EFFECT OF PLANT GROWTH REGULATORS ON GROWTH AND PRODUCTIVITY IN YARD LONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt.)

By

RESMI, R.

THESIS

Submitted in partial fulfilment of the requirement for the award of the Degree of

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DECLARATION

I hereby declare that the thesis entitled **"Effect of plant growth regulators on growth and productivity in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any other university or society.

Thrissur,
22-09-2001.

RESMI, R.
(Ad. No. 99-12-23)

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA.

Dr. T. R. GOPALAKRISHNAN
Associate Professor & Head
Department of Olericulture

Phone (Off): +91-487- 371 918
(Res) : +91-487- 371 917
Fax (Off) : +91-487- 370 019
Gram (Off): 'Agrivarsity'
Telex (Off) : 0887-268-KAU-IN
E – Mail (Off): kauhqr@ren.nic.in
(Res) : teeyarji@vsnl.com

26 September 2001

CERTIFICATE

This is to certify that the thesis entitled " **Effect of plant growth regulators on growth and productivity in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)** submitted in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE IN HORTICULTURE** to Kerala Agricultural University, Thrissur is a record of bonafide research work done independently by **Miss. RESMI, R.**, during the period of her study under my guidance and supervision, and that the thesis has not been previously submitted for the award of any degree, diploma, fellowship, associate ship or any other similar titles.

Dr. T. R. GOPALAKRISHNAN
(Major Advisor)

CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. **RESMI, R.**, a candidate for the degree of **Master of Science in Horticulture**, agree that the thesis entitled **"Effect of plant growth regulators on growth and productivity in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** may be submitted by Miss. Resmi. R., in partial fulfilment of the requirement for the degree.

26.9.01

Dr. T.R. Gopalakrishnan,
(Chairman, Advisory Committee)
Associate Professor and Head,
Department of Olericulture,
College of Horticulture,
Vellanikkara, Thrissur- 680 656.

Dr. S. Rajan,
(Member, Advisory Committee)
Officer on Special Duty,
KAU seed Authority,
Directorate of Research,
Kerala Agricultural University,
Vellanikara, Thrissur- 680 656

Dr. P. G. Sadankumar,
(Member, Advisory Committee)
Associate Professor, AICVIP,
Department of Olericulture,
College of Horticulture, Vellanikkara,
Thrissur. 680 656

Dr. K. Nandini,
(Member, Advisory Committee)
Associate Professor (Plant Physiology),
Department of Plant Breeding & Genetics,
College of Horticulture,
Vellanikara, Thrissur- 680 656

26.9.01

EXTERNAL EXAMINER

(Dr. P. K. Gopalakrishnan
Assoc. Dean (Retd.)
Peringathara House,
Vellanikkara. Thrissur

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"Truth alone will endure, all the rest will be swept away before the tide of time"

------- **Gandhiji**

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"*Gratitude is a fruit of great cultivation*"

------- **Dr. Samuel Johnson.**

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RESMI, R.

To my parents......

for their inspiration and perseverance

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INTRODUCTION

1. INTRODUCTION

India is bestowed with diverse agro climatic conditions ideally suited for growing a number of vegetable crops. Our country is the second largest vegetable producer in the world contributing about 12 per cent of the global vegetable production. We produce 82.7 million tonnes of vegetables from an area of 5.98 million hectares (Verma, 2001). In Kerala, vegetables are produced in an area of 74,288 hectare with a production of 6,02,736 tonnes. The per capita consumption of vegetables in Kerala is only 125 g per day as against the requirement of 285 g. It is estimated that about 7 lakh tonnes of vegetables are brought annually from neighbouring states to our state.

Legumes are rich in protein than other vegetables and also possess high energy minerals like phosphorous, calcium, potassium, vitamins and dietary fibre. They improve soil fertility through biological fixation of nitrogen, with an annual global fixation of 208 million metric tones. Legumes rank third among food crops, topped by root and tuber crops and cereals (FAO, 1998).

Among legumes, the genus *Vigna* include more than 100 species distributed in tropical and sub tropical regions. Cowpea is a common vegetable grown through out the country as a rich and cheaper source of vegetable protein (7.5 g / 100 g). The crop is thought to be originated in Central Africa and is distributed in India, Indonesia, Philippines and Srilanka (Sampson, 1936). Yard long bean

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt.), also known as asparagus bean is one among the sub species cultivated throughout Kerala. Its tender green pods are used as a delicious vegetable and is rich in crude protein (28 %), minerals like iron (2.5 mg /100 g), calcium (80 mg / 100 g), phosphorus (74 mg / 100 g), potassium, vitamin A (941 IU /100g) and vitamin C (13 mg/ 100g) and dietary fibre (2g / 100g). In Kerala, cultivation of vegetable type cowpea cultivars is more in demand than pulse and dual purpose types. The cowpea varieties/ cultivars grown in the state differ in their growth habit (trailing/semi-trailing / bush), pod colour (purple/green/light green/ white with greenish tinge), length of pod and boldness of seeds. The landless agricultural workers and marginal farmers who depend on vegetable cultivation for their livelihood prefer yard long bean cultivars because of its protracted fruiting, more yield and steady demand in the market. The crop is trailing or climbing in habit and grown with proper staking on pandals or trellis. It is cultivated in rice fallows and homesteads. Despite its high economic and nutritive value, this crop is not fully tapped to maximise its productivity.

The cowpea production is confronted by many constraints. Heavy incidence of pests and diseases particularly mosaic disease, stem blackening caused by *Colletotrichum* sp., pod borer and aphids are severe threats for successful cultivation of cowpea (Menon and Nair, 1983). In addition, delayed and erratic flowering, low pod set, flower and fruit drop also aggravates the problem in yard long bean cultivars. Application of plant growth regulators has been an effective tool for increasing flowering and pod setting, thereby increasing productivity in several vegetable crops. Several plant growth substances are put to practical use in crop production to tailor growth and development of plants in desired direction.

Naphthalene acetic acid (NAA) is a growth regulator already utilised in many vegetable crops especially in solanaceous vegetables for increased fruit set and yield by reducing flower shedding. Its efficiency is to be worked out in relation to an array of new chemicals. Though a growth retardant, 2,4-dichloro phenoxy acetic acid (2,4-D) at low concentration is proved to be giving promotory effect in many crops especially tomatoes.

The increased flower abortion reported under conditions of high temperature and severe soil moisture stress has led to the utilization of growth retardants to tackle the problem of reduced fruit set. Cycocel (CCC) has been found effective to reduce plant size there by minimizing the area of transpiration. They also regulate the closure of stomata and thus enhance the effective utilization of available water.

With this back ground, the present study was undertaken with the objective of selecting the most suited plant growth substance that will enhance the growth, flowering, fruit set and productivity in 'Lola', a popular and adapted variety of yard long bean in Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Yard long bean is an important leguminous vegetable crop grown in Kerala for its long tender pods having agreeable taste and high nutritive value. It stands second in area covered and preferred by the vegetable growers in the state.

2. 1. Plant growth regulators

The growth and development of the plant is influenced by the genetic make up, environment and interaction of a number of internal factors like growth substances. The growth substances can alter the physiological activities of the plant by altering the plant height, flower number and abscission of flowers after anthesis. Several plant growth substances are available which alter the relative growth rate of plant parts and affect dry matter production and yield (Yadava and Sreenath, 1975). A suitable concentration of growth regulators applied at appropriate time may increase the yield and thereby alter the dry matter distribution in the plant by regulating the growth and processes (Singh and Arora, 1994).

Plant growth regulators are organic substances other than nutrients which in small quantity is capable of quantitatively and qualitatively modifying the plant growth and development. These substances in a definite concentration interact with plant metabolism and alter biochemical and physiological action resulting in desired effect. These substances may be either naturally occurring within the plant or synthetically produced.

Broadly, plant growth regulators are classified into growth promoters and growth retardants based on their effects. Generally, plant growth regulators are classified according to their physiological action as

1. Auxins eg. Indole acetic acid (IAA), Indole butyric acid (IBA), Naphthalene acetic acid (NAA), 2,4 –Dichloro phenoxy acetic acid (2,4-D), Para chloro phenoxy acetic acid (PCPA)

2. Gibberellins eg. Gibberellic acid (GA)

3. Cytokinins eg. Kinetin, Zeatin

4. Ethylene eg. Ethylene

5. Dormins eg. Abscisic acid (ABA), Phaseic acid

6. Synthetic growth retardants eg. Cycocel (CCC), AMO 1618

(Purohit, 1993)

Auxins stimulate cell division and cell enlargement in apical region by increasing the amylase activity, cell wall extension, permeability, viscosity and plasticity. Auxins induce shoot and root growth at higher concentration by increasing the number of vascular bundles and callus formation.

Gibberellins are another group of compounds synthesized by young seedlings and immature seeds. It increases the DNA, RNA and protein synthesis and promotes cell elongation and shoot growth. It induces seed germination, break apical and bud dormancy, induce flowering in long day plants and parthenocarpy.

Cytokinins are mainly produced in root tip, cambial tissue and developing seeds. The main function is cell division by increasing the plastids and tracheids. In combination with auxins, cytokinin induces cell division even in non-meristematic cells also. Cytokinin also breaks dormancy, delay senescence and induce morphogenesis in cultured cells.

Ethylene is the only gaseous plant growth regulator and the main function is the induction of ripening. Ethylene induces abscission, increases resistance to pathogen. It also induces female flowers in lower nodes in cucurbits.

ABA or abscisic acid (dormins) is growth inhibitory substances by inhibiting α-amylase production which is essential for seed germination. ABA also act as stress hormone, induce abscission and senescence.

Growth retardants are synthetically produced compounds which retard physiological process but do not inhibit completely. Mainly, they function as anti-gibberellins ie, antagonistic to GA action. There are three types of growth retardants based on their action.

a) Ethylene releasing compound----eg: etacelasil

b) Inhibitors of GA translocation----eg: B-9, SADH (Succinic acid dihydrogenase) MH (Maleic hydrazide)

c) Inhibitors of GA biosynthesis -----It includes,

(i). Onium type compounds: CCC (Cycocel), AMO 1618

(ii). Compounds with Nitrogen - containing heterocycle: eg: Paclobutrazol

(iii). Cyclohexatrions: eg: cimetocarb

There are two aspects of hormone action. First one is the mechanism of action which include direct, specific molecular interaction. The second one is the mode of action which include succeeding series of steps which results in a measurable biochemical or physiological response.

Plant growth substances are used to control different developmental process so as to improve germination (Choudhary and Singh, 1960 and Adlakha and

Verma, 1965), to induce plant vigour (Choudhary and Singh, 1960), to induce earliness in flowering and fruiting (Gopalakrishnan and Choudhary, 1978) and to increase yield (Verma and Choudhary, 1980).

The reports on the effects of NAA, 2,4-D, PCPA and CCC are consolidated below:-

2.1.1. Auxins (NAA, 2, 4-D and PCPA)

The most important effect of auxin is the cell elongation. Leopold (1958) stated the presence of a large amount of growth hormone on fruitset in plants. Synthetic auxins, even substitute for pollination suggesting that auxin itself is responsible for fruitset. Auxin compounds delay senescence through maintenance of RNA synthesis and increased carbohydrate synthesis (Osborne, 1963). The auxin directed transport of nutrients, hormones and photosynthates and favours increased fruitset by their application (Krishnamoorthi, 1981)

2,4-D at very low concentration has got many yield contributing effects. The concentration of 2,4-D above the optimum concentration has a number of undesirable effects. Relatively high concentration of auxin may result in inhibitory effect as a result, some of the auxin molecule secure all free positions in the protein component of the enzyme molecule (Mayer and Anderson, 1955). The reduction in rate of photosynthesis as a result of its action of closing stomata also might be contributing to these effects (Mansfield, 1967). Usha (1988) reported that foliar application of 2,4-D at 5 ppm induced leaf and flower malformations in kharif and summer seasons. The plants were stunted in growth with curled and reduced leaf size.

PCPA is also having effects on flowering and fruiting. The concentration of PCPA above an optimal level will produce some malformations and lethal effects on crops. PCPA is very much effective for inducing fruitset in tomato under stress condition, especially in very low temperature (Ozgerven *et al.*, 1998).

2.1.2. Cycocel (CCC)

Growth retardants control transpiration as the total surface area exposed to the atomosphere is reduced, thus plant growth is checked. CCC (2-chloro ethyl trimethyl ammonium chloride), a growth retardant used as an anti-transpirant by its chlorophyll retention property in leaves and probably acts through its interference with biosynthesis of GA (Wittwer and Tolbert, 1960). A reduced level of GA in treated plants would result in reduced stomatal opening at lowered concentration (Halvey and Kessler, 1963 and Pandey and Sinha, 1990).

2.2. Studies on crops

2.2.1. Studies on cowpea

Yadava and Sreenath (1975) applied Phosphon – D (50 ppm) B-9 (500 ppm) at 40 days after sowing (DAS) and reported significant reduction in plant height. The higher concentration of phosphon –D (100 ppm) and B-9 (1000 ppm) significantly increased the fresh weight of shoots as compared to those of control in vegetable cowpea. CCC 1000 ppm significantly reduced the fresh weight of shoot (424.6g) but phosphon-D had no effect on dry matter accumulation. B-9 (1000 ppm) and CCC (500 ppm) increased grain weight (105.18 g) where as GA_3 (25 ppm) had no effect.

Yadava (1980) reported a higher pod yield (18.7 q ha^{-1}) and seed yield (12.3 q ha^{-1}) in vegetable cowpea with foliar application of NAA at 45 ppm. The increased yield over control was reported to be 37.3 per cent.

Tonapi (1985) observed more number of primary branches (18.3), number of nodes (83.3), plant spread (24.8 m^2), leaf area index and number of pods per plant in vegetable cowpea with foliar application of MH 30 ppm at flowering stage. Spraying of MH did not influence flowering period, duration of crop, days to first flower initiation, days to maturity, protein content and crude fibre.

A study conducted by Vilas (1985) revealed the positive effect of CCC 100 ppm on yield per plant (110 g), yield per hectare (14.77 q ha^{-1}) number of pods per plant and reduced plant height (41.7 cm) compared to water spray in *Vigna unguiculata* (L.) Walp.

Hunje (1986) reported that MH 60 ppm and cycocel 100 ppm was effective in bringing highest reduction in plant height, encouraging lateral growth of plant in terms of highest primary branches (16.33), nodes per plant (87.93) and spread of plant (47.49 m^2) in vegetable cowpea. The increase in seed yield was 76.62per cent over the control. The increase in yield can be attributed to increased number of pods per plant (96.37) seeds per pod (12.70) and 100 seed weight (9.20g).

CCC (300 ppm) and phosphon D (50 ppm) was found to be beneficial to decrease the plant height considerably in vegetable cowpea (Rudich, 1986). The overall vegetative growth was better in CCC 100 ppm, sprayed at flowering stage. Cycocel at 50 and 100 ppm was effective for early flowering and harvest of the pods. Cycocel spray at 100 ppm has been found to bring down the number of stomata, total chlorophyll content and days to maturity (Agarwal *et al.*, 1986).

Foliar spray of CCC 100 ppm at 30 DAS combined with TIBA (Tri-iodobenzoic acid) 25 ppm at 45 DAS were effective for higher crude protein content (24.5 %), 100 seed weight and vigour index in vegetable cowpea var. Pusa

Dofasli. The plant characters like days to first flower, days to 50 per cent flowering, days to maturity, number of pods per plant, number of seeds per pod and 100 seed weight were significantly higher than the control in both summer and kharif season. (Hunje *et al.*, 1992).

NAA 45 ppm along with 40 kg nitrogen per ha was effective in improving the pod weight (20.3 g) and seed yield (15.7 kg ha^{-1}) in cowpea during summer under Jabalpur condition (Jain *et al.*, 1993). But NAA at lower concentrations (15 and 25 ppm) along with 60 kg Nitrogen per hectare had significantly reduced the pod yield, fresh and dry weight of pods and percentage of protein content.

Hendy *et al.* (1993) observed an increase in soil nematodes with a single foliar spray of cycocel at 150 g per litre but CCC sprays with 300 and 600 g per litre at 30 DAS decreased the soil nematodes with an increase in the number of egg masses in cowpea.

Application of NAA 50 ppm at pre flowering and pod filling stage resulted in highest seed yield (15.3 q ha^{-1}) which was 48 per cent higher than the control yields in cowpea (Shinde and Jadhav, 1995). The application of NAA at higher concentration (60 and 75 ppm) resulted in increased nodules during summer season (Dhanalakshmi *et al.*, 1996)

Singh and Sharma (1996) obtained highest seed yield of 1.19 and 1.32 t per ha in rainy and summer season respectively with 40 ppm GA_3 under Port Blair condition in cowpea cv. Arka Garima. Application of 2,4-D at 5 ppm resulted in lowest seed yield, grain yield and protein content.

Foliar application of NAA, GA_3 and Kinetin increased nodulation by 40-200 per cent with optimal concentration of NAA (30 ppm), GA (25 ppm) and Kinetin (5 ppm) in cowpea. Maximum leaf growth was recorded with NAA treatment. Nodule senescence was delayed by 3 to 9 days with application of growth regulators. Reduction in nodule senescence was 15-69 per cent over control with lower level of NAA. The increase in seed yield was 80.6 per cent and 84.8 per cent with NAA and GA_3 respectively over the control treatment (Raghava *et al.*, 1996).

Triacontanol 5 ppm combined with cytozyme at 1.5 per cent increased the total soluble protein content (%) in cowpea (Asane *et al.*, 1998). An increase in seed weight, pod yield and crude fibre content were also reported. The increases in yield with the application of plant growth regulators were reported to be 37.5 per cent over the control.

