-70 DAS, a similar trend was observed with gibberellic acid (50 ppm) showing significantly higher LAD (5.93) followed by naphthalene acetic acid (100 ppm). Cycocel (500 ppm and 250 ppm) continued to record lower LAD compared to all other treatments.

4.2.10 Biomass duration (BMD, g days)

The data on BMD presented in Table 18 indicated that it increased with the age of the crop. The BMD differed significantly due to growth regulator treatments at all the growth stages.

At 40-55 DAS, gibberellic acid (50 ppm) showed significantly higher (599.58) BMD over all other treatments followed by cycocel (250 ppm) and cycocel (500 ppm) which did not differ significantly with each other. Control showed significantly lower BMD (542.30) followed by salicyclic acid (500 and 1000 ppm). At 55-70, a similar trend was recorded with gibberellic acid (50 ppm) showing higher BMD followed by cycocel (250 and 500 ppm). Control continued to record the lowest BMD which was significantly lower compared to all other treatments.

4.3 Fruit characters

4.3.1 Fruit length (cm)

The fruit length, (Table 19) was influenced significantly by different growth regulators. The maximum fruit length (21.4) was recorded with gibberellic acid (50 ppm) followed by gibberellic acid (100 ppm) and they did not differ significantly with each other. Minimum fruit length (16.6) was recorded in control which was significantly lower over all other treatments.

4.3.2 Fruit diameter (cm)

The fruit diameter at harvest (Table 19) indicated significant differences between the treatments. The maximum fruit diameter (4.6) was recorded in gibberellic acid (50 ppm) followed by cycocel (500 ppm) which were on par with each other. Among the treatments, salicyclic acid (1000 ppm) recorded the minimum (3.4) fruit diameter. However, the least fruit diameter was recorded in control as compared to all other treatments.

4.3.4 Fresh fruit weight (g/plant)

The data presented in Table 20 indicated a fresh fruit weight differed significantly due to growth regulators. Among the treatments, cycocel (500 ppm) recorded maximum (108.2) fresh fruit weight followed by cycocel (250 ppm) and gibberellic acid (50 ppm) and they were on par with each other. The minimum (82.3) fresh fruit weight was recorded in control which was significantly lower compared to all other treatments.

4.3.5 Dry fruit weight (g/plant)

The data on dry fruit weight (Table 20) indicated a similar trend as that of fresh weight. The maximum dry fruit weight (22.9) was recorded with cycocel (500 ppm) followed by gibberellic acid (50 ppm) and cycocel (250 ppm). The minimum dry fruit weight (13.6) was recorded in control which was significantly lower over all other treatments.

4.4 Biochemical parameters

4.4.1 Chlorophyll ‘a’ content (mg g fr.wt.$^{-1}$) in leaves

The data on chlorophyll ‘a’ content indicated significant differences between the treatments at all the stages and it declined from 55 to 70 DAS in all the treatments (Table 21).

Table 17. Influence of plant growth regulators on leaf area duration (LAD, days) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	4.45	5.93
T_2 - GA_3 (100 ppm)	4.22	5.42
T_3 - NAA (50 ppm)	4.22	5.62
T_4 - NAA (100 ppm)	4.26	5.70
T_5 - CCC (250 ppm)	3.69	4.71
T_6 - CCC (500 ppm)	3.56	4.54
T_7 - Salicylic acid (500 ppm)	4.05	5.39
T_8 - Salicylic acid (1000 ppm)	3.86	5.11
T_9 - Control	3.75	4.96
Mean	4.01	5.26
S.Em±	0.02	0.02
CD (5%)	0.05	0.06

Table 18. Influence of plant growth regulators on biomass duration (BMD, g days) at different growth stages in cucumber

Treatments	Days after sowing (DAS)	
	40-55	55-70
T_1 - GA_3 (50 ppm)	599.58	922.25
T_2 - GA_3 (100 ppm)	575.28	892.75
T_3 - NAA (50 ppm)	560.65	878.50
T_4 - NAA (100 ppm)	581.85	888.75
T_5 - CCC (250 ppm)	597.75	917.50
T_6 - CCC (500 ppm)	596.95	918.75
T_7 - Salicylic acid (500 ppm)	559.18	874.50
T_8 - Salicylic acid (1000 ppm)	551.50	850.50
T_9 - Control	542.30	830.53
Mean	573.89	886.00
S.Em±	8.38	8.46
CD (5%)	25.13	20.37

Table 19. Influence of plant growth regulators on fruit length (cm) and fruit diameter (cm) at harvest in cucumber

Treatments	Fruit length (cm)	Fruit diameter (cm)
T_1 - GA_3 (50 ppm)	21.4	4.6
T_2 - GA_3 (100 ppm)	20.2	4.0
T_3 - NAA (50 ppm)	18.6	3.8
T_4 - NAA (100 ppm)	19.5	4.0
T_5 - CCC (250 ppm)	17.4	4.1
T_6 - CCC (500 ppm)	17.1	4.4
T_7 - Salicylic acid (500 ppm)	17.2	3.7
T_8 - Salicylic acid (1000 ppm)	17.3	3.4
T_9 - Control	16.6	3.0
Mean	18.4	3.9
S.Em±	0.32	0.34
CD (5%)	1.05	1.02

T_1

T_2

T_3

T_4

T_5

T_6

T_7

T_8

T_9

Plate.4. Influence of plant growth regulator on fruit size at harvest in cucumber

Table 20. Influence of plant growth regulators on fresh fruit weight (g) and dry fruit weight (g) at harvest in cucumber

Treatments	Fresh fruit weight (g)	Dry fruit weight (g)
T_1 - GA_3 (50 ppm)	105.2	22.7
T_2 - GA_3 (100 ppm)	95.3	19.1
T_3 - NAA (50 ppm)	98.4	20.0
T_4 - NAA (100 ppm)	101.1	21.0
T_5 - CCC (250 ppm)	106.6	22.4
T_6 - CCC (500 ppm)	108.2	22.9
T_7 - Salicylic acid (500 ppm)	88.8	16.4
T_8 - Salicylic acid (1000 ppm)	87.7	15.6
T_9 - Control	82.3	13.6
Mean	97.1	19.3
S.Em±	1.1	1.4
CD (5%)	3.3	4.1

Table 21. Influence of plant growth regulators on chlorophyll 'a' (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	0.774	1.347	0.955
T_2 - GA_3 (100 ppm)	0.772	1.282	0.937
T_3 - NAA (50 ppm)	0.771	1.278	0.857
T_4 - NAA (100 ppm)	0.772	1.315	0.875
T_5 - CCC (250 ppm)	0.771	1.239	0.850
T_6 - CCC (500 ppm)	0.772	1.242	0.838
T_7 - Salicylic acid (500 ppm)	0.769	1.181	0.822
T_8 - Salicylic acid (1000 ppm)	0.767	1.199	0.839
T_9 - Control	0.769	1.160	0.816
Mean	0.771	1.255	0.866
S.Em±	0.002	0.022	0.026
CD (5%)	NS	0.068	0.078

At 55 DAS, gibberellic acid (50 ppm) recorded significantly higher chlorophyll content (1.347). Among the treatments, the lowest chlorophyll 'a' content (1.185) was recorded in salicyclic acid (500 ppm). However, the chlorophyll 'a' content in control was significantly lower (1.160) compared to salicyclic acid (500 ppm).

Among the treatments, at 70 DAS, gibberellic acid (50 ppm) recorded significantly higher chlorophyll 'a' content (0.958) and it was significantly superior over rest of the treatments. Significantly lower chlorophyll 'a' content (0.822) was recorded in salicyclic acid (500 ppm) over all other treatments, except control. However, the treatments salicyclic acid (500 ppm) and control did not differ significantly with each other.