Ganager (1998) reported an increased number of branches with TIBA (25 and 50 ppm) spray at pre flowering stage in cowpea. Application of CCC 1000 ppm reduced the number of internodes and plant height significantly over the control under Bangalore condition. The leaf dry weight increased upto 50 DAS and decreased there after in case of growth regulator applications (TIBA and CCC) Average growth rate of the plant increased upto 50-75 DAS and declined there after. Net Assimilation Rate (NAR) and Relative Growth Rate (RGR) were found to be maximum upto 25-50 DAS and then declined. NAA at 25 ppm significantly increased chlorophyll *a* and total chlorophyll content. Seed yield was maximum in TIBA 25 ppm which was about 27.5 per cent higher than the control.

2.2.2. Other leguminous vegetables

Singh and Jauhari (1965) observed significantly higher number of laterals with application of 250, 500 and 1000 ppm MH compared to control in *Pisum sativum*. The flowering was delayed by 12.6, 7.6, 5.3 and 2.2 days under 1000, 500, 250 and 50 ppm MH respectively over the control. An increased yield of 27.2 per cent was obtained with 250 ppm MH over control. An increase in pod number per plant, grain number per plant and 100-grain weight were also observed.

Doijode and Rao (1983) reported an increase in non-reducing sugar and total sugar content with application of NAA (30ppm) and GA 15 ppm in *Pisum sativum*. The increase in yield upto 28 per cent was obtained in NAA 15 ppm compared to control.

Das (1985) reported that foliar spray of triacontanol at 5 ppm and 10 ppm improved the vegetative characters and yield parameters in *Pisum sativum*. Cycocel alone at 500 and 1000 ppm reduced the plant height and increased the pod yield over control.

El. Abd *et al.* (1989) found out an increased number of pods per plant, pod and seed weight per plant and plant dry matter content in *Vicia faba* with application of 2,4-D at 4 ppm and PCPA at 50 ppm as foliar spray at 30 DAS. The yield increase over control was reported to be 35 per cent.

Application of 10 ppm NAA increased total chlorophyll content, seed yield, seed: pod ratio and 100 seed weight in *Vicia faba* (Huang *et al.*, 1989). Application of 50 ppm PCPA significantly increased development of secondary branches, chlorophyll content, crude protein content high fruitset and yield in low temperature condition.

Kim and Okubo (1990) found out the effects of GA_3 on growth and yield of lab- lab bean in two seasons namely kharif and summer seasons. GA_3 partly induced indeterminate growth of plants under non-inductive conditions. Auxins like NAA and 2,4-D were found to be effective for good yield increase (more than 30 %) over the control plants.

Mishriky *et al.* (1990) observed an increase in all growth parameters with application of CCC at 500 ppm in *Pisum sativum*. Other plant characters like height of plant and leaf area per plant get reduced with CCC application. But application of CCC at 500 ppm significantly increased grain weight and grain number per pod per plant.

Bisen *et al.* (1991) recorded a higher pod yield of 15.82 quintals per hactare with foliar spray of planofix at 100 ppm at six leaf stage in garden pea . Application of planofix significantly increased the number of secondary branches, pods per plant, pod length and yield . The increase in yield over the control was reported to be 12.33 per cent.

Rabie *et al.* (1991) obtained a drastic reduction in abscission of buds, flowers and pods with CCC 500 ppm application in *Vicia faba*. The total abscission was reduced by 3.6-6.4 per cent over control in cv. Giza 402. During pod shedding, auxin content was higher in CCC 500 ppm treatment. Gibberellin content was highest during pod shedding in CCC 100 and 250 ppm treatments.

Gupta (1992) reported that 500 ppm CCC as foliar spray at 30 DAS caused varied stomatal abnormalities including persistent stomata, giant stomata, stomata with unequal guard cells and with cytoplasmic connection and contiguous stomata in *Vicia faba*.

Foliar spray of GA_3 20 ppm recorded maximum values in respect of number of branches, protein content, leaf area, flowering, pod weight percentage, pod yield (64.7 kg ha^{-1}) and seed yield (43.91 kg ha^{-1}) in french bean. But 2, 4-D application at 2 ppm as foliar spray did not show any positive effect on growth and yield (Reddy *et al.*, 1992).

Desai *et al.* (1995) suggested that application of NAA and PCPA at pre-flowering stage was very much effective for increasing the yield and productivity in *Lablab purpureus*. The increased plant growth with application of PCPA 100 ppm may be due to the stimulatory action of PCPA which soften the cell wall and increases the plasticity resulting in stimulatory growth activity.

Jana and Paria (1996) found that growth regulators like NAA along with micro nutrient mixtures containing zinc, manganese and boron produced highest pod yield in Pea cultivar Arkel. Application of NAA 80 ppm along with 0.2 per cent zinc was found to be effective for increased pod yield (4.88 t ha^{-1}) than the untreated control. The increase in yield over control was reported to 17.38 per cent.

Foliar spray of triacontanol and NAA at 30 DAS increased leaf area index and number of secondary branches in *Lablab purpureus*. Application of triacontanol at 4 ppm at pre-flowering and pod filling stage induced early flowering, increased number of branches per plant, number of roots per plant and yield (1356 g / plant). While application of NAA at 50 ppm was effective for height of plant, length of pod, girth of pod and 1000 seed weight (Ghosh, 1996).

2.2. 3. Other legumes and pulses

Basnet *et al.* (1972) found the effect of growth regulators like CCC at 1000 ppm and antiauxins like TIBA for improving morphological characters and yield in Soyabean. The growth regulators were applied before blooming stage. The characters like number of branches, number of pods per plant, seed composition, oil and protein content were increased with growth regulator application.

Sarma and Shah (1979) reported the effect of growth and yield response in soyabean cv. Clark 63 by the foliar application of GA (15 and 10 ppm) and NAA (6.25, 12.50 and 25 ppm) in kharif season. The result showed an initial increase in plant height expressed in terms of relative growth rate and length of internodes due to spraying with GA 5 and 10 ppm. The foliar application of NAA failed to increase plant height, but fastened the flowering. Foliar spray with NAA (6.25 ppm) increased grain yield by 40 per cent.

Selvaraj *et al.* (1981) studied the effect of growth regulator spray on var. CO-3 redgram during kharif season. The application of planofix at 100 ppm significantly increased the grain yield. Application of ethrel (100 ppm) along with P_2O_5 did not bring out significant increase in yield.

Bangal *et al.* (1982) revealed that the foliar spray of urea (0.1 %) along with 2,4-D, 5 ppm at the time of flowering affected the grain weight per plant significantly in chickpea. The per cent increase in grain yield over control was highest in NAA 50 ppm treatment (36.0 %) followed by NAA 25 ppm (30.1 %). Application of 2, 4-D at 10 ppm reduced the yield by 3.2 per cent. The pod weight per plant was significantly more in NAA 50 ppm and CCC 1000 ppm treatment, which was significantly more than other treatments. Application of 2,4-D at 5 ppm increased the pod number by decreasing the flower drop and increasing the number of flowers.

Bangal *et al.* (1982) observed that treatment with NAA 25 ppm, CCC 500 ppm and 2, 4-D 2 ppm increased the pod number by decreasing the flower drop and increasing the flower number per plant in blackgram. The application of CCC decreased the plant height, fruiting branches, pod per plant and 100 seed weight in mung bean (Yadireddy, 1984).

Williams and Malhotra (1983) studied the effect of GA and CCC on nodulation in soyabean. Foliar spray of GA_3 completely inhibited the formation of root nodules. The application of CCC increased the number of nodules by 56 per cent.

Deshpande (1984) observed an increased seed yield with application of NAA at 10 ppm in chickpea. The increase in seed yield is not upto the mark compared to TIBA application. The increase in yield was due to the increased percentage of pod setting, number of seed per pod and decrease in number of dropped flowers per plant. But neither NAA nor TIBA had any noticable effect on seed quality in both kharif and summer seasons.

Katageri and Sheelavantar (1985) studied the effect of different irrigation schedules and NAA spray (10 ppm) on growth and yield of chickpea var. Annigeri during rabi season under Dharward condition. Maximum grain yield was obtained when irrigation was scheduled at 30 and 60 days (2.307 t ha^{-1}). The difference in seed yield is due to the difference in number of pods and seeds per plant. The spraying of NAA at flower initiation,increased the seed yield by 10 per cent and it was attributed to increased number of pods (43.01 per plant) and seeds (6.46 per pod).

Pujari (1985) studied the effect of growth regulators on flower abscission, seed yield and seed quality of five cultivars of pigeon pea. Both application of TIBA and NAA reduced the plant height significantly over control (water spray). TIBA and NAA did not significantly influence the number of flowers produced, number of primary branches but slightly reduced number of flower drop compared to water spray. Both TIBA and NAA had significant effect on percentage of pod setting, number of seeds per pod, 100 seed weight and total yield.

Reddy and Singh (1985) observed the effect of NAA (10 and 50 ppm), GA (10 and 50 ppm) and TIBA (10 and 25 ppm) with a control (water spray) in black gram cv. Pusa Baisakhi. The plant height increased by 26 per cent with GA 50 ppm followed by GA 100 ppm (20 %), NAA 50 ppm (5 %) and NAA 10 ppm (4 %). Plants treated with growth regulators showed an increase of 57 per cent dry matter production.

Reddy *et al.* (1987) studied the effect of foliar application of DAP (Di ammonium phosphate) and NAA on yield and yield attributes of pigeon-pea on sandy loam soil condition. Foliar application of 2 per cent DAP plus NAA at flowering and pod formation stage of the crop increased the pod number and seed yield significantly over control plants.

Katageri and Sheelavantar (1988) reported an increased total dry matter production chiefly through high leaf area per plant, leaf area index, leaf area duration in chickpea cv. A-1 by application of NAA 10 ppm. The increased grain yield of chickpea sprayed with NAA was also traced back to higher percentage of dry matter distribution in reproductive parts (pods) and hence increased retention of pods. NAA did not influence days to cessation of flowering, crop duration, plant height and number of branches per plant at maturity.

Singh (1989) and Singh *et al.* (1999) reported the effect of flower shedding with foliar application of NAA. The application of NAA and CCC at 30 and 300 ppm respectively, each reduced the flower shedding. The treatment with NAA (30 ppm) was most satisfactory for an increase in 18.8 per cent seed weight.

Mahla (1991) observed the effect of plant growth regulators like NAA 20 ppm and mixtallol 2 ppm along with 4 levels of P_2O_5 on growth characters of blackgram. Growth characters like plant height, number of branches per plant, dry matter production per plant and chlorophyll content were increased with application of NAA at 40 ppm.

Patel and Saxena (1994) reported the effect of seed soaking and foliar spray of growth regulators on growth and yield of blackgram. Treatment with GA_3 and NAA showed maximum vegetative growth at early stages, but number of flowers, pods and final yield were higher by 20 – 23 per cent in plants treated with NAA and Kinetin.

Bio -regulators like NAA (10, 20 and 30 ppm), Kinetin (10, 20 and 30 ppm) and KNO_3 (100, 200 and 300 ppm) sprayed at bud initiation and pod formation stage of chickpea, increased the plant height, number of branches, number of flower bud, number of flowers, vegetative growth and yield (Upadhyay, 1994). Application of NAA at 20 ppm induced early flowering whereas kinetin 30 ppm delayed it slightly.

Dhingra *et al.* (1995) found out that application of 20 ppm NAA was inhibitory to the accumulation of sugars and starch in chickpea in saline soils. NAA 30 ppm improved the seed protein and starch when applied at pre flowering stage at rabi season.

Lakshmamma and Rao (1996) conducted an experiment in sandy loam soil to study the effect of shading (0,33 and 66 %) and NAA (0,5,10 and 20 ppm) on growth&yield of blackgram. The treatment with 50 per cent shading increased the plant height, dry matter, chlorophyll content, flower drop and decreased seed yield. Application of NAA increased plant height, dry matter, chlorophyll content and nitrate reductase activity, but it reduced the flower drop percentage, which led to increased seed yields.

Rao and Narayan (1997) studied the effect of light water stress and foliar application of auxins on flower abscission and seed yield of pigeon-pea, cv. ICPL-288. Stress decreased the number of flowers and pod formation, per cent of fruit set, seed yield. Each of these parameters were increased by NAA application which increased seed yield from 1120 kg per hactare in control to 1380 kg per hactate.

Kalarani and Jayakumar (1998) reported the effect of foliar spray of NAA along with urea, DAP and K_2SO_4 on leaf senescence and chlorophyll content in soyabean. Among the treatments 1 per cent urea + DAP 2 per cent and NAA 30 ppm were found to be effective for reduced leaf senescence, increased yield (19.5 q ha^{-1}) and number of branches.

2.4.4. Other vegetables

Singh and Chhonkar (1965) reported an increase in plant height with application of α- NAA spray in cabbage. Application of α- NAA and 2, 4-D proved quite effective in reducing the transplanting shock, which resulted in quick recovery of seedlings. The formation of head started at 47 days of transplanting in 0.1 ppm NAA as once over application, but it was after 60 days in control plants. NAA used as plant spray, proved far superior to control in both earliness and time taken for complete head formation. Application of 2, 4-D caused early maturity by 2 to 3 days as compared to control. A maximum head diameter of 17.8 cm was recorded with 0.1 ppm 2,4-D against 11 cm in control plants.

Singh and Choudhary (1966) observed an improvement in size, weight and composition of tomato fruits with application of plant growth regulators. The largest fruit size of 4.82 cm was observed with 50 ppm PCPA. 2, 4-D was found to be best for increasing the size of fruits in all treatments. Combined application of 10 ppm 2, 4-D and 50 ppm PCPA was significantly better than control. GA_3 was found to be most effective in reducing the acidity of fruits whereas lower concentrations of 2,4-D and PCPA increased it. Ascorbic acid content with 2,4-D

10 ppm and PCPA 50 ppm was recorded to be 28.2 and 30.8 mg per 100 gm respectively.

Chandra and Raj (1972) obtained a progressive increase in flower production with application of 2,4 – D 10 ppm in tomato plants. Application of NAA and 2, 4 - D resulted in an increase of 17.5 per cent and 26.1 per cent increase in yield respectively compared to control. 2, 4- D 10 ppm spray caused highest flower shedding. An optimum iron content of 31 ppm was observed with 2, 4-D 10 ppm application. NAA 10 ppm gave maximum number of pods per plant, followed by 2, 4-D 10 ppm. GA 25 and 50 ppm treatment showed significant increase in length of pods over all other treated and control plants. 2, 4-D applied fruits are of various sizes, which include parthenocarpic fruits with 1 to 3 cm in length. 2, 4-D 10 ppm showed minimum width of pod. Minimum number of seeds per fruit were seen in 2, 4-D 20 ppm closely followed by control. IAA and NAA showed maximum seed content. Thus seed content in 2, 4-D and GA may be due to their parthenocarpic effect.

Rao and Rao (1978) recorded a significant increase in plant height (27.60 cm) number of leaves (16.50) in *Beta vulgaris* var.*benghalensis* cv. All Green with GA_3 20 ppm. Significant increase in number of leaves, plant height and leaf area were observed with plant growth regulator application. Leaf area was more with NAA 20 ppm (45.20 cm^2) and less in GA 20 ppm (36 cm^2).

Marisiddiah and Gowda (1978) studied the influence of varying concentrations of two growth retardants (Alar and Cycocel) at different stages of plant, on growth and yield of hybrid tomato cv. Karnataka. Treating the tomato plants with varying concentrations, generally reduced height but increased stem diameter, number of branches, total yield and fruits per plant. Varying concentrations of CCC and SADH significantly increased stem diameter, compared to untreated control. CCC at 2000 and 3000 ppm significantly increased number of lateral shoots.

Mangal *et al.* (1981) studied the influence of various chemicals like NAA, PCPA and ethrel on growth, flowering and yield of bitter gourd in Haryana condition. PCPA at 100 ppm improved plant growth significantly. The treatment of CCC at 250 and 500 ppm produced female flowers about 12 days earlier in comparison to control plant. Maximum fruit yield per plant (3123.00 gm) was produced under cycocel 250 ppm followed by cycocel 500 ppm. Treatment with 100 ppm PCPA alone improved the length of plant significantly over control. Maximum number of fruits per plant (27.16) was harvested with CCC at 250 ppm treatment. The same results were reported by Sutti (1989) in ash gourd in Coimbatore condition.

Sidhu *et al.* (1982) reported the effect of ethrel, cycocel and maleic hydrazide on growth, flowering, yield and quality of muskmelon. Ethrel treatment was found effective in inducing hermaphrodite flower at lower nodes, increasing the number of perfect flowers, number of fruits and ultimately the yield of crop. Ethrel at 500 ppm suppressed the male flowers and male to female sex ratio was lowered. The treatment of ethrel 250 ppm and cycocel 100 ppm proved equally effective in elongation of main axis in cucumber (Murty *et al.*, 1990).

Verma *et al.* (1987) reported the application of growth retardants like CCC, SADH and morphactin along with ethrel at two concentrations on fruiting and yield in pumpkin. All growth retardants at different stages induced the first fruit set at lower nodes from 8.6 to 14.0, while ethrel treatment produced the fruit set between 3.3 and 4.3 nodes. Ethrel at 100 ppm at the initial stages proved to be the best treatment in increasing the number of fruits. Ethrel developed smaller size of fruits which can be commercially exploited.

Alam and Islam (1989) obtained the effect of NAA, IBA, cycocel and 2, 4-D on growth, yield and chemical composition of potato under Bangladesh condition. It was observed that, IBA increased shoot extension, weight of haulms, total sugar and starch content, but decreased the chlorophyll content, tuber set while 2, 4-D decreased height, leaf area, weight of haulm, total sugar content, starch per cent, number of tuber set and yield. 2, 4-D generally decreased the yield. Among these chemicals, NAA 100 ppm gave best results in relation to yield. CCC at 1000 ppm and NAA 100 ppm produced taller plants than control. The largest leaf was produced by 200 ppm NAA and the smallest leaf was found in plants treated with 20 ppm 2,4-D. NAA treatment was more beneficial for number of tubers per plant, while 2, 4-D had adverse effect in production of tubers per plant. The same results were obtained in fenugreek with application of NAA (Alagukannan and Vijayakumar, 1999).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Olericulture, College of Horticulture, Vellanikkara, Thrissur during 2000-2001.