4.4.2 Chlorophyll 'b' content (mg g fr.wt.$^{-1}$) in leaves

The chlorophyll 'b' content was found to be maximum at 55 DAS and was reduced at 70 DAS in all the treatments (Table 22). Treatments differed significantly with each other only at 70 DAS. At 55 DAS, gibberellic acid (50 ppm) recorded significantly higher chlorophyll 'b' content (0.297) and was found to be significantly superior to cycocel (250 ppm), cycocel (500 ppm) salicyclic acid (1000 ppm) and salicyclic acid (500 ppm). The treatments gibberellic acid (100 ppm) and naphthalene acetic acid (50 ppm) were found to be on par with each other. Among the treatments, minimum chlorophyll 'b' content (0.254) was recorded in salicyclic acid (500 ppm). However, the chlorophyll 'b' content in control was significantly lower over salicyclic acid (500 ppm).

At 70 DAS, gibberellic acid (50 ppm) was found to be superior over all other treatments. Significantly lower chlorophyll 'b' (0.188) was recorded in salicyclic acid (500 ppm) over all treatments, except control.

4.4.3 Total chlorophyll content (mg g^{-1} fr.wt.) in leaves

Total chlorophyll content differed significantly between the treatments, and it was found to decrease with an advancement in crop growth (Table 23). At 55 DAS, among the treatments, gibberellic acid (50 ppm) (1.644) recorded significantly higher values over all other treatments, except naphthalene acetic acid (100 ppm). Similarly, gibberellic acid (100 ppm) naphthalene acetic acid (50 ppm), cycocel (250 ppm) and cycocel (500 ppm) did not differ significantly among themselves. Lowest total chlorophyll content was recorded in control.

At 70 DAS, the total chlorophyll content was maximum in gibberellic acid (50 ppm) (1.196) followed by gibberellic acid (100 ppm) (1.158) which differed significantly with rest of the treatments. Though control had significantly lower total chlorophyll content (1.027), it was on par with salicyclic acid (500 ppm) and salicyclic acid (1000 ppm).

4.4.4 Chlorophyll 'a' content (mg g fr.wt.$^{-1}$) in fruits

The chlorophyll 'a' content in fruits at harvest presented in Table 24 indicated significant differences between the treatments. Among the treatments, gibberellic acid (50 ppm) recorded significantly higher chlorophyll 'a' content (0.433). The minimum chlorophyll was found in control which was significantly lower over other treatments.

4.4.5 Chlorophyll 'b' content (mg g fr.wt.$^{-1}$) in fruits

The chlorophyll 'b' content in fruits at harvest presented in Table 24 indicated significant differences between the treatments. Among the treatments, gibberellic acid (50 ppm) recorded significantly higher chlorophyll 'b' content (0.121). The minimum chlorophyll was found in control which was significantly lower over other treatments and was significantly superior over gibberellic acid (100 ppm) and salicyclic acid (500 ppm) and rest of the treatments were on par with each other. However, the minimum chlorophyll 'b' content (0.113) was recorded in control which was significantly lower compared to all other treatments.

Table 22. Influence of plant growth regulators on chlorophyll 'b' (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	0.193	0.297	0.238
T_2 - GA_3 (100 ppm)	0.165	0.285	0.221
T_3 - NAA (50 ppm)	0.169	0.281	0.228
T_4 - NAA (100 ppm)	0.182	0.294	0.221
T_5 - CCC (250 ppm)	0.186	0.276	0.230
T_6 - CCC (500 ppm)	0.190	0.260	0.206
T_7 - Salicylic acid (500 ppm)	0.165	0.274	0.204
T_8 - Salicylic acid (1000 ppm)	0.155	0.254	0.118
T_9 - Control	0.154	0.240	0.184
Mean	0.172	0.275	0.212
S.Em±	0.002	0.002	0.003
CD (5%)	NS	0.008	0.009

Table 23. Influence of plant growth regulators on total chlorophyll content (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	0.967	1.664	1.196
T_2 - GA_3 (100 ppm)	0.937	1.567	1.158
T_3 - NAA (50 ppm)	0.940	1.559	1.085
T_4 - NAA (100 ppm)	0.954	1.609	1.096
T_5 - CCC (250 ppm)	0.957	1.515	1.062
T_6 - CCC (500 ppm)	0.962	1.502	1.044
T_7 - Salicylic acid (500 ppm)	0.934	1.459	1.026
T_8 - Salicylic acid (1000 ppm)	0.932	1.453	1.027
T_9 - Control	0.923	1.400	1.000
Mean	0.945	1.522	1.078
S.Em±	0.003	0.020	0.020
CD (5%)	NS	0.060	0.070

4.4.6 Total chlorophyll content (mg g^{-1} fr.wt.) in fruits

The data on total chlorophyll content in fruits at harvest indicated significant differences between the treatments (Table 24). Among the treatments, maximum chlorophyll content (0.553) was recorded in gibberellic acid (50 ppm) which was significantly higher than the rest of the treatments; while, minimum total chlorophyll content was recorded in control which was significantly lower compared to all other treatments.

4.4.7 Nitrate reductase activity (nmoles NO_2 g fr. $wt.^{-1}$ h^{-1})

The data on nitrate reductase activity presented in Table 25 indicated significant differences between the treatments both at 55 and 70 DAS. It was observed in general that the nitrate reductase activity was maximum at 55 DAS and reduced further at 70 DAS in all the treatments.

At 55 DAS, gibberellic acid (50 ppm) recorded significantly higher nitrate reductase activity (125.3 nmoles) over all other treatments. While, significantly lower nitrate reductase activity was recorded in control (114.6 nmoles). However, the treatments gibberellic acid (100 ppm) and cycocel (250 ppm) were at par with each other.

At 70 DAS, gibberellic acid (50 ppm) continued to maintain significantly higher nitrate reductase activity and control had significantly lower nitrate reductase activity compared to all other treatments. However, all the treatments except naphthalene acetic acid (100 ppm) did not differ significantly among themselves.

4.4.8 Reducing sugars (mg. g fr.$wt.^{-1}$) in leaves

The data on reducing sugars indicated significant differences between the treatments at all the stages except at 40 DAS. The reducing sugars decreased between 40 and 70 DAS.

At 55 DAS, the reducing sugar was maximum (2.20) in gibberellic acid (50 ppm) and was found to be significantly superior over rest of all the treatments. The minimum reducing sugar was recorded in salicyclic acid (500 ppm) among the treatments which was on par with control. Among the treatments, gibberellic acid (50 ppm) at 75 DAS recorded significantly higher reducing sugar (1.16) over all other treatments. And rest of the treatments was on par with each other. Significantly lower reducing sugar (1.07) was recorded in control.

4.4.9 Non reducing sugars (mg. g fr.$wt.^{-1}$) in leaves

The data on non reducing sugars indicated significant differences between the treatments. The non reducing sugar increased from 40 to 70 DAS (Table 27).

At 55 DAS, the maximum non reducing sugar (6.20) was recorded in gibberellic acid (50 ppm) which was significantly higher over rest of the treatments. While, significant differences were found in all the treatments. The minimum non reducing sugar, (5.94) was recorded in salicyclic acid (1000 ppm). However, control was found significantly lower than all the treatments.

At 75 DAS, maximum non reducing sugar (6.38) was recorded in gibberellic acid (50 ppm) which did not differ significantly with rest of the treatments. The minimum reducing sugar (6.25) was recorded in control which was significantly lower compared to all other treatments, except salicyclic acid (1000 ppm).