3.1. MATERIALS

The field experiments were laid out in the research fields of Department of Olericulture. The experimental site is located at an altitude of 22.25 m above Mean Sea Level (MSL) at $10^{0}32^{1}$ N latitude and $76^{0}16^{1}$ E longitude. This region enjoys a warm humid tropical climate. The experimental site has a well-drained sandy loam soils. Data on maximum temperature, minimum temperature, rainfall and relative humidity during entire cropping period were collected from Meteorological Observatory of College of Horticulture, Vellanikkara, and are presented in weekly averages and weekly totals (Appendix I a and Appendix I b).

3.1.1. Seasons of experimentation

The crops were raised during two cropping seasons *viz.* rabi and summer (Table 3.1.).

Table 3.1. Periods of cropping during experimentation

Sl. No	Cropping season	Cropping period
1	Rabi	September 2000 to January 2001
2	Summer	February 2001 to May 2001

3.1.2. Variety

The adaptable and consumer accepted variety, 'Lola' (VS-13-2) developed by the Kerala Agricultural University was selected for the study. Due to its green tinged extra long pods, 'Lola' has good demand among farmers and consumers in Kerala (Plate 3.1).

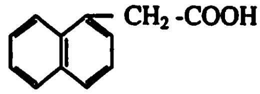
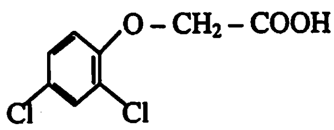
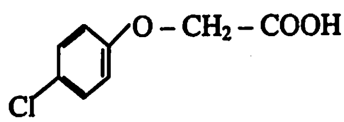
3.1.3. Growth regulators

Four plant growth regulators *viz.* Naphthalene acetic acid (NAA), 2,4-dichloro phenoxy acetic acid (2,4-D), Para chlorophenoxy acetic acid (PCPA), and cycocel (CCC) which under various concentrations constituted different treatments.

The chemical name and formula of different plant growth regulators are furnished in Table 3.2. There were thirteen treatments excluding control (No spray).

Plate 3.1. Yard long bean variety 'Lola'

Table 3.2. The chemical name and formula of the various plant growth regulators used in the experiment.

Common name	Chemical name	Chemical structure
NAA	Naphthalene acetic acid	
2, 4-D	2,4- dichloro phenoxy acetic acid.	
PCPA	Parachloro phenoxy acetic acid	
CCC	2-chloro ethyl trimethyl ammonium chloride.	CH_3 | $Cl\text{-}CH_2\text{-} CH_2\text{-}N^+\text{-} CH_3Cl$ | CH_3

3.2. METHODS

3.2.1. Layout and experimental design

The experiment was laid out in Randomisd Block Design (RBD) with forteen treatments replicated thrice. Three lines at a spacing of 1.5 m x 0.45 m constituted one plot and the gross plot size was 13.5 m^2 per treatment per replication. A distance of 1.5 m was given between each line in plots to prevent the drift of spray particles.

3.2.2. Treatments

Four plant growth regulators by changing the concentration constituted the following treatments.

T_1	NAA 15 ppm 3 sprays at 30, 45 and 60 DAS**
T_2	NAA 30 ppm 3 sprays at 30, 45 and 60 DAS
T_3	NAA 45 ppm 3 sprays at 30, 45 and 60 DAS
T_4	2,4 D 2 ppm 3 sprays at 30, 45 and 60 DAS
*	
T_5	2,4 D 4 ppm 3 sprays at 30, 45 and 60 DAS
*	
T_6	2,4 D 6 ppm 3 sprays at 30, 45 and 60 DAS
*	
T_7	PCPA 25 ppm 3 sprays at 30, 45 and 60 DAS
*	

T_8	PCPA 50 ppm 3 sprays at 30, 45 and 60 DAS	*
T_9	PCPA 75 ppm 3 sprays at 30, 45 and 60 DAS	*
T_{10}	CCC 300 ppm one spray at 20 DAS	
T_{11}	CCC 400 ppm one spray at 20 DAS	
T_{12}	CCC 500 ppm one spray at 20 DAS	
T_{13}	Water spray	
T_{14}	No spray (Control)	

*--During second season (summer), growth regulators (2,4 D and PCPA) were sprayed only at 45 and 60 DAS

** Days After Sowing

3.2.3. Application of growth regulators

The spray solutions at desired concentration were prepared considering the concentration of active ingredient in the formulations. A spray volume of 3 litres for 13.5m² area was used.

Water-soluble growth regulators like CCC was dissolved in required amount of distilled water and sprayed directly on the foliage of the plant using a hand sprayer. Auxins like 2, 4-D, NAA and PCPA, which are insoluble in water were first dissolved in 70 per cent absolute alcohol (ethanol) and mixed with required quantity of water.

The growth substances NAA, 2,4-D and PCPA were applied thrice at 30, 45, and 60 days after sowing and CCC only at 20 DAS during rabi season. During summer season, 2,4-D and PCPA were applied at 45 and 60 days after sowing, NAA at 30, 45 and 60 DAS, while CCC was applied at 20 days after sowing. The spraying was done during morning hours to reduce wind drift.

3.2.4. Sowing and after cultivation

Sowing was done on 26 September 2000 and 14 February 2001 for rabi and summer seasons respectively. Seeds were soaked in 3 per cent Bavistin for six hours and sown in lines of 3 m length @ 7 seeds per line. Regular weeding operations were carried out to keep the plots weed free during the entire cropping period. Before vining of the plants, trellis of 6 feet height were made with coir and galvanised iron (GI) poles and plants were trained to trellis by fixing thin twigs near the plants. Separate trellis were provided for each line to prevent the intermingling of the lines with lines of adjacent plots.

During the cropping period, various cultural operations and applications of manures and fertilizers were carried out as per Package of Practices Recommendations of Kerala Agricultural University (K.A.U., 1996). Twenty tonnes of Farm Yard Manure (FYM) per hectare were applied at the time of land preparation. A fertilizer dose of 20: 30:10 kg NPK per hectare was applied. Half the quantity of nitrogen, whole phosphorus and potash were applied at the time of land preparation. The remaining quantity of nitrogen was applied at 15 – 20 days after sowing. Cow dung slurry was also drenched at regular intervals.

During summer season, irrigation was given once in three days for the entire cropping period. During rabi season, need based irrigation was given as there was intermittent rainfall. Fruits were harvested at correct harvestable maturity stage once in three days for vegetable purpose.

3.2.5. Plant protection

During the entire cropping period, plant protection chemicals were applied against aphids, powdery mildew and fruit borer. Tobacco decoction was sprayed whenever aphid infestation was noticed. In severe cases of disease or pest outbreak, need based safer insecticides or fungicides were applied.

3.2.6. Biometrical observations

3.2.6.1. Vegetative characters

1. Length of vine (m)

The total length of the main vine was measured at the final harvest of the crop.

2. The number of secondary branches.

The total number of branches arising from the main primary branches were counted after final harvest of the crop.

3.2.6.2. Earliness.

1. Days to first flower.

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

2. Days to 50 per cent flower.

The number of days taken from sowing to appearance of flowers in 50 per cent of the plants in each plot was also recorded.

3. Days to first harvest.

The number of days taken from sowing to first harvest of the fruits at vegetable maturity was recorded.

4. Percentage of fruit set

Ten flowers were tagged randomly from each plant and percentage of fruit set was worked out at 60 DAS in both seasons.

3.2.6.3. Yield and quality attributes

1. Length of fruit (cm) at 3rd, 6th and 9th harvest

2. Average fruit weight (g) at 3rd, 6th and 9th harvest

For recording the fruit characters, ten fruits were taken from each plot at 3rd, 6th and 9th harvest and mean values were computed to obtain average fruit length and fruit weight.

3. Mean fruit length (cm)

4. Mean fruit weight (g)

For recording mean fruit length and mean fruit weight, the average fruit length and fruit weight from every harvests were added and divided by the number of harvests.

5. The number of fruits per plant.

The total number of fruits harvested from a plot was divided by the number of plants (21) to get the number of fruits per plant.

6. Number of fruits per plot.

The total number of fruits from each plot was counted at each harvest and added up.

3. Fruit yield per plant (g)

The total fruit weight (g) from each plot was divided by the number of plants (21) to get fruit yield per plant.

4. Fruit yield per plot (kg / 13.5 m^2)

The total weight of fruits (g) collected from each plot was added up.

9. Malformations on plant and fruit characters, if any

Leaf and flower abnormalities due to the application of plant growth regulators if any, were recorded.

3.2.6.4. Biochemical characters

1. Protein content (%)

The pods were harvested at correct harvestable maturity for vegetable purpose, oven dried and ground to fine powder. The nitrogen content of the ground samples was estimated by micro-kjeldahl distillation and digestion method as described by Jackson (1973). The nitrogen content (%) of the sample was then multiplied with a factor 6.25 to get the crude protein content (%).

3.2.7. Pest and diseases

Observations on the incidence of major pest and diseases *viz.* aphids and mosaic were recorded.

The percentage of disease incidence ranging from zero to 25 per cent was also calculated by using the formula

$$\text{Per cent of disease incidence} = \frac{\text{Number of plants affected by disease}}{\text{Total number of plants}} \times 100$$

3.2.8. Statistical analysis

Data related to each character were analysed for Randomized Block Design (RBD) as suggested by Panse and Sukhatme (1967). Duncan's Multiple Range Test (DMRT) was used for comparing the treatments. To determine the seasonal influence on each character, pooled analysis over seasons were also carried out.

3.2.9. Estimation of net returns due to application of plant growth regulators

The yield data from different treatments were transformed to monetary values based on current market price of cowpea (Rs.7/kg). Gross returns due to application of plant growth regulators were worked out separately for each treatment taking into consideration of cost of inputs and cost of application (Appendix II and Appendix III).

RESULTS

4. RESULTS

The general analysis of variance (ANOVA) disclosed significant variation due to treatments for all the 19 characters studied during rabi season. During summer season, only twelve characters namely length of vine at final harvest, number of secondary branches, days to first flower, days to 50 per cent flower, days to first harvest, percentage of fruit set, number of fruits per plant, number of fruits per plot, fruit yield per plant, fruit yield per plot, mean pod length and mean pod weight exhibited significant variation due to different hormone treatments. Characters like length of fruit at 3^{rd}, 6^{th} and 9^{th} harvest, average pod weight at 3^{rd}, 6^{th} and 9^{th} harvest and protein content were not affected by the treatments.

4.1. Vegetative characters

4.1.1. Length of vine at final harvest (m)

Length of vine at final harvest exhibited significant response due to various growth regulators in both the seasons (Table 4.1.).

During rabi season, maximum vine length was recorded in T_1 (6.56 m) and minimum in T_9 (4.79 m). During summer season also, maximum vine length was observed in T_1 (6.60 m) while it was minimum in T_8 (4.19 m).

The pooled analysis of data revealed maximum vine length in T_1 (6.58 m) which received NAA 15 ppm and minimum in T_8 (4.56 m) which received PCPA 50 ppm. Vine length was maximum during rabi season (5.73 m) compared to summer season (5.55 m).

The treatment which received different concentrations of NAA was found to be effective for increasing the vine length compared to control. However, 2, 4-D and PCPA had negative effect on vine length.

4.1.2. Number of secondary branches

Treatment variation on the number of secondary branches was significant in both rabi and summer seasons. During rabi season, the number of secondary branches were maximum in T_1 (18.33) which was on par with T_{10} (18.00) and T_{11} (17.67). The number of secondary branches were minimum in T_9 (13.33) which was on par with T_4, T_5, T_6, T_7 and T_8 (13.67) (Table 4.2).

During summer season, the maximum number of secondary branches were obtained in T_{10} (19.33) which was on par with T_{11} and T_{12} (18.33) while it was minimum in T_5 and T_6 (11.67). The pooled analysis of the data revealed that maximum number of secondary branches in T_{10} (18.67) which received CCC 300 ppm and minimum in T_5 and T_6 (12.67). Seasonal variation was observed for the number of the secondary branches and was maximum in rabi (15.21) compared to summer (14.97) season.

The treatments which received CCC and NAA has increased the number of branches while 2, 4-D and PCPA has reduced the number of branches in both seasons.

Table 4.1. Length of vine (m) at final harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	6.56^{a}	6.60^{a}	6.58
T_2 - NAA 30 ppm	6.29^{b}	6.45^{ab}	6.37
T_3 - NAA 45 ppm	6.07^{bc}	6.21^{abc}	6.14
T_4 - 2,4-D 2 ppm	6.36^{e}	5.76^{d}	5.56
T_5 - 2,4-D 4 ppm	5.20^{ef}	5.04^{e}	5.12
T_6 - 2,4-D 6 ppm	5.07^{fg}	4.65^{f}	4.86
T_7 – PCPA 25 ppm	5.07^{fg}	4.42^{fg}	4.75
T_8 - PCPA 50 ppm	4.93^{gh}	4.19^{g}	4.56
T_9 - PCPA 75 ppm	4.79^{h}	4.40^{fg}	4.60
T_{10} – CCC 300 ppm	6.00^{c}	6.05^{bcd}	6.02
T_{11} – CCC 400 ppm	6.09^{bc}	6.07^{bcd}	6.08
T_{12} – CCC 500 ppm	6.14^{bc}	6.06^{bcd}	6.10
T_{13} – Water spray	5.96^{c}	6.05^{bcd}	6.01
T_{14} – No spray (Control)	5.64^{d}	5.83^{cd}	5.74
Mean	5.73	5.55	5.64

Ttreatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.2. Number of secondary branches at final harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	18.33^{a}	17.33^{abc}	17.83
T_2 - NAA 30 ppm	16.66^{bc}	16.33^{bc}	16.50
T_3 - NAA 45 ppm	15.67^{cd}	15.00^{cde}	15.33
T_4 - 2,4-D 2 ppm	13.67^{e}	13.00^{ef}	13.33
T_5 - 2,4-D 4 ppm	13.67^{e}	11.67^{f}	12.67
T_6 - 2,4-D 6 ppm	13.67^{e}	11.67^{f}	12.67
T_7 – PCPA 25 ppm	13.67^{e}	13.00^{def}	13.33
T_8 - PCPA 50 ppm	13.67^{e}	13.00^{ef}	13.33
T_9 - PCPA 75 ppm	13.33^{e}	12.00^{f}	12.66
T_{10} – CCC 300 ppm	18.00^{ab}	19.33^{a}	18.67
T_{11} – CCC 400 ppm	17.67^{ab}	18.33^{ab}	18.00
T_{12} – CCC 500 ppm	16.67^{bc}	18.33^{ab}	17.50
T_{13} – Water spray	14.33^{de}	15.00^{cde}	14.67
T_{14} – No spray (Control)	14.00^{e}	15.67^{cd}	14.83
Mean	15.21	14.97	15.09

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.2. Earliness

4.2.1. Days to first flower

Treatment effect for the opening of first flower was significant in both rabi and summer seasons. During rabi season, the number of days taken for first anthesis was maximum in T_8 (73.33) while it was minimum in T_{10} (39.33). Duncan's multiple range test (DMRT) revealed that T_{10} varies significantly from all other treatments (Table 4.3.)

During summer season, maximum number of days taken for the anthesis of first flower was in T_9 (56.33) while it was minimum inT_1 (48.00).

Seasonal variation was present for days to first flower opening. During rabi season the plants flowered earlier (48.21) than summer (52.57). Pooled analysis revealed that, maximum number of days for opening of the first flower was in T_8 (63.17) which received PCPA 50 ppm while it was minimum for T_{10} (46.17) which received CCC 300 ppm.

The treatment which received PCPA, NAA and 2, 4-D took more days to flower while CCC at 300 and 500 ppm was found to be effective for early flowering in rabi season. NAA was also found to be effective for early flowering during summer.

Table 4.3. Days to first flower in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	46.33^{cd}	48.00^{f}	47.17
T_2 - NAA 30 ppm	47.33^{cd}	49.33^{ef}	48.33
T_3 - NAA 45 ppm	50.00^{c}	52.33^{bcde}	51.17
T_4 - 2,4-D 2 ppm	47.33^{cd}	55.00^{ab}	51.17
T_5 - 2,4-D 4 ppm	49.00^{c}	51.33^{cdef}	50.17
T_6 - 2,4-D 6 ppm	40.67^{cd}	51.00^{cdef}	45.83
T_7 – PCPA 25 ppm	48.00^{cd}	50.67^{def}	49.33
T_8 - PCPA 50 ppm	73.33^{a}	53.00^{abcd}	63.17
T_9 - PCPA 75 ppm	62.67^{b}	56.33^{a}	59.50
T_{10} – CCC 300 ppm	39.33^{d}	53.00^{abcd}	46.17
T_{11} – CCC 400 ppm	46.33^{cd}	54.33^{abc}	50.33
T_{12} – CCC 500 ppm	41.00^{cd}	54.00^{abcd}	47.50
T_{13} – Water spray	41.33^{cd}	54.33^{abc}	47.83
T_{14} – No spray (Control)	42.33^{cd}	53.33^{abcd}	47.83
Mean	48.21	52.57	50.39

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.2.2. Days to 50 per cent flower

Treatment variation for 50 per cent of the plants to flower was significant in both rabi and summer seasons. During rabi season, the number of days taken for 50 per cent plants to flower was maximum in T_8 (90.67) which was on par with T_9 (88.33) and T_6 (86.67), while it was minimum for T_{14} (47.67) (Table 4.4)

During summer season, number of days for 50 per cent of the plants to flower was maximum in T_7 (80.00), and minimum in T_{10} and T_{11} (56.33). Seasonal variation was noticed for 50 per cent of plants to flower. The number of days taken for 50 per cent flowering was more in summer season (68.43) than rabi (67.14) season.