4.4.10 Total sugars (mg. g fr.$wt.^{-1}$) in leaves

The data on total sugars indicated significant differences between the treatments except at 40 DAS. At 55 DAS, gibberellic acid (50 ppm) recorded significantly higher total sugars (8.40) over all other treatments. While, significantly a lower total sugar was recorded in control (7.80) which was significantly lower over all other treatments.

Table 24. Influence of plant growth regulators on chlorophyll 'a', chlorophyll 'b' and total chlorophyll content (mg g fresh wt^{-1}) in fruits at harvest in cucumber

Treatments	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll
T_1 - GA_3 (50 ppm)	0.433	0.121	0.553
T_2 - GA_3 (100 ppm)	0.431	0.118	0.549
T_3 - NAA (50 ppm)	0.430	0.117	0.547
T_4 - NAA (100 ppm)	0.431	0.117	0.548
T_5 - CCC (250 ppm)	0.427	0.114	0.542
T_6 - CCC (500 ppm)	0.428	0.116	0.544
T_7 - Salicylic acid (500 ppm)	0.439	0.118	0.548
T_8 - Salicylic acid (1000 ppm)	0.430	0117	0.548
T_9 - Control	0.425	0.113	0.538
Mean	0.429	0.118	0.118
S.Em±	0.001	0.001	0.001
CD (5%)	0.003	0.005	0.005

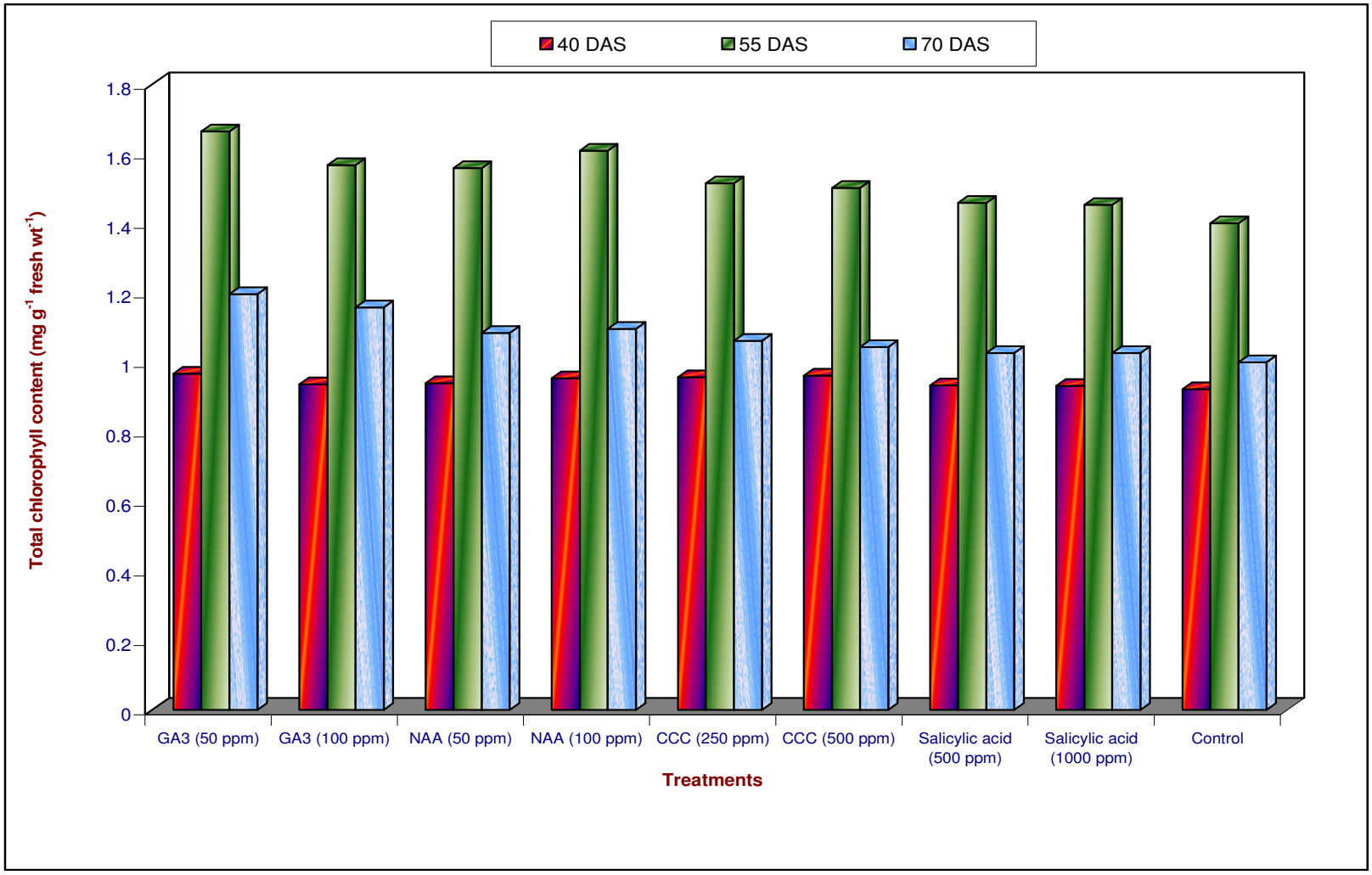

Fig. 2: Influence of plant growth regulators on total chlorophyll content in cucumber

Table 25. Influence of plant growth regulators on nitrate reductase activity (nmol NO_2 g. fr.wt.$^{-1}$ $hr^{-1}hr^{-1}$) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	91.80	125.28	79.41
T_2 - GA_3 (100 ppm)	91.62	121.76	77.53
T_3 - NAA (50 ppm)	88.44	115.40	77.39
T_4 - NAA (100 ppm)	88.36	117.02	76.37
T_5 - CCC (250 ppm)	92.94	112.90	78.88
T_6 - CCC (500 ppm)	95.98	119.16	79.02
T_7 - Salicylic acid (500 ppm)	88.03	118.26	77.24
T_8 - Salicylic acid (1000 ppm)	87.51	116.69	77.38
T_9 - Control	84.85	114.62	75.41
Mean	89.94	119.01	77.62
S.Em±	0.58	1.41	0.82
CD (5%)	NS	4.25	2.46