Pooled analysis revealed that maximum number of days taken for 50 per cent of plants to flower was highest in T_8 (84.83) which received PCPA 50 ppm which was on par with T_9 (83.33) which received PCPA 75 ppm while it was minimum in T_{12} (55.00), which received CCC 500 ppm.

During rabi season, 2,4-D and PCPA treatments delayed 50 per cent flowering. During summer season, NAA and CCC at all concentrations reduced the number of days taken for 50 per cent flowering.

Table 4.4. Days to 50 per cent flower in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	52.67^{bc}	61.67^{ef}	57.17
T_2 - NAA 30 ppm	52.67^{bc}	57.67^{ef}	55.17
T_3 - NAA 45 ppm	57.33^{b}	62.67^{e}	60.00
T_4 - 2,4-D 2 ppm	81.67^{a}	72.67^{cd}	77.17
T_5 - 2,4-D 4 ppm	85.67^{a}	76.33^{abc}	81.00
T_6 - 2,4-D 6 ppm	86.67^{a}	73.67^{bcd}	80.17
T_7 – PCPA 25 ppm	85.00^{a}	80.00^{a}	82.50
T_8 - PCPA 50 ppm	90.67^{a}	79.00^{ab}	84.83
T_9 - PCPA 75 ppm	88.33^{a}	78.33^{abc}	83.33
T_{10} – CCC 300 ppm	57.33^{b}	56.33^{f}	56.83
T_{11} – CCC 400 ppm	55.00^{bc}	56.33^{f}	55.67
T_{12} – CCC 500 ppm	50.33^{bc}	59.67^{ef}	55.00
T_{13} – Water spray	49.00^{bc}	72.67^{cd}	60.83
T_{14} – No spray (Control)	47.67^{c}	71.00^{d}	59.33
Mean	67.14	68.43	67.79

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.2.3. Days to first harvest

The treatment variation for days to first harvest was significant in both rabi and summer seasons. During rabi season, the number of days taken for first harvest was maximum in T_9 (89.00), while it was minimum in T_{10} (46.00) (Table 4.5).

During summer season, early harvest was obtained in T_1 (54.67), while the harvest was late in T_9, T_{10} and T_{12} (64.00).

The pooled analysis revealed that the number of days taken for first picking was highest in T_9 (76.50), which received PCPA 75 ppm, while it was minimum in T_{14} (54.00) which received no spray. The days to first harvest was early during summer (59.93) compared to rabi season (60.10).

All the growth regulators except CCC at 300 ppm delayed the first harvesting during rabi season. During summer season, NAA at lower concentrations (15 and 30 ppm) reduced the number of days taken for first harvest.

4.2.4. Percentage of fruit set

Treatment variation for fruit set percentage was significant in both rabi and summer seasons. During rabi season, the maximum fruit set percentage was obtained in T_1 and T_{10} (100 %) (Table 4.6). Due to malformations, flowering got delayed in 2,4-D and PCPA sprays compared to control.

During summer season, maximum fruit set was obtained in T_2 (63.33 %), while it was minimum for T_8 (14 %) which was on par with T_9 (14.67 %) and T_7 (17.33 %).

Pooled analysis indicated that fruit set percentage was highest in T_2(80.33), which received NAA 30 ppm and was on par with T_{10} (76.33) which received CCC 300 ppm. Seasonal variation was also observed for percentage of fruit set. It was maximum during rabi (63.36 %) compared to summer (36.57 %).

The treatments which received NAA and CCC increased the percentage of fruit set, while PCPA and 2,4-D reduced the fruit set.

Table 4.5. Days to first harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	57.00^{cd}	54.67^{d}	55.83
T_2 - NAA 30 ppm	59.33^{c}	56.33^{cd}	57.83
T_3 - NAA 45 ppm	58.33^{cd}	58.00^{bcd}	58.17
T_4 - 2,4-D 2 ppm	56.67^{cd}	62.00^{ab}	59.33
T_5 - 2,4-D 4 ppm	60.00^{c}	60.00^{abc}	60.00
T_6 - 2,4-D 6 ppm	58.67^{cd}	58.00^{bcd}	58.33
T_7 – PCPA 25 ppm	60.00^{c}	58.00^{bcd}	59.00
T_8 - PCPA 50 ppm	84.33^{b}	60.00^{abc}	72.17
T_9 - PCPA 75 ppm	89.00^{a}	64.00^{a}	76.50
T_{10} – CCC 300 ppm	46.00^{e}	64.00^{a}	55.00
T_{11} – CCC 400 ppm	60.33^{c}	60.00^{abc}	60.17
T_{12} – CCC 500 ppm	55.00^{d}	64.00^{a}	59.50
T_{13} – Water spray	48.67^{e}	60.00^{abc}	54.53
T_{14} – No spray (Control)	48.00^{e}	60.00^{abc}	54.00
Mean	60.10	59.93	60.02

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.6. Percentage of fruit set in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	100.00[a]	50.00[bc]	75.00
T_2 - NAA 30 ppm	97.33[ab]	63.33[a]	80.33
T_3 - NAA 45 ppm	97.00[ab]	49.00[bc]	73.00
T_4 - 2,4-D 2 ppm	35.00[c]	27.33[ef]	31.17
T_5 - 2,4-D 4 ppm	37.67[c]	26.00[ef]	31.83
T_6 - 2,4-D 6 ppm	33.33[c]	25.67[ef]	29.50
T_7 – PCPA 25 ppm	10.67[d]	17.33[f]	14.00
T_8 - PCPA 50 ppm	0.00[e]	14.00[f]	8.00
T_9 - PCPA 75 ppm	0.00[e]	14.67[f]	7.33
T_{10} – CCC 300 ppm	100.00[a]	52.67[ab]	76.33
T_{11} – CCC 400 ppm	90.67[b]	46.33[bcd]	68.50
T_{12} – CCC 500 ppm	97.33[ab]	52.33[ab]	34.83
T_{13} – Water spray	93.00[ab]	35.33[de]	64.17
T_{14} – No spray (Control)	92.67[ab]	38.00[cde]	65.33
Mean	63.36	36.57	47.09

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.3. Yield and yield attributes

4.3.1. Length of fruit (cm) at 3rd harvest

The various treatments showed significant difference on length of fruit at third harvest only during rabi season. In rabi season, the fruit length was maximum in T_{10} (39.11) which was on par with T_{11} (38.26) and T_1 (36.10) while it was minimum inT_8 (25.61) (Table 4.7). During summer season, the length of fruit at third harvest were found to be non significant.

Seasonal variation was not manifested in length of fruit at third harvest and it remained almost same for rabi and summer seasons (32.62 and 32.61 respectively). Pooled analysis indicated that fruit length was maximum in T_{10} (38.89) which received CCC 300 ppm, while it was minimum in T_8 (27.95) which received PCPA 50 ppm.

During rabi season, NAA and CCC was found to be effective for increasing the fruit length. 2, 4-D and PCPA at all concentrations has got a negative effect on fruit length at third harvest.

Table.4.7. Length of fruit (cm) at 3rd harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer (NS)	
T_1 – NAA 15 ppm	36.10^{a}	33.10	34.60
T_2 - NAA 30 ppm	32.56^{c}	32.40	32.49
T_3 - NAA 45 ppm	32.07^{c}	31.18	31.63
T_4 - 2,4-D 2 ppm	30.67^{cd}	30.73	30.71
T_5 - 2,4-D 4 ppm	28.43^{de}	28.15	28.39
T_6 - 2,4-D 6 ppm	31.30^{cd}	33.30	32.30
T_7 – PCPA 25 ppm	32.73^{bc}	33.54	33.14
T_8 - PCPA 50 ppm	25.61^{e}	30.28	27.95
T_9 - PCPA 75 ppm	31.51^{cd}	32.20	31.86
T_{10} – CCC 300 ppm	39.11^{a}	38.67	38.89
T_{11} – CCC 400 ppm	38.26^{a}	33.87	36.06
T_{12} – CCC 500 ppm	35.88^{ab}	34.62	35.25
T_{13} – Water spray	32.81^{c}	33.03	32.92
T_{14} – No spray (Control)	29.60^{cd}	31.50	30.31
Mean	32.62	32.61	32.61

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.3.2. Length of fruit (cm) at 6^{th} harvest

Fruit length at sixth harvest was influenced by different treatments during rabi season only. During rabi, fruit length was maximum in T_{10} (37.31) and minimum in T_8 (24.81) (Table 4.8).

The seasonal variation was manifested in length of fruit at 6^{th} harvest. The fruit length was more during summer season (33.15) and minimum in rabi season (31.44).

Pooled analysis revealed maximum fruit length in T_{10} (36.68) which received CCC 300 ppm and was on par with T_1 (35.31) and T_{11} (35.03) while it was minimum in T_5 (27.06) which received 2, 4-D 4ppm.

The treatments, which received NAA and CCC and 2,4-D 2 ppm, were effective for increasing the fruit length, while PCPA was not effective in rabi season.

Table 4.8 Length of fruit (cm) at 6th harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	34.99^{abc}	35.63	35.31
T_2 - NAA 30 ppm	32.52^{bcd}	32.47	32.50
T_3 - NAA 45 ppm	32.02^{cd}	33.71	32.87
T_4 - 2,4-D 2 ppm	33.37^{abc}	35.41	34.39
T_5 - 2,4-D 4 ppm	25.77^{fg}	28.34	27.06
T_6 - 2,4-D 6 ppm	27.04^{efg}	29.10	28.07
T_7 – PCPA 25 ppm	29.10^{def}	35.73	32.42
T_8 - PCPA 50 ppm	24.81^{g}	31.86	28.34
T_9 - PCPA 75 ppm	28.34^{defg}	34.13	31.24
T_{10} – CCC 300 ppm	37.31^{a}	36.04	36.68
T_{11} – CCC 400 ppm	36.22^{ab}	33.84	35.03
T_{12} – CCC 500 ppm	36.25^{ab}	33.44	34.85
T_{13} – Water spray	30.94^{cde}	32.10	31.52
T_{14} – No spray (Control)	31.47^{cd}	32.21	31.84
Mean	31.44	33.15	32.29

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.3.3. Length of fruit (cm) at 9th harvest

Fruit length at 9th harvest was significant only during rabi season. During rabi, fruit length was maximum in T_{10} (35.73) which was on par with T_{11} (35.23), while it was minimum in T_8 (22.08). During summer season, the length of fruit at 9th harvest was found to be not significant (Table 4.9).

Seasonal variation was noticed for fruit length at 9th harvest and it was more in summer season (32.67), than rabi season (29.64).

In pooled analysis, it was observed that fruit length remained high at T_{11} (36.10) which received CCC 400 ppm and T_{10} (35.92) which received CCC 300 ppm), while it was minimum in T_6 (28.17) which received 2,4-D 6 ppm.

The treatments which received NAA and CCC were found to be effective for increasing the fruit length, while PCPA and 2, 4-D were not effective in rabi season.

4.3.4. Mean fruit length (cm)

The mean fruit length exhibited a significant response with application of plant growth regulators in both the seasons (Table 4.10.). During rabi season, the mean pod length was maximum in T_{10} (37.80) followed by T_1 (34.49) and T_{11} (34.46), while it was minimum in T_9 (24.58).

During summer season also the mean pod length was maximum in T_{10} (36.86) followed by T_{11} (34.28) and T_{12} (33.38) but it was minimum in T_9 (24.49). Seasonal variation was observed for the mean pod length. It was minimum in rabi (30.78) compared to summer (30.00) season.

Pooled analysis indicated maximum pod length in T_{10} (37.33) which received CCC 300 ppm followed by T_{11} (34.37), which received CCC 400 ppm and minimum in T_6 (25.48) which received 2,4-D 6 ppm.

The treatments which received NAA and CCC increased the mean pod length during both the seasons. 2,4-D and PCPA at lower concentrations (2 and 25 ppm respectively) also increased mean fruit length.

4.3.5. Average fruit weight (g) at 3rd harvest

Individual pod weight at 3rd harvest was significantly influenced by different treatments during rabi season only. During rabi season, average fruit weight was maximum in T_{10} (18.69) which was on par with T_1 (17.94) and T_{11} (17.38), while it was minimum in T_9 (13.80) (Table 4.11).

Maximum pod weight at 3rd harvest was observed during summer (17.70) compared to rabi (16.61) season. Pooled analysis showed that pod weight at third harvest was maximum in T_{10} (19.23), which received CCC 300 ppm, while it was minimum for T_4 (14.80) which received 2, 4-D 2 ppm.

Effect of plant growth regulators on average pod weight at 3rd harvest was found to be significant only during rabi season. The treatments which received NAA 15 and 30 ppm and CCC 300 and 400 ppm were found to be effective for increasing the average pod weight at third harvest. 2, 4-D and PCPA was not found to be effective during rabi season.

4.3.6. Average fruit weight (g) at 6th harvest

Average pod weight at sixth harvest was also significantly influenced by different treatments only during rabi season (Table 4.12). During rabi, maximum pod weight were observed in T_{10} (18.55), while it was minimum for T_8 (12.97) which was on par with T_6 (13.60).

Weight of fruit varied significantly with seasons and it was maximum in summer (17.62), while it was minimum in rabi (15.59) season. Pooled analysis revealed that fruit weight was maximum in T_{10} (19.36), which received CCC 300 ppm, while it was minimum for T_8 (14.80) which received PCPA 50 ppm.

The treatment which received CCC was found to be effective to increase the average pod weight but NAA and 2,4-D was effective only at lower concentration (15 ppm and 2 ppm respectively). While, PCPA was not effective for increasing average pod weight in both the seasons.

Table 4.9. Length of fruit (cm) at 9th harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	32.34^{ab}	34.23	33.29
T_2 - NAA 30 ppm	31.27^{bc}	31.20	31.24
T_3 - NAA 45 ppm	30.56^{bc}	30.77	30.67
T_4 - 2,4-D 2 ppm	29.33^{bc}	32.80	31.07
T_5 - 2,4-D 4 ppm	25.29^{de}	31.43	28.36
T_6 - 2,4-D 6 ppm	25.11^{de}	31.23	28.17
T_7 – PCPA 25 ppm	28.82^{bc}	31.45	30.14
T_8 - PCPA 50 ppm	22.08^{e}	34.27	28.18
T_9 - PCPA 75 ppm	27.55^{cd}	30.37	28.96
T_{10} – CCC 300 ppm	35.73^{a}	36.10	35.92
T_{11} – CCC 400 ppm	35.23^{a}	36.97	36.10
T_{12} – CCC 500 ppm	32.23^{ab}	34.54	33.39
T_{13} – Water spray	30.11^{bc}	29.07	29.59
T_{14} – No spray (Control)	29.21^{bc}	32.94	31.08
Mean	29.64	32.67	31.15

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.10 Mean fruit length (cm) in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	34.49^{b}	32.82^{b}	33.66
T_2 - NAA 30 ppm	32.19^{c}	30.13^{c}	31.16
T_3 - NAA 45 ppm	31.41^{cd}	30.07^{c}	30.74
T_4 - 2,4-D 2 ppm	31.12^{cd}	29.73^{c}	30.41
T_5 - 2,4-D 4 ppm	26.74^{e}	26.34^{d}	26.54
T_6 - 2,4-D 6 ppm	25.74^{ef}	25.21^{de}	25.48
T_7 – PCPA 25 ppm	31.17^{cd}	30.69^{c}	30.93
T_8 - PCPA 50 ppm	27.30^{e}	26.31^{d}	26.81
T_9 - PCPA 75 ppm	24.58^{f}	24.49^{e}	24.54
T_{10} – CCC 300 ppm	37.80^{a}	36.86^{a}	37.33
T_{11} – CCC 400 ppm	34.46^{b}	34.28^{b}	34.37
T_{12} – CCC 500 ppm	34.16^{b}	33.38^{b}	33.77
T_{13} – Water spray	30.20^{d}	30.01^{c}	30.11
T_{14} – No spray (Control)	29.62^{d}	29.62^{c}	29.62
Mean	30.78	30.00	30.39

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.11 Average fruit weight (g) at 3rd harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	17.94^a	18.23	18.09
T_2 - NAA 30 ppm	17.37^a	17.37	17.37
T_3 - NAA 45 ppm	15.79^{ab}	17.37	16.58
T_4 - 2,4-D 2 ppm	14.16^b	15.43	14.80
T_5 - 2,4-D 4 ppm	15.98^{ab}	19.23	17.61
T_6 - 2,4-D 6 ppm	16.62^{ab}	17.90	17.26
T_7 – PCPA 25 ppm	15.63^{ab}	16.77	16.20
T_8 - PCPA 50 ppm	13.99^b	17.57	15.78
T_9 - PCPA 75 ppm	13.80^c	18.37	16.09
T_{10} – CCC 300 ppm	18.69^a	19.77	19.23
T_{11} – CCC 400 ppm	17.38^a	17.30	17.34
T_{12} – CCC 500 ppm	16.23^{ab}	17.73	16.98
T_{13} – Water spray	16.70^{ab}	19.20	17.95
T_{14} – No spray (Control)	17.65^a	15.58	16.62
Mean	16.61	17.70	16.99

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table. 4.12 Average fruit weight (g) at 6th harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	16.81^{abc}	17.90	17.36
T_2 - NAA 30 ppm	16.05^{abcd}	18.47	17.26
T_3 - NAA 45 ppm	15.27^{bcd}	18.73	17.00
T_4 - 2,4-D 2 ppm	16.67^{abc}	15.17	15.92
T_5 - 2,4-D 4 ppm	13.82^{cd}	15.97	14.90
T_6 - 2,4-D 6 ppm	13.60^{cd}	18.70	16.15
T_7 – PCPA 25 ppm	14.09^{cd}	17.97	16.03
T_8 - PCPA 50 ppm	12.97^{cd}	16.63	14.80
T_9 - PCPA 75 ppm	13.80^{cd}	16.63	15.22
T_{10} – CCC 300 ppm	18.55^{a}	20.17	19.36
T_{11} – CCC 400 ppm	17.73^{ab}	16.40	17.07
T_{12} – CCC 500 ppm	16.83^{abc}	18.07	17.45
T_{13} – Water spray	15.77^{abcd}	18.53	17.15
T_{14} – No spray (Control)	16.39^{abc}	17.37	16.88
Mean	15.59	17.62	16.61

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.3.7. Average fruit weight (g) at 9th harvest

Average fruit weight due to different treatments was significant only during rabi season. During rabi season, average fruit weight at 9th harvest was maximum in T_{11} (16.87), while it was minimum in T_8 (12.66) (Table 4.13). During summer season, the treatment variation remained non-significant. The fruit weight varied significantly between season and it was maximum in summer (16.87), and was minimum in rabi (14.74) season. Maximum fruit weight was obtained in T_{10} (18.05), which received CCC 300 ppm, while it was minimum in T_5 (14.60) which received 2, 4-D 4 ppm.

The treatments which received CCC was found to be effective for increasing the average pod weight at 9th harvest, while 2, 4-D and PCPA was not effective for increasing the average pod weight.

4.3.8. Mean fruit weight (g)

The mean pod weight exhibited a significant response with application of plant growth regulators in both the seasons (Table 4.14). During rabi season, the mean pod weight was maximum in T_{10} (17.95) which was on par with T_1 (17.81), T_2 (17.32) and T_{11} (17.24) while it was minimum in T_6 (14.01). During summer season also maximum mean pod weight was obtained in T_{10} (16.89) which was on par with T_1 (16.79), while it was minimum in T_9 (12.09) which was on par with T_8 (12.19) and T_7 (12.55).

Seasonal variation was also manifested for the mean pod weight. It was more during rabi (15.73) compared to summer (14.53) season. From the pooled analysis, it was observed that mean pod weight was maximum in T_{10} (17.42), which received CCC 300 ppm followed by T_1 (17.30) which received NAA 15 ppm, while it was minimum in T_9 (13.05) which received PCPA 25 ppm.

The treatments, which received all concentrations of NAA and CCC and 2,4-D at 2 ppm increased the mean pod weight during both the rabi and summer seasons. But PCPA at all concentrations was found to be ineffective for increasing pod weight.

4.3.9. Number of fruits per plant

During rabi and summer seasons, number of fruits per plant were significantly influenced by various treatments. During rabi season, maximum number of fruits were obtained from T_{10} (28.37) followed by T_1 (27.21). The fruit number per plant was minimum in T_9 (11.54) and T_8 (11.92) (Table 4.15).

During summer season also, number of fruits per plant was maximum in T_{10} (26.84) closely followed by T_{11} (26.39). The number of fruits per plant was minimum in T_9 (14.70) followed by T_7 (15.59) and T_8 (15.50).

From pooled analysis, it was observed that number of fruits per plant was highest in T_{10} (27.61) which received CCC 300 ppm, while it was minimum for T_9 (13.12) which received PCPA 75 ppm. Seasonal variation was observed for the number of fruits per plant and it was maximum during rabi (20.83) compared to summer (20.32) season.

The treatments which received all concentrations of NAA and CCC were found to be effective for increasing the number of fruits per plant while PCPA and 2, 4-D at all concentrations were not effective for increasing the number of fruits per plant. During summer season, all concentrations of NAA, CCC and 2 ppm of 2,4- D increased the number of fruits per plant.

4.3.10. Number of fruits per plot (13.5 m^2 area)

The different treatments had significant effect on number of fruits per plot in both rabi and summer seasons. During rabi season, the number of fruits per plot was maximum for T_{10} (573.92), which was on par with T_1 (572.39). The number of fruits per plot was minimum in T_8 (225.10)(Table 4.16).

During summer season also, the number of fruits per plot was maximum for T_{10} (561.91) followed by T_{11} (555.01) and T_{12} (524.40) while it was minimum in T_9 (302.97).

From the pooled analysis, it was observed that the number of fruits per plot was maximum in T_{10} (567.94) which received CCC 300 ppm, while it was minimum in T_9 (277.94) which received PCPA 75 ppm.

The growth regulators except PCPA and 2,4-D were found to have a positive effect on increasing the number of fruits per plot during rabi and summer seasons.

4.3.11. Fruit yield (g) per plant

During rabi and summer seasons, the fruit yield per plant was significantly influenced by various treatments. During rabi season, fruit yield per plant was maximum in T_1 (524.46) followed by T_{10} (476.13) and T_2(474.41) while it was minimum in T_8 (167.73) followed by T_9(175.14)) (Table 4.17).

During summer season, fruit yield per plant was maximum in T_{10} (428.16) which was on par with T_1(396.82), while it was minimum in T_9 (191.19). Per plant yield was maximum(339.76g) during rabi compared to summer(312.99). Mean of yield per plant,over two seasons was maximum in T_1 (460.44)) which received NAA 15 ppm, while it was minimum in T_9(183.17) which received PCPA 75 ppm.

During rabi season, the treatments which received NAA and CCC were found to be effective for increasing the fruit yield while 2,4-D and PCPA were not effective.

Table 4.13. Average fruit weight (g) at 9th harvest in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	16.11^{abc}	16.03	16.07
T_2 - NAA 30 ppm	15.61^{abcd}	13.97	14.79
T_3 - NAA 45 ppm	14.07^{cdef}	17.30	15.69
T_4 - 2,4-D 2 ppm	14.41^{bcdef}	14.90	14.66
T_5 - 2,4-D 4 ppm	13.89^{def}	15.30	14.60
T_6 - 2,4-D 6 ppm	12.83^{ef}	17.90	15.37
T_7 – PCPA 25 ppm	13.62^{def}	16.33	14.98
T_8 - PCPA 50 ppm	12.66^{f}	17.93	15.30
T_9 - PCPA 75 ppm	13.19^{ef}	18.27	15.73
T_{10} – CCC 300 ppm	16.42^{ab}	19.67	18.05
T_{11} – CCC 400 ppm	16.87^{a}	15.14	16.01
T_{12} – CCC 500 ppm	16.38^{ab}	18.23	17.31
T_{13} – Water spray	16.89^{abcde}	18.47	17.68
T_{14} – No spray (Control)	15.40^{abcd}	16.74	16.07
Mean	14.74	16.87	15.88

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.14. Mean fruit weight (g) in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	17.81^{a}	16.79^{a}	17.30
T_2 - NAA 30 ppm	17.32^{a}	15.60^{bc}	16.46
T_3 - NAA 45 ppm	16.35^{b}	14.39^{de}	15.37
T_4 - 2,4-D 2 ppm	15.14^{c}	14.09^{e}	14.62
T_5 - 2,4-D 4 ppm	14.31^{cde}	13.89^{e}	14.10
T_6 - 2,4-D 6 ppm	14.01^{e}	12.83^{f}	13.42
T_7 – PCPA 25 ppm	15.29^{cd}	12.55^{f}	13.92
T_8 - PCPA 50 ppm	14.37^{cde}	12.19^{f}	13.28
T_9 - PCPA 75 ppm	14.10^{de}	12.09^{f}	13.05
T_{10} – CCC 300 ppm	17.95^{a}	16.89^{a}	17.42
T_{11} – CCC 400 ppm	17.24^{a}	16.49^{ab}	16.87
T_{12} – CCC 500 ppm	16.17^{b}	16.26^{ab}	16.22
T_{13} – Water spray	15.16^{c}	15.27^{cd}	15.22
T_{14} – No spray (Control)	15.03^{c}	14.10^{e}	14.57
Mean	15.73	14.53	15.13

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.15 Number of fruits per plant in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	27.21^{b}	24.56^{bc}	25.88
T_2 - NAA 30 ppm	25.31^{d}	23.52^{c}	24.42
T_3 - NAA 45 ppm	25.26^{d}	22.42^{d}	23.84
T_4 - 2,4-D 2 ppm	17.19^{g}	20.56^{e}	18.88
T_5 - 2,4-D 4 ppm	13.25^{i}	19.31^{fg}	16.28
T_6 - 2,4-D 6 ppm	17.38^{g}	18.16^{g}	17.77
T_7 – PCPA 25 ppm	15.75^{h}	15.59^{h}	15.67
T_8 - PCPA 50 ppm	11.92^{j}	15.50^{h}	13.71
T_9 - PCPA 75 ppm	11.54^{j}	14.70^{h}	13.12
T_{10} – CCC 300 ppm	28.37^{a}	26.84^{a}	27.61
T_{11} – CCC 400 ppm	26.23^{c}	26.39^{a}	26.31
T_{12} – CCC 500 ppm	24.41^{e}	25.27^{b}	24.84
T_{13} – Water spray	20.15^{f}	20.32^{ef}	20.24
T_{14} – No spray (Control)	20.56^{f}	18.33^{g}	19.44
Mean	20.83	20.32	20.58

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table.4.16. Number of fruits per plot in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	572.39[a]	512.51[d]	542.45
T_2 - NAA 30 ppm	544.86[b]	492.04[e]	518.45
T_3 - NAA 45 ppm	531.35[c]	477.65[f]	504.50
T_4 - 2,4-D 2 ppm	340.75[g]	418.43[g]	379.59
T_5 - 2,4-D 4 ppm	269.52[i]	398.02[h]	333.77
T_6 - 2,4-D 6 ppm	369.62[f]	385.35[i]	377.49
T_7 – PCPA 25 ppm	323.96[h]	370.14[j]	347.05
T_8 - PCPA 50 ppm	225.10[k]	333.53[k]	279.32
T_9 - PCPA 75 ppm	252.91[j]	302.97[l]	277.94
T_{10} – CCC 300 ppm	573.92[a]	561.95[a]	567.94
T_{11} – CCC 400 ppm	551.36[b]	555.01[b]	553.19
T_{12} – CCC 500 ppm	515.36[d]	524.40[c]	519.88
T_{13} – Water spray	446.78[e]	422.70[g]	434.70
T_{14} – No spray (Control)	437.55[e]	390.16[i]	413.85
Mean	425.37	438.92	432.15

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

Table 4.17. Fruit yield (g) per plant in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	524.46^{a}	396.82^{a}	460.44
T_2 - NAA 30 ppm	474.41^{b}	324.07^{bc}	399.24
T_3 - NAA 45 ppm	426.85^{cd}	353.93^{b}	390.39
T_4 - 2,4-D 2 ppm	276.26^{g}	304.75^{c}	290.51
T_5 - 2,4-D 4 ppm	210.99^{i}	292.07^{c}	251.53
T_6 - 2,4-D 6 ppm	253.47^{h}	287.47^{c}	270.47
T_7 – PCPA 25 ppm	209.47^{i}	246.52^{d}	277.99
T_8 - PCPA 50 ppm	167.73^{j}	225.93^{de}	196.83
T_9 - PCPA 75 ppm	175.14^{j}	191.19^{e}	183.17
T_{10} – CCC 300 ppm	476.13^{b}	428.16^{a}	452.15
T_{11} – CCC 400 ppm	436.03^{c}	395.34^{a}	415.69
T_{12} – CCC 500 ppm	415.49^{d}	351.03^{b}	383.26
T_{13} – Water spray	365.48^{e}	292.13^{c}	328.80
T_{14} – No spray (Control)	344.68^{f}	292.42^{c}	318.55
Mean	339.76	312.99	326.37

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.3.12. Fruit yield per plot (kg/13.5 m^2)

Productivity of the crop was significantly influenced by different treatments in both seasons. During rabi season, fruit yield per plot was highest in T_1 (10.11), while it was minimum in T_9 (3.66) followed by T_8 (3.80). During summer season, fruit yield was found to be highest in T_{10} (8.65) followed by T_1 (8.26) and it was minimum inT_9 (4.18) followed by T_8 (4.84) (Table 4.18).

Pooled analysis revealed highest yield in T_{10} (9.29) which received CCC 300 ppm which was on par with T_1 (9.18) which received NAA 15 ppm. Yield recorded was minimum in T_9 (3.92) which received PCPA 75 ppm. The seasonal variation was also observed with a maximum pod yield during rabi (6.97) compared to summer (6.76).

During rabi season, NAA 15 ppm was found to be effective for increasing the crop productivity (Plate 4.1). But in summer season, CCC at 300 ppm increased the fruit yield (Plate 4.2).

Table 4.18. Fruit yield per plot (kg/13.5 m^2) in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	10.11^{a}	8.26^{b}	9.18
T_2 - NAA 30 ppm	9.51^{bc}	7.94^{c}	8.73
T_3 - NAA 45 ppm	8.69^{d}	7.63^{d}	8.16
T_4 - 2,4-D 2 ppm	5.50^{f}	6.63^{f}	6.07
T_5 - 2,4-D 4 ppm	4.19^{gh}	6.47^{f}	5.33
T_6 - 2,4-D 6 ppm	4.22^{g}	6.14^{g}	5.18
T_7 – PCPA 25 ppm	4.68^{h}	5.39^{h}	5.04
T_8 - PCPA 50 ppm	3.80^{i}	4.84^{i}	4.32
T_9 - PCPA 75 ppm	3.66^{i}	4.18^{j}	3.92
T_{10} – CCC 300 ppm	9.94^{ab}	8.65^{a}	9.29
T_{11} – CCC 400 ppm	9.37^{c}	8.43^{b}	8.90
T_{12} – CCC 500 ppm	8.71^{d}	7.35^{e}	8.03
T_{13} – Water spray	7.57^{e}	6.51^{f}	7.04
T_{14} – No spray (Control)	7.48^{e}	6.22^{g}	6.85
Mean	6.97	6.76	6.86

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.4. Biochemical characters

4.4.1. Protein content (%)

Protein content was significantly influenced by different treatments only during rabi season. In rabi season, the crude protein percentage was maximum in T_{12} which received CCC 500 ppm (27.27 %) while it was minimum in T_9 (21.23 %). The protein content remained more or less same in both rabi and summer seasons (24.10 % and 24.23 % respectively) (Table 4.19).

Pooled analysis revealed that maximum protein percentage was obtained in T_{10} (26.10), which received CCC 300 ppm and it was minimum in T_{14} (22.34), which was the control (No spray).

The treatments which received 2,4-D, NAA and CCC was found to be effective for improving the protein content in rabi season, while PCPA was effective only at lower concentration (25 ppm) during rabi season.

Table 4.19. Protein content (%)in different seasons

Treatments	Seasons		Mean
	Rabi	Summer	
T_1 – NAA 15 ppm	26.66[ab]	23.98	25.32
T_2 - NAA 30 ppm	25.73[bc]	22.45	24.09
T_3 - NAA 45 ppm	25.49[bc]	23.12	24.31
T_4 - 2,4-D 2 ppm	24.73[cd]	24.16	24.45
T_5 - 2,4-D 4 ppm	23.97[d]	26.12	25.05
T_6 - 2,4-D 6 ppm	22.22[ef]	25.13	23.68
T_7 – PCPA 25 ppm	22. 65[e]	25.46	23.81
T_8 - PCPA 50 ppm	21.87[ef]	23.12	22.50
T_9 - PCPA 75 ppm	21.23[f]	24.36	22.80
T_{10} – CCC 300 ppm	25.61[bc]	26.59	26.10
T_{11} – CCC 400 ppm	25.90[bc]	25.02	25.46
T_{12} – CCC 500 ppm	27.27[a]	23.79	25.53
T_{13} – Water spray	22.46[e]	23.79	23.13
T_{14} – No spray (Control)	22.05[ef]	22.62	22.34
Mean	24.10	24.23	24.18

Treatments having same alphabets as the superscripts in each season belong to one homogeneous group.

4.5. Malformations on fruit and plant characters

Leaf abnormalities were observed for 2,4-D and PCPA application. Abnormalities were observed on the day of application and continued upto 30 days, in case of 2, 4-D spray and up to 60 days in PCPA.

In case of 2, 4-D (2,4 and 6ppm) application, 75 per cent of the foliage was malformed. Malformations were observed as vein banding, crinkling, curling and narrowing of leaf lamina (Plate 4.4). No leaf lobbing was observed. Leaves were strap shaped, measuring a leaf area of 5.6 cm^2 compared to control (90 cm^2). The inter nodal length was increased drastically. In malformed plants it was 25 cm while it was only 15 cm for normal plants. Pod length was also reduced to 25 cm in 2,4-D treated plants compared to normal plants (34 cm). Pod weight was also reduced compared to control plants. In case of 2,4-D treated plants, total chlorophyll content was found to be 2.028 mg per gm of tissue, which was less compared to normal leaf (2.09). Chlorophyll *b* content was also less (0.619 mg per g) in 2,4-D applied plants compared to normal plants (0.635). Recovery of the plants from malformations were observed at 30 days after first application.

In case of PCPA (25, 50 and 75 ppm) application, 90 per cent of the plants were malformed. Malformations were observed as upward cupping of leaves, thickening of leaf lamina, funnel shaped leaves with dark green coloured leaves etc (Plate 4.5). The leaves were noticed as non-lobbed and no compound leaflets were observed. Leaf area was also less (28 cm^2) compared to control plants (90 m^2). The inter nodal length was too long (30 cm) in malformed plants compared to normal plants (15 cm) (Plate. 4.3). The plants appeared as rosette in nature with no further growth. The recovery of the plants was noticed after 60 days of application. In case of total chlorophyll content, PCPA applied plants showed higher values (2.68 mg per g) compared to control (2.09 mg per g). PCPA sprayed plants had high chlorophyll *b* content (1.06), than untreated plants (0.635mg / g).