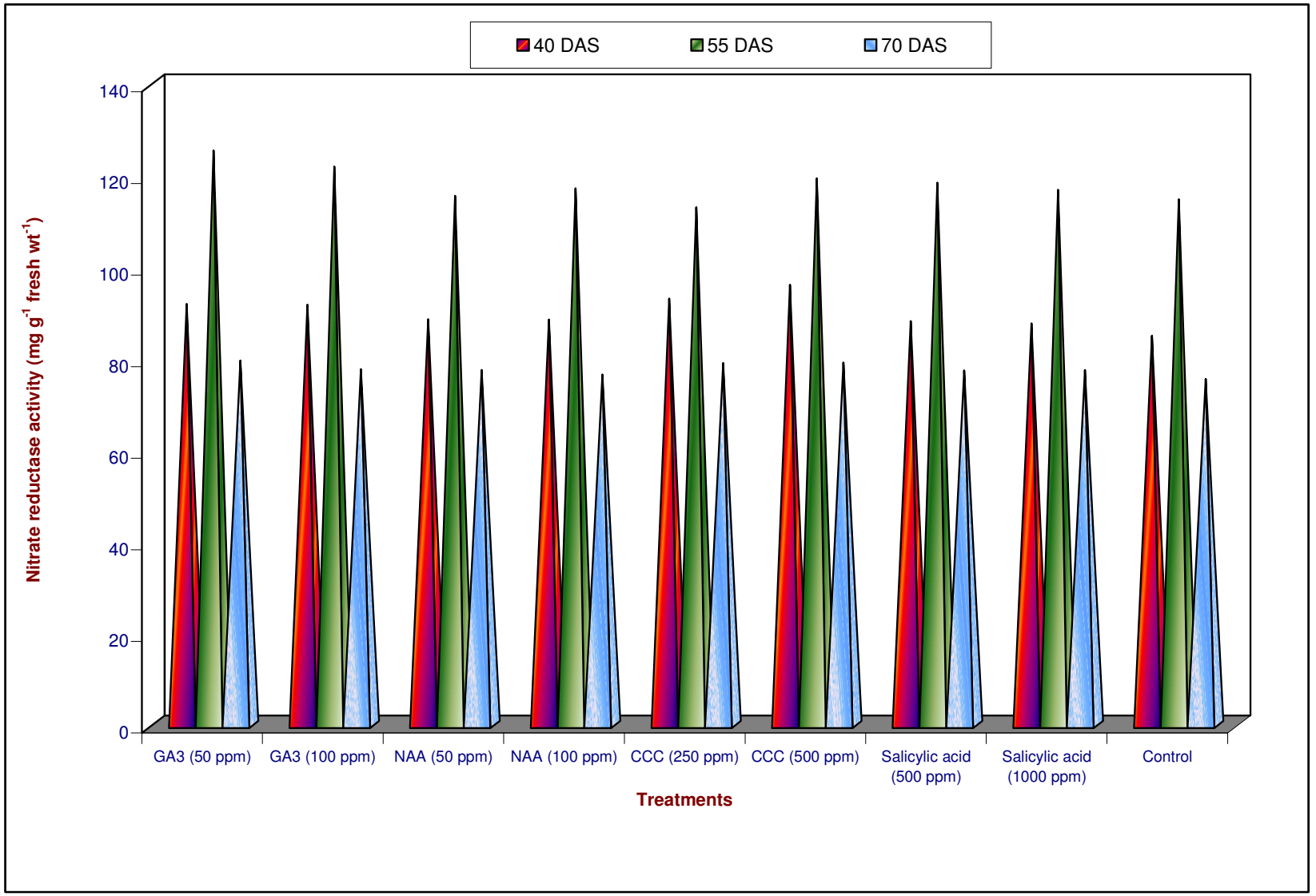

Fig. 3: Influence of plant growth regulators on nitrate reductase activity in cucumber

Table 26. Influence of plant growth regulators on reducing sugars (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	1.85	2.20	1.16
T_2 - GA_3 (100 ppm)	1.78	2.01	1.10
T_3 - NAA (50 ppm)	1.85	2.13	1.13
T_4 - NAA (100 ppm)	1.84	2.00	1.12
T_5 - CCC (250 ppm)	1.83	2.14	1.14
T_6 - CCC (500 ppm)	1.86	2.15	1.15
T_7 - Salicylic acid (500 ppm)	1.82	1.90	1.08
T_8 - Salicylic acid (1000 ppm)	1.80	1.96	1.10
T_9 - Control	1.76	1.90	1.07
Mean	1.82	2.04	1.11
S.Em±	0.03	0.04	0.01
CD (5%)	NS	0.12	0.05

Table 27. Influence of plant growth regulators on non reducing sugars (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	3.33	6.20	6.38
T_2 - GA_3 (100 ppm)	3.31	6.08	6.35
T_3 - NAA (50 ppm)	3.30	6.00	6.3
T_4 - NAA (100 ppm)	3.30	6.03	6.34
T_5 - CCC (250 ppm)	3.26	6.10	6.36
T_6 - CCC (500 ppm)	3.38	6.15	6.37
T_7 - Salicylic acid (500 ppm)	3.31	6.06	6.31
T_8 - Salicylic acid (1000 ppm)	3.29	5.94	6.26
T_9 - Control	3.28	5.90	6.26
Mean	3.31	6.04	6.32
S.Em±	0.034	0.02	0.02
CD (5%)	NS	0.06	0.06

Table 28. Influence of plant growth regulators on total sugars (mg g fresh wt^{-1}) in leaves at different stages in cucumber

Treatments	Days after sowing (DAS)		
	40	55	70
T_1 - GA_3 (50 ppm)	5.18	8.40	7.54
T_2 - GA_3 (100 ppm)	5.09	8.09	7.45
T_3 - NAA (50 ppm)	5.13	8.13	7.44
T_4 - NAA (100 ppm)	5.14	8.03	7.46
T_5 - CCC (250 ppm)	5.19	8.24	7.50
T_6 - CCC (500 ppm)	5.24	8.30	7.52
T_7 - Salicylic acid (500 ppm)	5.13	7.96	7.39
T_8 - Salicylic acid (1000 ppm)	5.10	7.90	7.36
T_9 - Control	5.04	7.80	7.32
Mean	5.13	8.19	7.44
S.Em±	0.05	0.05	0.19
CD (5%)	NS	0.71	0.57

Table 29. Influence of plant growth regulators on reducing sugars, non reducing sugars and total sugars (mg g fresh wt^{-1}) in fruits at harvest in cucumber

Treatments	Reducing sugars	Non reducing sugars	Total sugars
T_1 - GA_3 (50 ppm)	0.63	3.64	4.27
T_2 - GA_3 (100 ppm)	0.59	3.55	4.14
T_3 - NAA (50 ppm)	0.57	3.41	3.98
T_4 - NAA (100 ppm)	0.61	3.51	4.12
T_5 - CCC (250 ppm)	0.61	3.57	4.18
T_6 - CCC (500 ppm)	0.63	3.59	4.22
T_7 - Salicylic acid (500 ppm)	0.58	3.56	4.14
T_8 - Salicylic acid (1000 ppm)	0.53	3.53	4.06
T_9 - Control	0.51	3.29	3.80
Mean	0.58	3.52	4.10
S.Em±	0.02	0.18	0.18
CD (5%)	0.04	0.53	0.53