4.6. Incidence of pests and diseases

Pests like aphids (*Aphis craccivora*), leaf miners (*Liriomyza trifolii.*), pod borer (*Adisura atkinsonii*) and fungal diseases like powdery mildew (*Erisiphe polygoni*) were noticed during the cropped period were promptly controlled by the application of plant protection chemicals. However, mosaic disease caused by cowpea mosaic virus could not be controlled.

The percentage of mosaic incidence was worked out for both rabi and summer seasons .The incidence of mosaic was maximum during summer (24.55 %) compared to rabi season (14.75 %) (Table 4.20). In case of mosaic incidence, minimum mosaic was noticed in CCC treatments. The CCC applied plants have a mean mosaic incidence of 4.55 per cent during summer compared to 24.55 per cent in the non treated control.

Malformations due to plant growth regulator application

Plate 4.3. Unsprayed control

Plate 4.4. 2,4-D spray

Plate 4.5. PCPA spray


R2T14
(NO Spray)


R1T4
(2,4-D 2PPM


PCPA

Table 4.20. Percentage of mosaic incidence in rabi and summer seasons

Treatments	Rabi (%)	Summer (%)
T_1 – NAA 15 ppm	8.75	10.18
T_2 - NAA 30 ppm	9.15	10.55
T_3 - NAA 45 ppm	7.16	8.55
T_4 - 2,4-D 2 ppm	8.87	11.31
T_5 - 2,4-D 4 ppm	7.51	10.77
T_6 - 2,4-D 6 ppm	7.84	9.49
T_7 – PCPA 25 ppm	9.19	12.13
T_8 - PCPA 50 ppm	8.39	11.14
T_9 - PCPA 75 ppm	7.35	10.54
T_{10} – CCC 300 ppm	3.45	5.55
T_{11} – CCC 400 ppm	2.51	4.17
T_{12} – CCC 500 ppm	2.85	3.93
T_{13} – Water spray	15.33	20.78
T_{14} – No spray (Control)	14.75	24.55
Mean	8.08	10.97

DISCUSSION

5. DISCUSSION

Yard long bean, also known as asparagus bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) is one of the most popular leguminous vegetable crop grown in Kerala. It is valued for its tender green pods rich in protein (28 %) and minerals like phosphorus (74 mg/100g), potassium, calcium (2.5 mg/100g), vitamins A (941 IU/100g) and C (13 mg/100g) and dietary fibre (2 /100g). The crop is grown throughout the year and is highly preferred by the vegetable farmers because of its protracted fruiting, steady demand and better price in the market.

Very often, incidence of mosaic disease, flower fall and low fruit set lead to low productivity and causes heavy loss to the farmers. The application of plant growth regulators was found as an efficient tool in improving the growth and productivity in many vegetable crops (Singh and Choudhary, 1966; Verma and Choudhary, 1980; and Thakkur and Arora, 1986)

Enormous variation which can be brought about through judicious application of plant growth substances reveals the significance of their discovery and usage in crop production. Availability of a number of naturally occurring and synthetic growth regulators opened up new vistas to look for substances with specific actions. The synthetic growth regulators impart their effect by modifying the plant growth and development through changes in the endogenous levels of naturally occurring hormones. The application of these substances increases the endogenous hormonal level and induces several morphological, physiological and biochemical changes which interfere with the growth and productivity of the crop.

In the present investigation, the effect of four plant growth regulators at varying concentrations on yard long bean var. 'Lola' (VS – 13 – 2) were studied during rabi and summer seasons. Naphthalene acetic acid at 15, 30 and 45 ppm; 2,4-D at 2, 4 and 6 ppm; PCPA at 25, 50 and 75 ppm and CCC at 300, 400 and 500 ppm constituted different treatments and were compared with water spray and unsprayed control. The results obtained from the study are discussed below.

5.1. Vegetative growth

The effect of plant growth regulators on vegetative characters like length of vine and number of branches were more pronounced during rabi season than summer. NAA at all concentrations increased the vigour of plants by increasing vine length and number of branches. With increase in concentration of NAA, both the characters were found decreased. The vine length was maximum at lower concentration (15 ppm) of NAA (T_1) during rabi (6.56 m) and summer (6.60 m) seasons (Fig. 5.1). During rabi, number of branches were also maximum at NAA 15 ppm (18.33) closely followed by CCC at 300 ppm (18.00). However, during summer season, all concentrations of CCC produced more number of branches (18.33 to 19.33) than NAA (15.00 to 17.33) (Fig. 5.2).

The NAA has increased the vine length and number of branches through the action of enhanced cell growth and cell elongation at the inter nodal region. The significant increase in vine length observed with application of NAA is in agreement with the findings of Singh and Upadhyay (1967). The growth regulator like NAA initiates cell division and cell elongation by continued synthesis of RNA and protein. It is also well documented that exogenous application of auxin causes pH changes in terms of H^+ extrusion and H^+ inturn which leads to wall loosening causing cell elongation (Dhanalakshmi *et al.*, 1996).

The application of NAA might have increased the growth of plants due to stimulation of root growth for increased absorption of nutrients from soils. Induction of the stimulus responsible for the formation of tracheary elements by the external application of auxin in intact plants as reported by Thompson (1970) can be suggested as a possible reason for increasing the vine length. The increase in height of plants and number of secondary branches in case of NAA can also be due to its stimulatory growth activity and plasticity within the cells. The elongation of the main axis is also due to the osmotic uptake of water under the influence of growth regulators, which maintain a swelling force against softening of cell wall. It was also observed that certain amount of check on apical

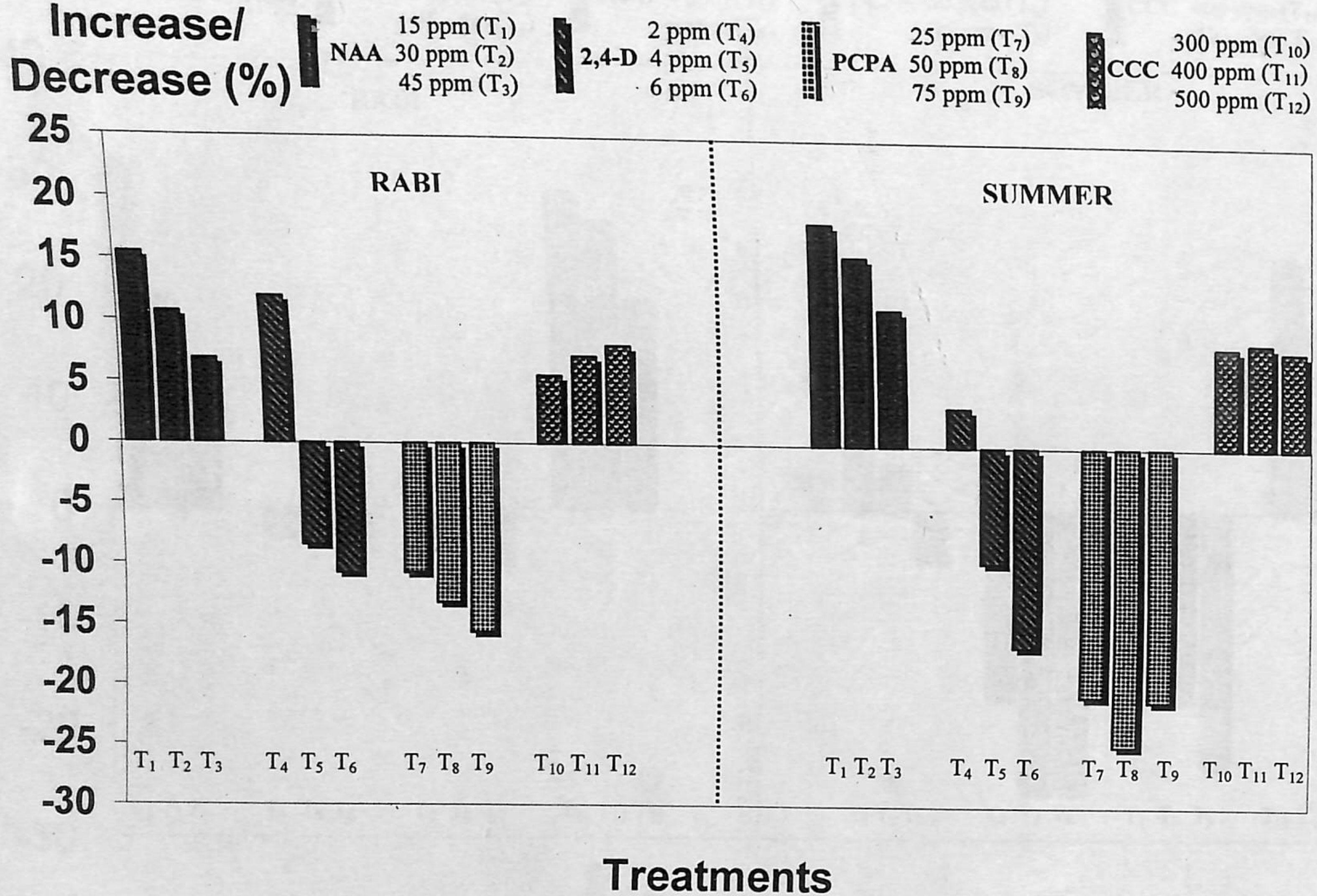


Fig. 5.1. Length of vine with application of plant growth regulators in different seasons

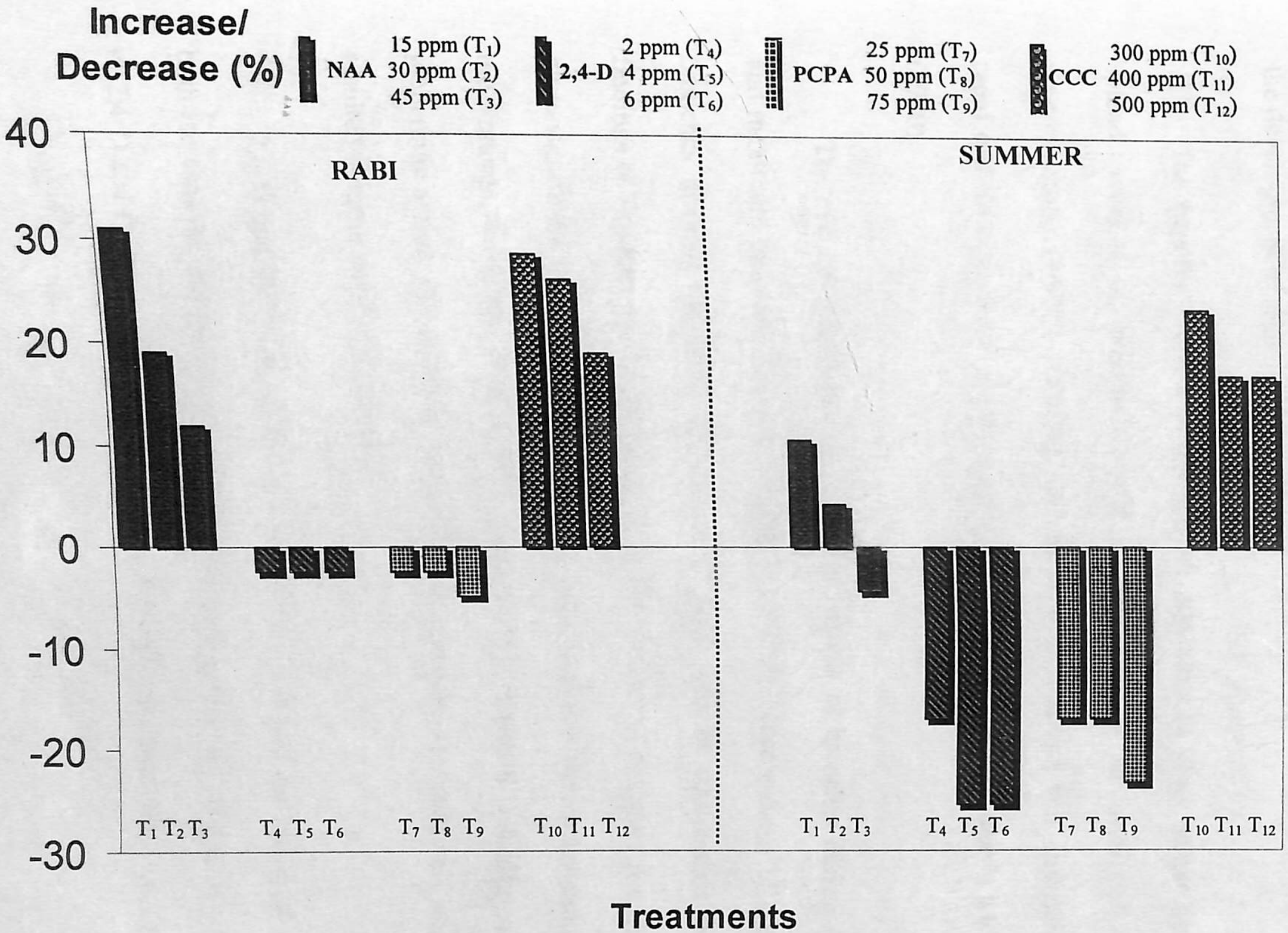


Fig. 5.2. Number of secondary branches in different treatments over seasons

dominance could invariably result in the accelerated development of the auxilliary buds into new branches. Additional auxilliary buds naturally provide extra site for the development of more inflorescence.

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

The cycocel (CCC) has increased the number of branches during summer and maximum branches were recorded in T_{10} (19.33). More number of secondary branches through the foliar application of CCC was in consonance with the findings of Willams and Malhothra (1983). The number of branches per plant was more significant in CCC 300 ppm during summer and this was in agreement with the findings of Mangal *et al.* (1981). Since CCC is a growth retardant, its anti-gibberellic action will naturally reduce the elongation of the main axis and hence resulted in more auxilliary branches.

2,4-D and PCPA at all concentrations have reduced the length of vine in both the seasons and the number of branches during summer season. Application of 2,4-D and PCPA at 30 days after sowing has led to malformations of the leaves and branches. In case of 2,4-D application, malformations were observed as crinkling of leaves and narrowing of leaf lamina. The leaves appeared strap-shaped and leaf area was drastically reduced to 5.6 cm^2 from 90 cm^2 in normal plants. The growth was also found stunted. Malformations with application of PCPA were observed as upward cupping of leaves and thickening of leaf lamina, funnel shaped leaves without any leaflets. The growth was also reduced drastically. The chlorophyll *b* content in the leaves of PCPA treated plants were high (1.06 mg/g of tissue) compared to normal plants (0.63 mg/g of tissue).

The reduction in plant height and number of branches with application of 2,4-D and PCPA may be due to its herbicidal action at supra optimal level. 2,4-D, though primarily a weedicide has found wide application for regulating various growth responses when used in low concentrations. The different types of leaf malformations, epinasty and bushy growth were observed in bhindi (Rukhmani, 1990). Kuraishi and Mair (1963) inferred that restriction of plant height was mainly due to the reduction in diffusible auxin level in the plant tissues. Reduction in plant height and vine length was primarily due to reduced photosynthetic area caused by retardation of cell division and cell elongation mostly at the sub apical meristem brought about by its application.

5.2. Earliness

Earliness is considered as a desirable trait in cowpea and helps the farmers to market the produce early in the season for fetching maximum price. Days to first flower, days to first harvest and days to 50 per cent flowering are considered as indicators of earliness. During the present investigation, the crop sown during rabi season was early for the number of days to first flower (48.21), days to 50 per cent flower and days to first harvest (67.14 and 60.10 respectively) compared to summer crop. Incidence of mosaic diseases and aphid infestation at the vegetative stage might have delayed the flowering and harvest of the crop during summer season. During rabi season, CCC at 300 ppm was the earliest to flower (39.33 days) and fruit harvest (46.00 days). During summer season also, days to 50 per cent flower was minimum in all CCC treatments (56.33 each in T_{10} and T_{11} and 59.67 days in T_{12}).

In the present study, CCC 300 ppm significantly reduced the number of days taken for flowering and fruiting. Earliness induced by CCC might be due to increased synthesis of endogenous growth substances in plant parts and their simultaneous translocation to the buds, there by triggering the metabolic processes and narrowing the carbon nitrogen ratio (Ries, 1985). Since CCC was applied at 20 DAS, it might have caused reduction in endogenous growth regulators and hence early transformation of the plant from vegetative to the reproductive phase than unsprayed plants. The reduction in endogenous gibberellin content through application of CCC can also be a probable reason (Islam and Mitchsi, 1993). Early flowering by spray of CCC at 300 ppm has lead to early harvest of pods in T_{10} (Fig. 5.4).

Plants sprayed with NAA 15 ppm (T_1) was the earliest to flower (48 days) and first harvest (54.67 days) during summer season (Fig. 5.3). In all the three NAA treatments (T_1 to T_3), days to 50 per cent flowering were earlier than non-treated control. In the present investigation, seasonal variation was observed in the effect of NAA and CCC in inducing earliness.

According to Menon (1981) NAA acts through fundamental processes like nucleic acid synthesis, enzyme synthesis and activation. This may be due to higher dry matter accumulation in the reproductive parts (mostly pods) in the crop receiving NAA spray than unsprayed crop. Earliness in flowering and fruit set is an indication of early transformation of plants to reproductive phase (Das and Rabha, 1999). Though, NAA and CCC induced earliness, their mode of action varied. Since CCC is a stress hormone, its effects were more pronounced in high temperature (summer) condition by reducing the content of endogenous growth regulators especially gibberellins. NAA was found to have positive effect during rabi season by directly increasing the endogenous growth substances like auxins & gebberellins, which in turn reduces cell elongation and growth. The application of

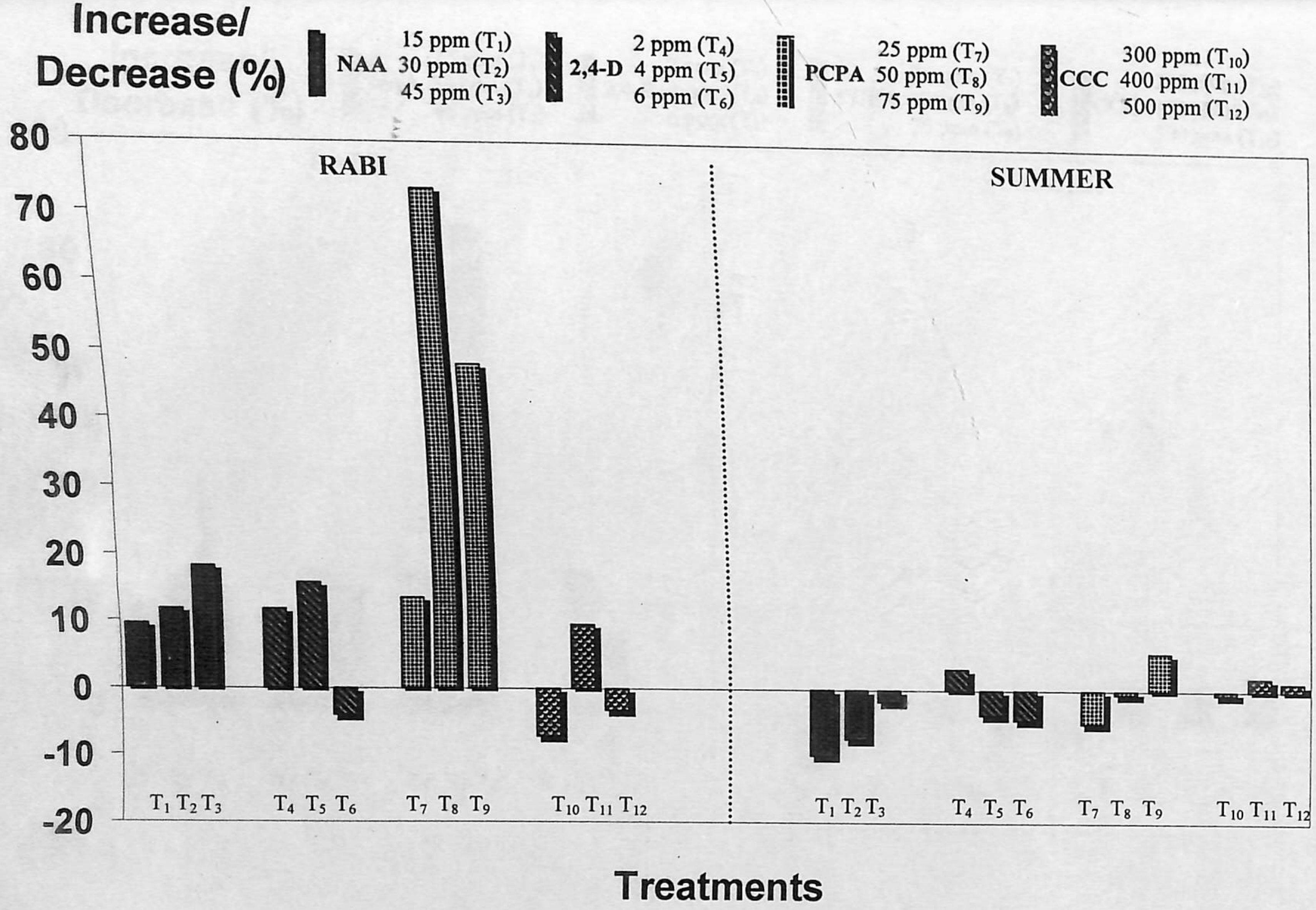


Fig. 5.3. Days taken to first flower in different treatments over seasons

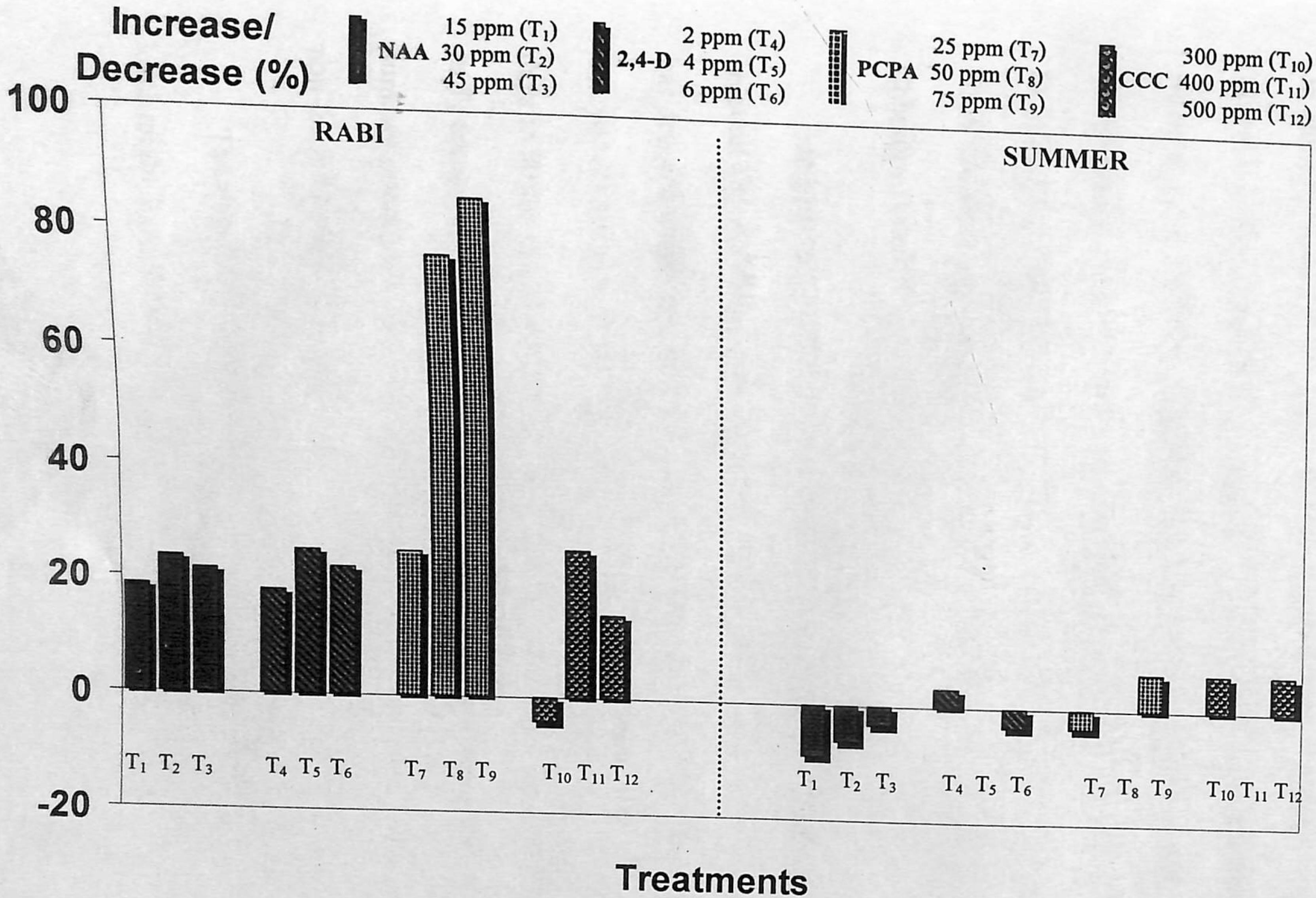


Fig. 5.4. Days taken to first harvest in different treatments over seasons

NAA was most effective in inducing earliness as reflected by early fruit set and harvest in all seasons. Higher values of index to earliness during summer season were earlier reported in okra (Rukhmani, 1990). Similar results were also reported in chilli by Usha (1988). Osborne (1963) opined that the auxins maintain the rate of RNA synthesis and thereby delay senescence. NAA produced large number of flowers and early flower initiation which was ascribed to the reason that florigen or flowering hormone which was synthesized under the influence of endogenous IAA, which in turn influence the production of flower primordia. Application of NAA induced early maturity of heads in cabbage by 4-7 days (Singh and Chhonkar, 1965).

In general, 2,4-D and PCPA treated plants delayed the flowering in both the seasons and was more pronounced during the rabi season. PCPA at 50 ppm (T_8) has delayed the flowering to 73.3 days from sowing during rabi season. PCPA also delayed 50 per cent flowering in both rabi and summer seasons considerably. The days to 50 per cent flowering in 2,4-D treated plants ranged from 85 in T_7 to 90.67 in T_8 compared to non-treated control T_{14} (47.67 days) during rabi season. During summer season also, the 2,4-D treatments were late for 50 per cent flowering than non-treated control (71 days).

The vegetative malformations caused by 2,4-D and PCPA at supra optimal level might have contributed for the lateness in 2,4-D and PCPA treated plants.

These foliar abnormalities caused retardation of cell division and cell elongation mainly in the sub apical meristem brought about by its application. Another probable reason may be due to the retardation in diffusible auxin level in the plant tissue with the application of 2,4-D and PCPA at supra optimal level. This is in consonance with the findings of Kuraishi and Mair (1963). Compared to rabi season, the overall performance of the crop was not encouraging during the summer season. This was mainly because of high temperature, uneven distribution of rainfall and incidence of pest like aphids and disease like mosaic during summer months.

Another probable reason for reduced yield in summer can be due to reduced water uptake with high transpiration and photo degradation of endogenous growth substances.

5.3. Fruit set

Seasonal variation was observed for days to first flower in the present study. During rabi season, the flowering started 48 days after sowing and during summer season, it took 52 days. The percentage of fruit set was also more during rabi season (63.36) compared to summer (36.57) and was significantly influenced by the application of growth regulators during both seasons (Fig. 5.5). During rabi season, the fruit set percentage was above 90 per cent in all the three concentrations of NAA and CCC. All the opened flowers set fruits in plants

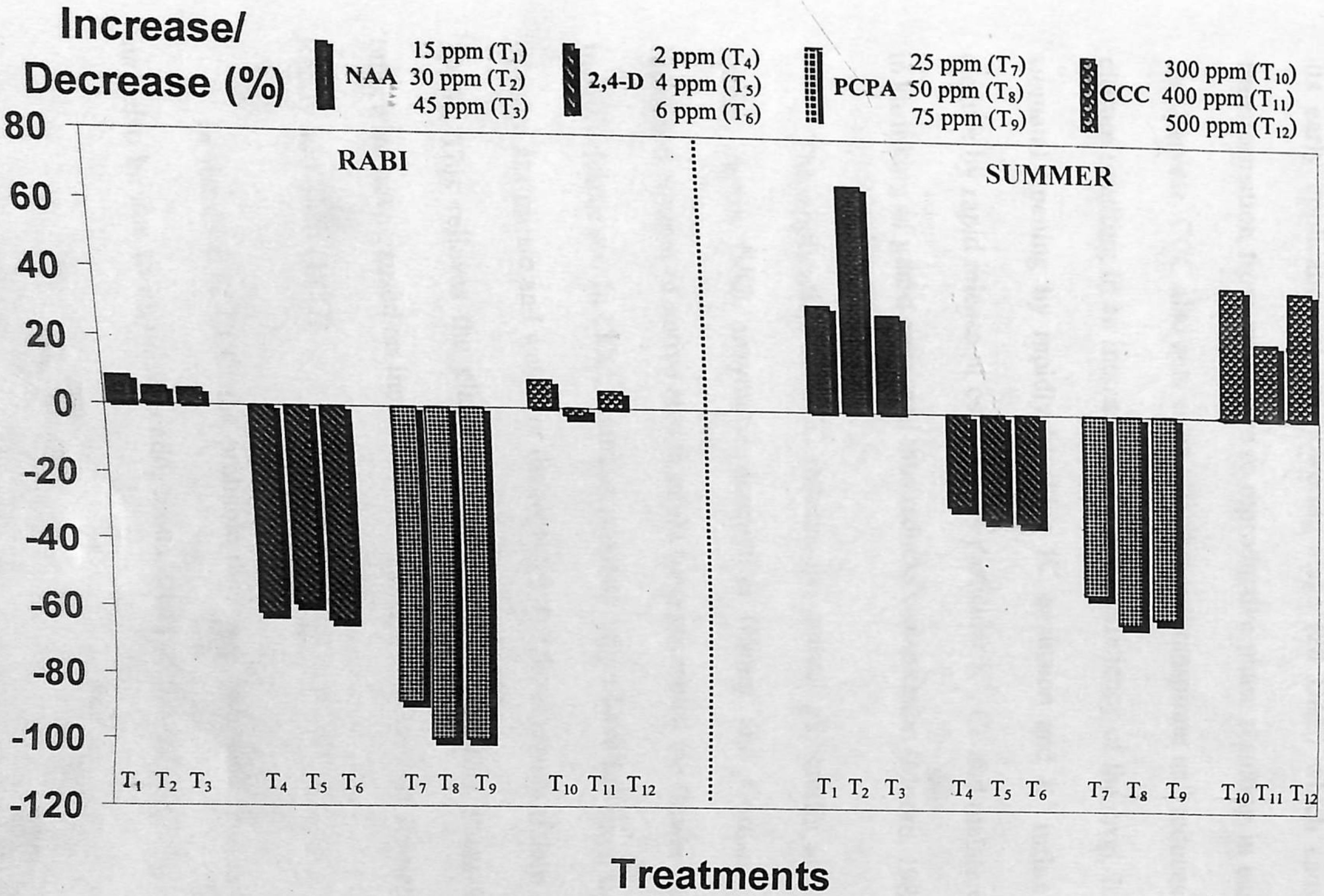


Fig. 5.5. Percentage of fruit set in different treatments over seasons

sprayed with NAA 15 ppm and CCC 300 ppm during rabi season. During summer season also, percentage of fruit set was maximum with NAA and CCC treatments.

The increased fruit set percentage with application of CCC may be due to its early application at pre-flowering stage (20 DAS) which causes a sudden transformation from vegetative to reproductive phase resulting in early flowering and harvest. CCC also acts as an effective antitranspirant and reduces the stomatal closure resulting in an increase in water use efficiency of the crop. It prevents the stomatal opening by rapidly blocking H^+ exclusion and K^+ influx and initiate closure by rapid release of osmotica, in particular K^+, Cl^- and malate which results in shrinking of guard cells and thus reduces transpiration (Moore, 1989).

The application of CCC reduces the natural gibberellin and protects the natural auxin from enzymatic destruction (Henry and Gordan, 1980). This increased content of native auxins might have prevented the flower abscission and increased fruit set. In CCC, retardant property might have favoured the diversions of more assimilate and water for the reproductive development (Islam and Mitchsi, 1993). This relieves the plants off water and carbohydrate stress which could otherwise have caused an increased flower drop as reported by Rudich (1986) and Reddy and Shah (1987).

In the case of CCC, the probable reason of increased fruit set percentage may also be due to increased endogenous levels of natural auxin by reducing the gibberellin content by the application of growth retardants (Das, 1985). The application of CCC also increases the chlorophyll retention activity of plants even during summer season and hence helps the plants to overcome the stress condition.

The effect of NAA stimulates more number of ovaries and prevents their subsequent abscission resulting in increased fruit set. The same result was also reported by Usha (1988) with application of NAA in chilli, which increases the ascorbic acid and IAA content of flower buds (Chandra and Raj, 1972).

NAA increased the flower and fruit retention by reducing the shedding of fertilized flower. It is also suggested that the diffusible auxins moving from a dominant sink act as a correlative signal regulating abscission of competitive sinks. Addicot and Lynch (1955) attributed the exhaustion of growth substances as the immediate cause of flower drop. Ali (1964) proved that auxins are the agents which stimulate the ovaries to develop. He also demonstrated that synthetic auxins like NAA induced unpollinated ovaries to develop full sized fruits and retaining them till maturity. The improved retention of pods by reduced abscission of reproductive parts with exogenous application of NAA have been reported in cowpea (Jayaram and Ramaiah, 1980). The plant growth regulators like auxins increased the allocation of drymatter to the developing pods and seeds and thereby indicating their influence in reproductive potential of the plant (Zayed *et al.*, 1986). Normally, NAA reduces flower and pod shedding when applied at flower initiation and vegetative stage (Alagukannan and Vijayakumar, 1999).

The fruit set percentage was minimum in PCPA and 2,4-D treatments. The treatments with PCPA 50 and 75 ppm (T_8 and T_9) did not set fruits in rabi season. When PCPA application was delayed to 45 DAS during summer, there was a gradual increase in percentage of fruit set (14 to 17.33). The percentage of fruit set in 2,4-D treatments ranged from 33.33 to 37.67 during rabi season compared to untreated control (92.67). In 2,4-D treatments, a reduction in fruit set was noticed during summer. A decrease in percentage of fruit set with increase in concentration of 2,4-D was also observed in summer season.

Weedicidal property of 2,4-D and PCPA has hindered the growth of vegetative parts and flower retention in cowpea. Bangal *et al.* (1983) and Brar (1992) also reported similar results in chick pea with foliar spray of growth retardant like 2,4-D and some growth inhibitors. In case of PCPA application, fruit set percentage was higher in summer compared to rabi season, and it may be due to its delayed application at 45 DAS. The low fruit set in 2,4-D and PCPA may also be due to vegetative malformations and maximum flower shedding.