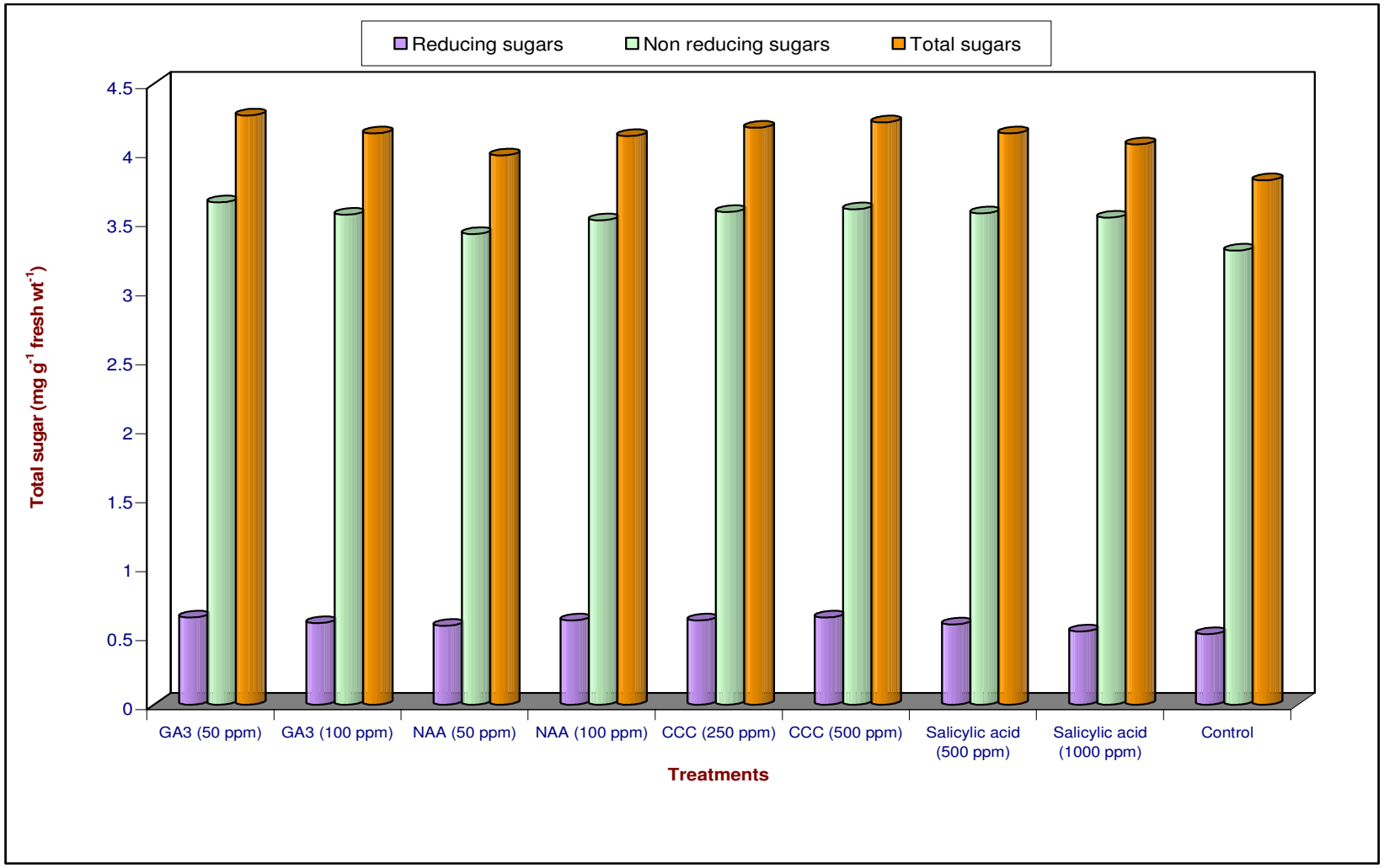

Fig. 4: Influence of plant growth regulators on total sugars in cucumber

Table 30. Influence of plant growth regulators on yield and yield components at harvest in cucumber

Treatments	Number of fruits/plant	Fruit yield (Kg/plant)	Fruit yield (t/ha)
T_1 - GA_3 (50 ppm)	8.7	1.71	11.41
T_2 - GA_3 (100 ppm)	7.9	1.66	11.07
T_3 - NAA (50 ppm)	7.7	1.65	11.01
T_4 - NAA (100 ppm)	8.4	1.68	11.21
T_5 - CCC (250 ppm)	8.4	1.69	11.27
T_6 - CCC (500 ppm)	8.6	1.70	11.34
T_7 - Salicylic acid (500 ppm)	7.6	1.62	10.81
T_8 - Salicylic acid (1000 ppm)	7.5	1.61	10.74
T_9 - Control	7.1	1.42	9.47
Mean	7.9	1.64	10.92
S.Em±	0.13	0.01	0.17
CD (5%)	0.34	0.02	0.52

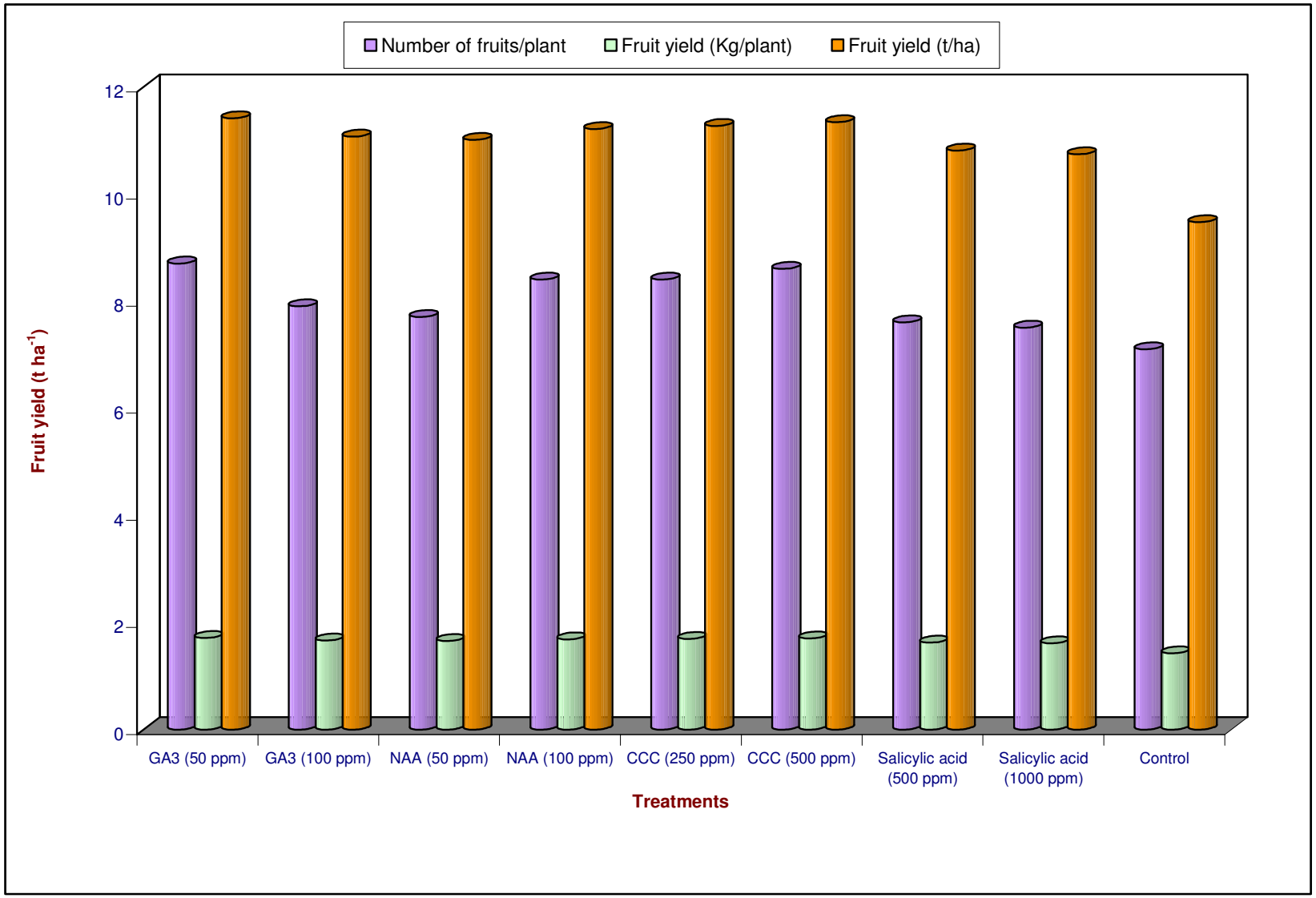

Fig. 5: Influence of plant growth regulators on fruit yield in cucumber

At 70 DAS, gibberellic acid (50 ppm) recorded significantly higher (7.54) total sugars over all other treatments and control had significantly lower (7.32) total sugars compared to all other treatments.

4.4.11 Reducing sugars (mg. g fr.wt.$^{-1}$) in fruits

The data on reducing sugars in fruits at harvest indicated significant differences between the treatments. Among the treatments, the maximum reducing sugars (0.63) was recorded in gibberellic acid (50 ppm) and cycocel (500 ppm). The minimum reducing sugars (0.51) was recorded in control which was on par with salicyclic acid (1000 ppm).

4.4.12 Non Reducing sugars (mg. g fr.wt.$^{-1}$) in fruits

The data on non reducing sugars in fruits at harvest presented in Table 29 indicated significant differences between the treatments. Among the treatments, the maximum non reducing sugar (3.64) was recorded in gibberellic acid (50 ppm) which was significantly higher over all other treatments. While, the minimum non reducing sugar (3.41) was recorded in naphthalene acetic acid (50 ppm). However, the control was found to be significantly lower (3.29) over all other treatments.

4.4.13 Total sugars (mg. g fr.wt.$^{-1}$) in fruits

The total sugars in fruits at harvest indicated significant differences between the treatments (Table 29). The maximum total sugar (4.27) was recorded in gibberellic acid (50 ppm) over all other treatments. While, significantly lower total sugar was recorded in control (3.80) which was significantly lower over all other treatments.

4.5 Yield and yield components

4.5.1 Number of fruits per plant

The data on the number of fruits per plant indicated significant differences between the treatments (Table 30). The maximum number of fruits per plant (8.7) was recorded in gibberellic acid (50 ppm) and it was significantly superior over gibberellic acid (100 ppm), naphthalene acetic acid (50 ppm), salicyclic acid (500 ppm), salicyclic acid (1000 ppm) and control and the treatments naphthalene acetic acid (100 ppm) and cycocel (250 ppm) were on par with each other. The minimum number of fruits was recorded in control (7.1) which was significantly lower over all other treatments.

4.5.2 Fruit yield (kg/plant)

The data on the fruit yield was taken on the basis of kg/ plant (Table 30) and it indicated significant differences between the treatments. The fruit yield was found to be maximum (1.71 kg/plant) in gibberellic acid (50 ppm) which was on par with cycocel (500 ppm) and the other treatments did not differ significantly with each other. While, the minimum fruit yield (1.42) was recorded in control which was significantly lower compared to all other treatments.

4.5.3 Fruit yield (t/ha)

The data on fruit yield was also recorded on t/ha which indicated significant differences between the treatments (Table 30). The fruit yield was found to be maximum (11.41) in gibberellic acid (50 ppm) which was on par with cycocel (500 ppm) and the other treatments did not differ significantly with each other. While the minimum fruit yield (9.47) was recorded in control which was significantly lower over all other treatments.

4.6 Disease scoring

The data on disease scoring (Table 31) indicated that maximum percent disease severity of powdery mildew was recorded in control (24.6) which was significantly higher

compared to all treatments. The minimum disease severity was recorded in salicyclic acid (500 ppm) followed by salicyclic acid (1000 ppm) which were on par with each other.

Table 31. Influence of plant growth regulators on disease incidence at 55 DAS in cucumber (Powdery mildew)

Treatments	Per cent Disease Index (PDI)
T_1 - GA_3 (50 ppm)	22.5
T_2 - GA_3 (100 ppm)	22.2
T_3 - NAA (50 ppm)	21.3
T_4 - NAA (100 ppm)	22.5
T_5 - CCC (250 ppm)	21.2
T_6 - CCC (500 ppm)	21.3
T_7 - Salicylic acid (500 ppm)	20.3
T_8 - Salicylic acid (1000 ppm)	20.8
T_9 - Control	24.6
Mean	21.9
S.Em±	0.6
CD (5%)	1.7

5. DISCUSSION

Cucumber (*Cucumis sativus* L.) is one of the most important cultivated popular cucurbitaceous vegetable crops grown in India. This family is characterized by various forms of sex expression varying from strict gynoecious to hermaphrodite as well as monoecious, which is most common one (Kubicki, 1972). Though many varieties and hybrids have been developed in cucumber, the yield potential is low and hence, there is need to improve the yield potential to meet the demand. Although high yielding hybrid-crop varieties do extremely well under normal management practices, very seldom their full genetic potential is realised. Facing with such constraints, application of plant growth regulators (PGRs), for higher yields, is gaining momentum. PGR-induced higher yields are due to altered photosynthate distributive patterns within the plant and as such do not require any additional agricultural inputs. Hence, there is an urgent need to improve the productivity through manipulation of source-sink relationship by using plant growth regulators.

Plant growth regulators modify plant organs differentially and influence the source-sink relation and improve yield potential. Such substances are therefore potentially useful in agriculture because suitable concentrations applied at appropriate time will increase the yield either by altering dry matter distribution in the plant or by regulating growth (Watson, 1958). Considering the importance of consuming nutritive rich vegetables and fruits in the daily diet, it was thought to investigate the influence of plant growth regulators for enhancing productivity potential in cucumber. The results obtained from the investigation are discussed in this chapter.

5.1 Morphological characters

Application of plant growth regulators had significant influence on morphological characters like vine length, number of leaves, number of female flowers and fruit set percent in cucumber. Remarkable increase in vine length was observed with GA_3 (50 ppm) and the minimum was recorded in cycocel (500 ppm). There are numerous reports showing that gibberellins promote growth of intact plants. The promotion of growth either in terms of increase in the vine length or the leaf area and leaf number has been thought to be by increasing plasticity of the cell wall followed by hydrolysis of starch to sugars which lowers the water potential of cell, resulting in the entry of water into the cell causing elongation. These osmotic driven responses under the influence of gibberellins might have attributed to increase in photosynthetic activity, accelerated translocation and efficiency of utilizing photosynthetic products, thus resulting in increased cell elongation and rapid cell division in the growing portion (Sargent, 1965). These results are in conformity with the findings of Singh and Choudhary (1989) in watermelon and summer squash. The stimulative effect of GA_3 at 25 ppm on vine length was also noticed in watermelon by Arora *et al*. (1985). A similar increase in vine length in cucumber was also observed by Vadigeri *et al*.(2001).

The number of leaves per plant differed significantly among the treatments and increased due to the application of plant growth regulators. Among the treatments, GA_3 @ 50 ppm (155.8) followed by GA_3 @ 100 ppm (152.3) and NAA @ 100 ppm (151.7) recorded maximum number of leaves. Increase in the number of leaves might be due to its additional availability of gibberellins in seed which might have increased the level of amylase in the aleurone tissues of seed for better conversion of complex starch into simple sugars for providing energy to growth (Ram Arsey., 2001). The decrease in both the vine length as well as number of leaves with CCC could be due to the nature of onium compounds to which CCC belongs and it is known to interfere in the GA biosynthetic pathway before the cyclisation of gernayl pyrophosphate.

CCC @ 500 ppm produced maximum number of female flowers (10.8) per plant and the minimum number of female flowers (10.0) was produced in control. It has been observed in the present study that the application of plant growth regulators has profound influence on assimilatory surface area and its associated characters. The maximum increase in leaf area was observed with GA_3 @ 50 ppm followed by NAA @ 100 ppm. This could be attributed to the stimulatory effect of the plant growth regulators on cell division and cell enlargement,

which lead to enhanced leaf area and hence influenced the growth and development. The increase in both leaf number and leaf area could be due to the effect of GA's on cell division and cell enlargement.

The percent fruit set differed significantly among the treatments and increased due the application of PGRs. Among these, the maximum percentage of fruit set per plant was obtained with GA_3 (50 ppm), while the minimum percentage of fruit set per plant was obtained in control.

5.2 Physiological parameters

The amount of total dry matter produced is an indication of the overall efficiency of utilization of resources and better interception of light. The partitioning of total dry matter in leaf, vines and reproductive parts varied significantly due to the growth regulator treatments.

The total dry matter accumulation increased from 40 to 70 DAS. GA_3 (50 ppm) recorded significantly higher total dry matter compared to control. The dry weight of reproductive parts also increased continuously throughout the growing period due to growth regulator treatments. The enhanced dry weight of reproductive parts is due to increased fruits per plant and also efficient translocation of assimilates from leaf and vines to reproductive parts.

5.3 Growth parameters

Crop yield is mainly dependent on the interplay of various physiological and biochemical functions of the plant in addition to the impact of growing conditions. The cause and effect relationship is difficult to understand mainly because of complexity in understanding the interplay of several processes and functions which ultimately lead to changes not only in growth, development and physiology, but also on the yield, which is the most complex character. It is well established that the infrastructure of the plant is decided by the growth parameters like leaf area, LAI, AGR, CGR, RGR, TDM, NAR and BMD. The growth analysis technique has been adopted as one of the standard approaches in the absence of sophisticated instruments to analyze the structure of yield in several crops.

It has been observed in the present study that the application of plant growth regulators had profound influence on assimilatory surface area and its associated characters. Leaf area fairly gives a good idea of photosynthetic capacity of the plant. Significant differences were also noticed with regard to leaf area among the treatments at all the stages. The leaf area increased from 40 to 70 DAS (Figure 9). The leaf area was decreased by application of growth retardants (CCC) as compared to GA_3 @ 50 ppm, whereas, PGRs maintained a higher leaf area at later stage of the crop growth.

Crop growth rate (CGR) is influenced by LAI, photosynthetic rate and leaf angle and is an index of amount of light interception. The CGR increased and reached its peak at 40-55 DAS and declined gradually thereafter towards maturity. Such a decline could be attributed to decrease in rate of dry matter production due to senescence and shading. The rapid increase in CGR observed under the effect of growth regulators over that of control might be due to higher production of dry matter due to increased photosynthetic activities coupled with increased cell multiplication.

Net assimilation rate (NAR) denotes increase in plant dry weight $unit^{-1}$ leaf area $unit^{-1}$ time. The NAR was maximum at 40-55 DAS and then decreased. NAR tended to increase with growth regulator treatments at fruiting stage which might be related to the increased sink demand. Also, more photosynthetic products were available to growing parts like flowers and fruits showing higher assimilation.

Biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sinks. Significantly higher BMD values were recorded in growth regulator treatments at all the stages of cucumber. This suggests that growth regulators resulted in increased TDM, LAI, LAD, AGR, CGR, NAR and SLW and finally resulted in increased BMD.

5.4 Biochemical parameters

The plant performance is attributed to the genetic factors, differences in the biochemical parameters are of great importance, as the plant metabolism depends on various biochemical constituents. It is known that thousands of reactions are undergoing in the plants simultaneously which ultimately decide the growth and development and the final yield. Plant growth regulators have been shown to influence these processes in one way or the other.

Chlorophylls have been rightly designated as “pigments of life” because of their central role in living systems responsible for harvesting sunlight and transforming its energy into biochemical energy essential for life on earth. In the present study, it was observed that plant growth regulators had profound influence on chlorophyll content. Significant differences were observed among the treatments with respect to chlorophyll ‘a’, ‘b’ and total chlorophyll contents both in leaf and fruit. The maximum chlorophyll ‘a’, ‘b’ and total chlorophyll contents were recorded with GA_3 (50 ppm) followed GA_3 at 100 ppm. The increase in the photosynthetic rate due to GA_3 was attributed to enhanced ultra-structural morphogenesis of plastids and increase in the Rubisco activity (Arteca and Donga, 1981).

The foliar application of GA_3 (50 ppm and 100 ppm) resulted in higher chlorophyll content. It has been suggested that the application of PGRs increased the availability of assimilates, which in turn might have caused maximum chlorophyll synthesis.

Plant growth regulators exhibited significant differences in Nitrate reductase activity (NRA) in leaves (Table 25). However, there was no significant difference between the treatments. The enzyme nitrate reductase (NR) catalyses the reduction of nitrate to nitrite (Beevers and Hageman, 1969) and is a rate limiting step in nitrogen metabolism. The present study revealed that the nitrate reductase activity was maximum at 55 DAS in leaf and increased significantly with the foliar application of GA_3 @ 50 ppm followed by CCC @ 500 ppm and 250 ppm as compared to control. Similarly, Lawlor and Fock (1975) suggested that CCC induced increase in photosynthesis is associated with an increase in the enzyme activity and nucleic acid metabolism. Similarly, Goswami and Srivastava (1989) also reported increase in nitrate activity due to the application of growth regulators.

Significant increase in reducing sugars was noticed with the application of GA_3. The reducing sugar content was maximum with GA_3 (50 ppm) followed by foliar application of CCC @ 500 ppm. Non reducing sugars was also increased with GA_3 (50 ppm) followed by foliar spray of CCC@ 500 ppm. The increase in the sugar content with advancement in age could be due to stimulation of α-amylase and other hydrolytic enzymes promoting the hydrolysis of storage reserves due to senescence. It is expected that with advancement in the crop growth, metabolic activity of the plants is increased to support the reproductive growth.

5.5 Yield and yield components

Yield is a complex character which involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of nutrients and water from the soil and the hormonal balance, in addition to several environmental factors to which plant is exposed during the growing period (Schaffer and Andersen, 1994). Improvement in yield, according to Humphries (1979) could happen in two ways i.e. by adopting the existing varieties to grow better in their environment or by altering the relative proportion of different plant parts so as to increase the yield of economically important parts. The growth regulators are capable of redistribution of dry matter in plants, thereby bring about an improvement in yield potential (Chaplot *et al.,* 1992). In addition, crop yield depends not only on the accumulation of photosynthates during the crop growth and development, but also on its partitioning in the desired storage organs. These in turn are influenced by the efficiency of metabolic processes within the plant. The growth regulators are capable of redistribution of dry matter in the plant, thereby bring about improvement in yield (Chetti, 1991 and Chandrababu *et al.,* 1995).

The fruit yield in cucumber depends on the accumulation of photo assimilates and partitioning in different plant parts. The yield in cucumber was found to be strongly influenced

by the application of different growth regulators, thus indicating the importance of these compounds in increasing the yield potential through their effect on various morpho-physiological and biochemical traits. Among them, the maximum yield was noticed with gibberellins. This could be attributed to the stimulatory effect of GA_3 on cell division and cell elongation. From the findings it is evident that there is increase in vine length, leaf number and leaf area thereby providing more sources for the better development of sinks. The fruit yield in cucumber is expressed in terms of fresh weight since, the edible portion of fruit pulp contains large amount of water and sugars. Gibberellic acid is a natural plant hormone which is synthesized in plants and it is well known that the application of GA_3 improves fruit yield and quality in many cucurbitaceous and other horticultural crops.

The number of fruits per plant was significantly higher with the foliar application of GA_3 @50 ppm followed by CCC @ 500 ppm. The fruit yield was also significantly higher with the foliar application of GA_3 @ 50 ppm followed by CCC @ 500 ppm and the lowest fruit yield was recorded in control. The higher fruit yield was obtained as a result of more hermaphrodite flowers per plant and better vegetative growth (Sidhu *et al*., 1982). Similar results were also reported by Dostigir *et al.,* (2006) in bittergourd. An increase in fruit yield in treated plants may further be attributed to the reason that plants remain physiologically more active to build up sufficient source for the developing flowers and fruits, ultimately leading to higher yield. The increase in fruit yield by GA_3 is probably due to an increase in carbohydrate metabolism and accumulation of carbohydrates (Mishra et al., 1972) as well as auxin directed mobilization of metabolites from source to sink (Weaver, 1973 and Vasantkumar and Sreekumar, 1981).

5.6 Economics

The present study also indicated that, among the various growth regulators the cost: benefit ratio was higher with NAA @ 100 ppm (1:2.68) followed by GA_3 @ 50 ppm (1:2.65) and NAA @ 50 ppm (1:2.63) (Table 32).

Future line of work

- There is a need to evaluate commercially available plant growth regulators for optimizing yield potential in cucumber.
- There is a need to study for comparison of bio- efficiency of plant growth regulators in different cultivars of cucumber.
- There is a need to identify suitable bio-regulator for improving flower production and fruit set per cent in cucumber.
- It is also important to study the interaction between externally applied growth regulators and endogenous hormones.

Table 32. Influence of plant growth regulators on economics in cucumber

Treatments	Yield (t ha^{-1})	Gross returns (Rs/ha)	Cost of treatments (Rs/ha)	Total cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1 - Gibberellic acid (50 ppm)	11.41	114100	1250	31250	82850	1 : 2.65
T_2 - Gibberellic acid (100 ppm)	11.07	110700	500	32500	78200	1 : 2 .41
T_3 - Napthalene acetic acid (50 ppm)	11.01	110100	250	30250	79850	1 : 2.63
T_4 - Napthalene acetic acid (100 ppm)	11.21	112100	500	30500	81600	1 : 2.68
T_5 - Cycocel (250 ppm)	11.27	112700	1450	31450	81250	1 : 2.58
T_6 - Cycocel (500 ppm)	11.34	113400	2900	32900	80500	1 : 2.45
T_7 - Salicylic acid (500 ppm)	10.81	108100	100	30100	78000	1 : 2.59
T_8 - Salicylic acid (1000 ppm)	10.74	107400	200	30200	77200	1: 2.56
T_9 – Control	9.47	94700	-	30000	-	-

Basic cost of cultivation : Rs. 30,000 /ha
Cost of Gibberellic acid : Rs. 50/g
Cost of Napthalene acetic acid : Rs. 250 /25 g
Cost of Cycocel : Rs. 290 / 25 g
Cost of Salicylic acid : Rs. 400 / Kg
Market price of cucmber : Rs. 10 / Kg

6. SUMMARY AND CONCLUSIONS

A field experiment was conducted during *rabi* / summer, 2009 at Main Agriculture Research Station, University of Agricultural Sciences, Dharwad to study the growth, development, physiology, yield and quality of cucumber (*Cucumis sativus* L.) as influenced by plant growth regulators (PGRs). The experiment was laid out in randomized block design replicated thrice with different foliar sprays of plant growth regulators *viz*., GA_3 (50 and 100 ppm), NAA (50 and 100 ppm), CCC (250 and 500 ppm) and salicyclic acid (500 and 1000 ppm). The results obtained from the investigation are summarized in this chapter.

- Among the treatments, GA_3 (50 ppm) showed significantly higher vine length at all the stages. The lowest vine length was noticed in CCC (500 ppm) compared to control.
- The number of leaves per plant differed significantly with maximum in GA_3 (50 and 100 ppm) at 55 and 70 DAS
- The number of female flowers per plant differed significantly with a maximum in CCC (500 ppm) followed by CCC (250 ppm).
- The percent fruit set differed significantly among treatments with a maximum in GA_3 (50 ppm) followed by CCC (500 ppm) and the lowest fruit set was recorded in control.
- PGRs showed significant effect on days to flower initiation and GA_3 (50 ppm) hastened the days for first male flower initiation followed by GA_3 (100 ppm). CCC (500 ppm) hastened the days for first female flower initiation followed by NAA (100 ppm) as compared to control.
- The dry weight of reproductive parts and total dry matter increased upto harvest and all the treatments showed higher values as compared to control GA_3 (50 ppm) showed significantly higher total dry matter followed by CCC (500 ppm) and CCC (250 ppm) as compared to control.
- Leaf area and leaf area index increased from 40 to 70 DAS. The leaf area and leaf area index was found to be significantly higher in GA_3 (50 ppm) at all the stages. The lowest leaf area was recorded in cycocel (500 ppm) compared to all other treatments.
- Specific leaf weight increased significantly due to PGR treatments and was more at 70 DAS. The SLW was more in CCC (500 ppm) followed by CCC (250 ppm).

- Important growth parameters *viz*., AGR, CGR, RGR, NAR, LAD and BMD were significantly influenced by the application of PGRs and were found to be lower in control. GA_3 (50 ppm) was found to be superior to other treatments in most of the parameters followed by CCC (500 ppm).
- The foliar spray of PGRs enhanced the chlorophyll content (a, b and total) in leaf and the effect was more with GA_3 (50 ppm). Chlorophyll content (a, b and total) increased upto 55 DAS and declined thereafter in all the treatments.
- There was a decline in nitrate reductase activity (NRA) in leaf with an advancement in crop age. The NRA was found to be higher in GA_3 (50 ppm) followed by CCC (500 ppm) and CCC (250 ppm) at 70 DAS.
- Significantly higher reducing, non reducing and total sugars were recorded in GA_3 (50 ppm) followed by CCC (500 ppm) and the lowest was recorded in control.
- The reducing, non reducing and total sugars in fruits were maximum in GA_3 (50 ppm) followed by CCC (500 ppm) and the lowest was recorded in control.
- The fruit characters *viz.,* fruit length and fruit diameter was maximum in GA_3 (50 ppm) and the lowest was recorded in control.
- The results on number of fruits per plant indicated that it was maximum with GA_3 (50 ppm) followed by CCC (500 ppm) and the lowest number of fruits per plant was recorded in control.
- The treatments differed significantly with respect to fruit yield (kg/plant & t/ha) with GA3 (50 ppm) having maximum values compared to other treatments.
- From the point of economics, NAA (100 ppm) was found to be more profitable in terms of net returns followed by GA_3 (50 ppm)) and NAA (500 ppm) compared to other treatments.

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INFLUENCE OF PLANT GROWTH REGULATORS ON GROWTH, PHYSIOLOGY AND YIELD IN CUCUMBER (*Cucumis sativus* L.)

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ABSTRACT

A field study was conducted during *rabi* 2009-10 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the influence of plant growth regulators on growth, physiology and yield in cucumber (*Cucumis sativus* L.). The experiment was laid out in randomized block design with nine treatments and three replications. The treatments consistsed of two growth promoters *viz*., gibberrellic acid (50 and 100 ppm), naphthalene acetic acid (50 and 100 ppm), a retardant CCC (250 and 500 ppm), salicylic acid (500 and 1000 ppm) and a control.

Results revealed that the application of plant growth regulators significantly increased morpho-physiological traits *viz.,* vine length, number of leaves and number of female flowers per plant as compared to control. Growth parameters *viz.,* leaf area, LAI, AGR, RGR, CGR, NAR, LAD, SLW and BMD were also influenced by the application of plant growth regulators. The biochemical parameters *viz.,* chlorophyll content (ch a, ch b and total chlorophyll), Nitrate Reductase Activity (NRA) and sugar content (reducing, non-reducing and total sugars) increased significantly due to the application of plant growth regulators. Application of growth regulators increased the dry weight of leaf, reproductive parts and total dry weight significantly and the total dry weight showed a positive correlation with yield.

All the yield contributing characters v*iz.,*fruit lenth, fruit diameter, percent fruit set, number of fruits per plant and fruit yield increased significantly due to plant growth regulators. The fruit yield was significantly higher with the foliar application of GA_3 (50 ppm) followed by CCC (500 ppm) compared to control. The economics of using different growth regulators revealed that the B : C ratio was maximum with NAA (100 ppm) followed by GA_3 (50 ppm).