5.4 Fruit size

The length of pod and average pod weight were significantly altered by the different plant growth regulators. NAA and CCC at all concentrations increased the length of pod during rabi season. The mean pod length was maximum at T_{10} (37.80 cm), where CCC 300 ppm was sprayed. T_{10} was on par with T_1 (NAA 15 ppm). Seasonal variations for the pod characters were also manifested during the study. During summer, maximum pod length was recorded in CCC 300 ppm (36.86 cm). The positive effect of CCC on pod length was also confirmed at all concentrations during summer. In CCC treatments, the length was maximum at 300 ppm concentration at all the harvests (Fig. 5.6).

During rabi season, increase in pod length with CCC application may be due to its chlorophyll retention ability in the leaf, which in turn increases the translocation of sources to sink in the reproductive parts. CCC acts as a stress hormone, to tolerate the drought and high temperature prevailing during summer season, thereby overcomes the adverse climatic conditions. One of the probable reason may be due to reduced incidence of mosaic in CCC applied plants (4.55 %), compared to control (20.78 %).

Naphthalene acetic acid was also found to increase the pod length in cow pea. Similar increase in fruit length of okra on treating with auxins like NAA (Nandapuri, *et al.*, 1969) and IAA (Rattan *et al.*, 1987) have been reported earlier.

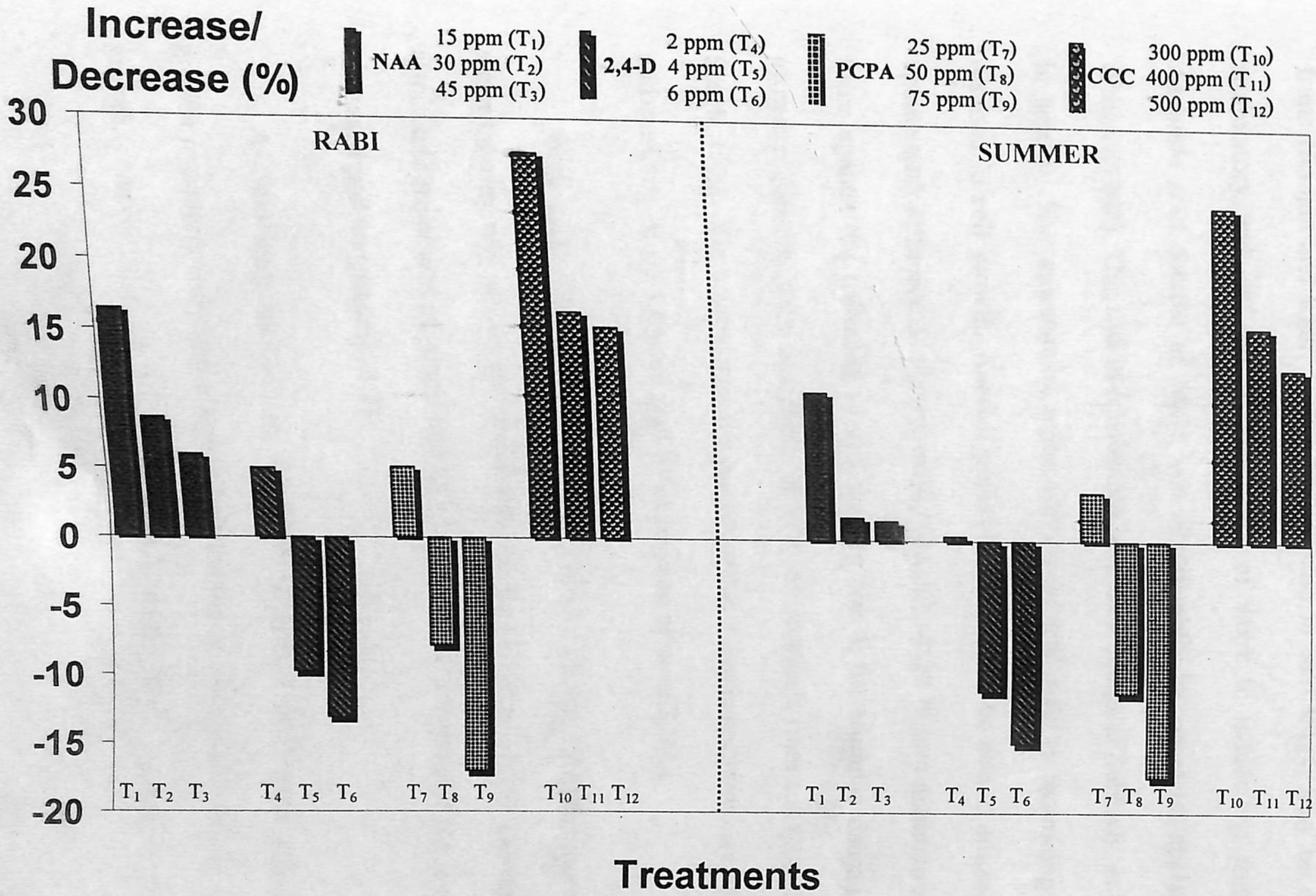


Fig. 5.6. Mean fruit length in different treatments over seasons

Cell expansion brought about by the action of auxin from pollen together with external application of chemical hormones might have resulted in bigger sized fruits (Ranjan and Kaur, 1980). The increase in fruit length may be due to the stimulatory and cell enlargement effect of auxin to induce the fruit growth. Ascorbic acid content of fruits was significantly increased on applying NAA (Purohit,1993). This was in consonance with the findings of Subbiah *et al.* (1980) in tomato. This stimulatory action softens the cell wall by increasing plasticity resulted in cell growth. Another probable reason may be due to enhanced water uptake with influence of plant growth regulator which in turn maintain a swelling force against the softening of cell wall or due to the stimulus caused by these growth regulators in the absorption of available nutrients from soil (Randhawa and Singh, 1970). The increased water uptake is due to increased plasticity of the shoot and elasticity of the root cell wall by expression of more RNAs.

Both CCC (300 and 400 ppm) and NAA (15 and 30 ppm) increased pod weight during rabi season and which were on par (17.24 to 17.95). During summer also, same trend was observed and CCC at all concentrations and NAA at 15 ppm increased pod weight (Fig. 5.7).

A significant increase in the fresh weight of pods with application of growth regulators indicated a higher partitioning of assimilate towards vegetative growth. Application of CCC and NAA might have increased the overall

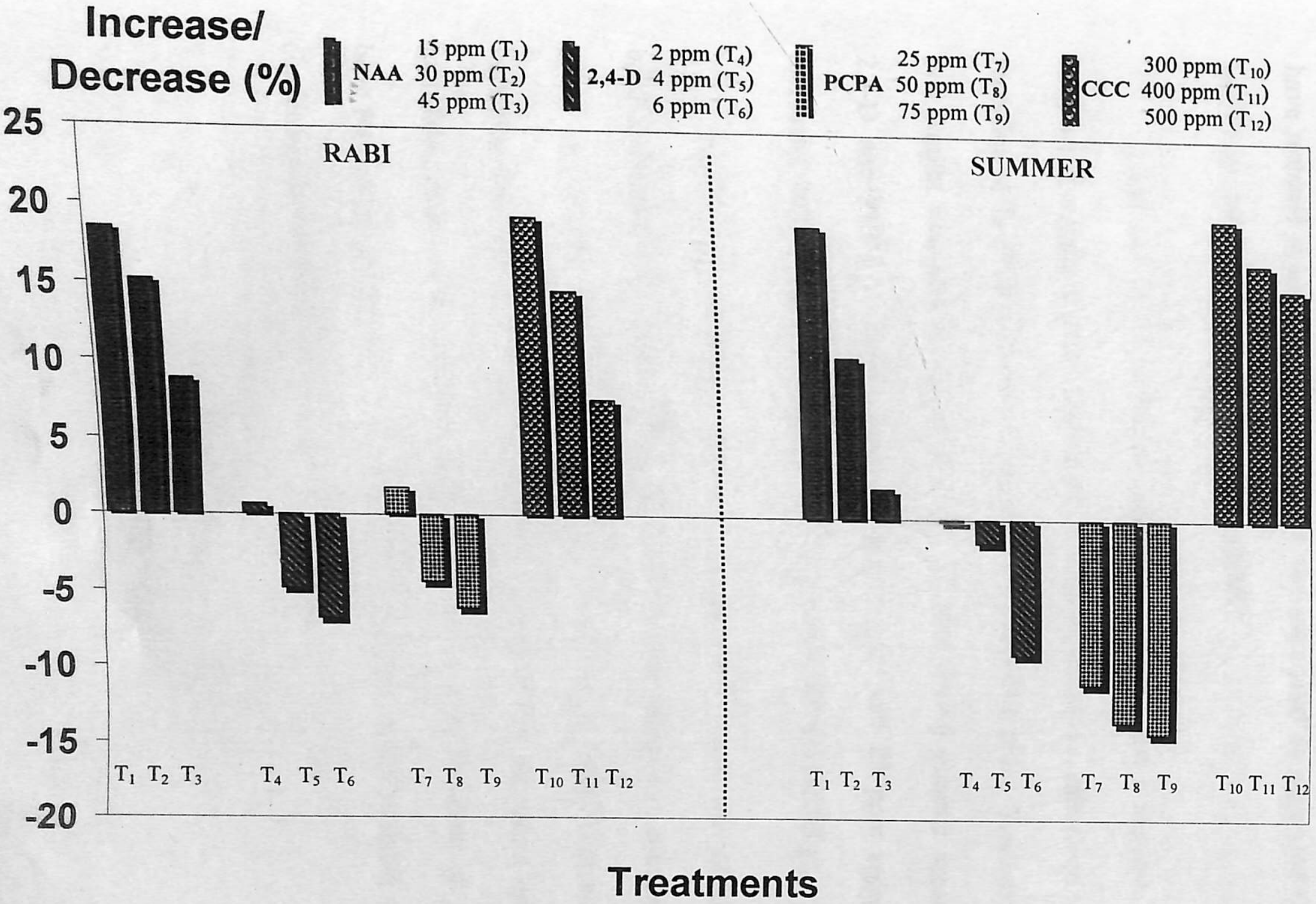


Fig. 5.7. Mean fruit weight in different treatments over seasons

photosynthetic potential which might have enabled the crop to produce higher dry matter production and accumulation in reproductive parts. It also enhanced the photosynthesis and reproductive efficiency in restructured plant type. This might have resulted in increase in seed weight and seed yield as suggested by Rathore and Wort (1971) and Shinde and Jadhav (1995).

2,4-D and PCPA at higher concentrations exhibited a negative effect on length and weight of pods. During the present investigation, minimum length was recorded at T_9 (PCPA 75 ppm) followed by T_6 (2,4-D 6 ppm). Similarly, average pod weight was also minimum in PCPA 75 ppm during summer season. while, 2,4-D and PCPA at lower concentrations (2 ppm and 25 ppm respectively) increased the fruit weight in rabi season compared to control (15.03 g).

An increase in fruit length and average fruit weight was obtained with application of 2,4-D 1 ppm in chilli (Raj, 1985). With increase in concentration of 2,4-D and PCPA, the fruit length and pod weight were found decreasing. This indicates that higher concentration of 2,4- D and PCPA are supra optimal for increasing pod length and fruit weight. The differential response of yard long bean for concentrations of 2,4-D and PCPA reveals the need of studying still lower concentrations of the above plant growth regulators.

5.5. Fruit yield

The per plot yield and per plant yield were significantly influenced by the application of plant growth regulators during rabi and summer seasons. NAA at all concentrations has increased the fruit yield. During rabi season, maximum per plot yield was obtained in T_1 (10.11 kg /13.5m^2 with a productivity of 7.49 t ha^{-1}) which received NAA 15 ppm. This increase in fruit yield was 34.58 per cent over the control and accounts to an additional yield of 1.72 tonnes per hectare. T_1 was closely followed by T_{10} (CCC300 ppm) during rabi. The per plant yield was also increased by the application of NAA and CCC during rabi with maximum being 524.46 g in T_1 (NAA 15 ppm) (Fig. 5.10).

During summer season, per plot yield was maximum in T_{10} (8.65 kg / 13.5m^2) which accounts to a per hectare yield of 6.41 tonnes per hactare where CCC 300 ppm was sprayed. This was closely followed by CCC 400 ppm (6.25 t ha^{-1}) which was on par with NAA 15 ppm (6.12 t ha^{-1}). The number of fruits per plant and per plot was also high (27.61 and 567.94 g respectively) in CCC 300 ppm treatment which was on par with CCC 400 ppm (26.31 and 553.19 respectively) (Fig. 5.8). During summer, three treatments namely T_1 (NAA 15 ppm), T_{10} (CCC 300 ppm) and T_{11} (CCC 400 ppm) were on par and were rated as top yielders (395.34 to 428.14 g / plant) (Fig.5.11).

As in the case of fruit number per plant, a maximum number of fruits per plot during rabi was recorded in T_{10} at CCC 300 ppm (573.92) followed by T_1 at NAA 15 ppm (572.39). All concentrations of NAA and CCC have increased the number of fruits per plant during rabi season. During summer, T_{10} which received CCC 300 ppm has yielded maximum number of fruits per plot (561.95) (Fig.5.9). Both the number of fruits and total fruit weight were inversely proportional to the concentration of plant growth regulators used in the present investigation.

The increase in yield per plot can be attributed to increase in partitioning of total dry matter to reproductive parts at 60 DAS. The foliar applied NAA may cause augmentation of auxin supply from the leaves and thereby helping in the development of better system inside the root for more uptake of nutrients to favour total drymatter production. The treatment with auxin compounds changed the orientation and canopy size of the plant and increased the more lateral branches which allow the plant to utilize the sunlight efficiently. Increase in yield with application of CCC can be attributed to delay in senescence of leaves, increased lateral branches and spread of plant (Bangal *et al.*, 1982). NAA sprayed crop allows higher degree of translocation of carbohydrate from stem to pods during maturation. It didn't influence the flowering period and duration of the crop. More yield in NAA treated plants was related to the rise in total carbohydrate content which in turn increased number of fruits harvested. The leaf area is not

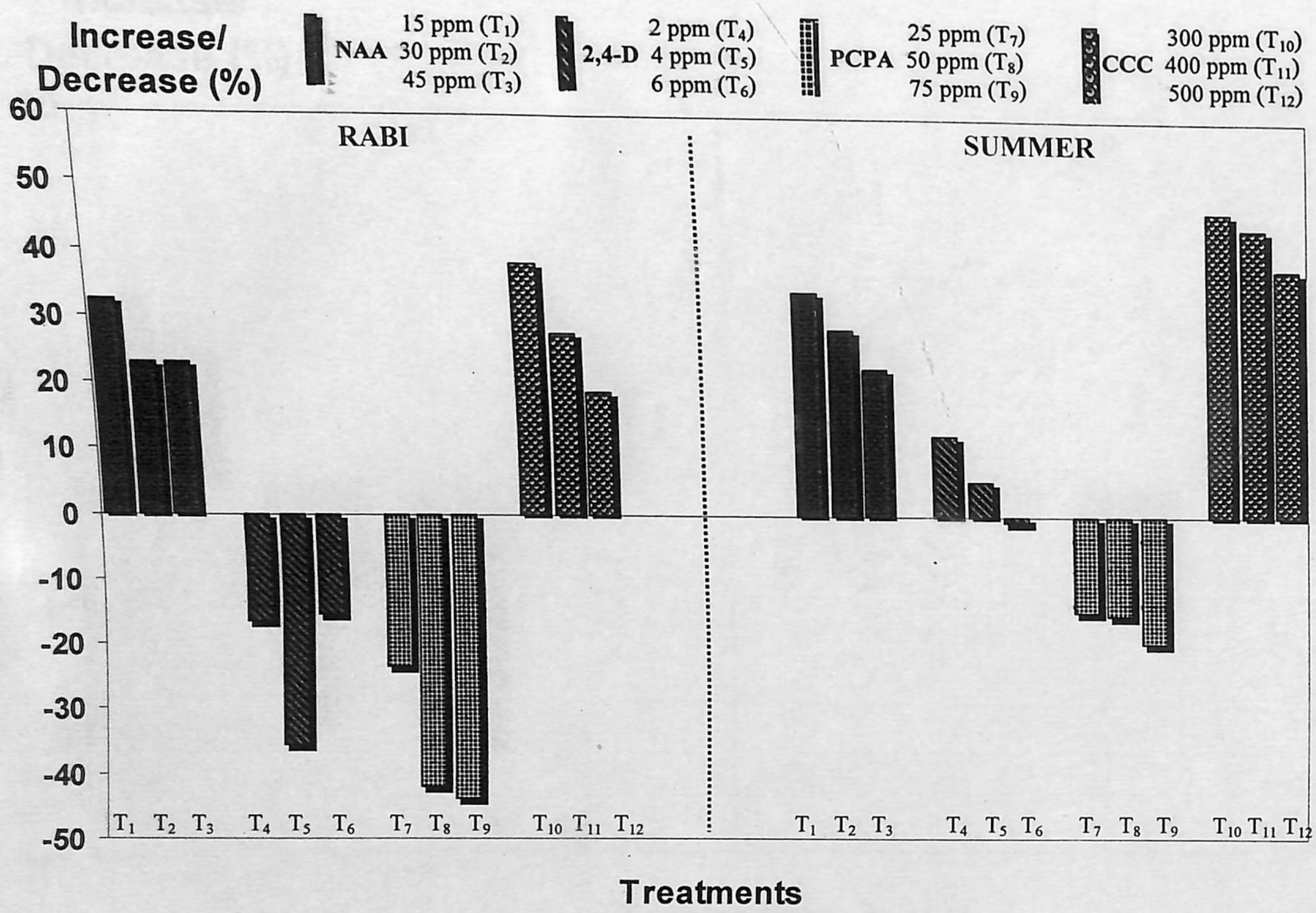


Fig. 5.8. Number of fruits per plant in different treatments over seasons

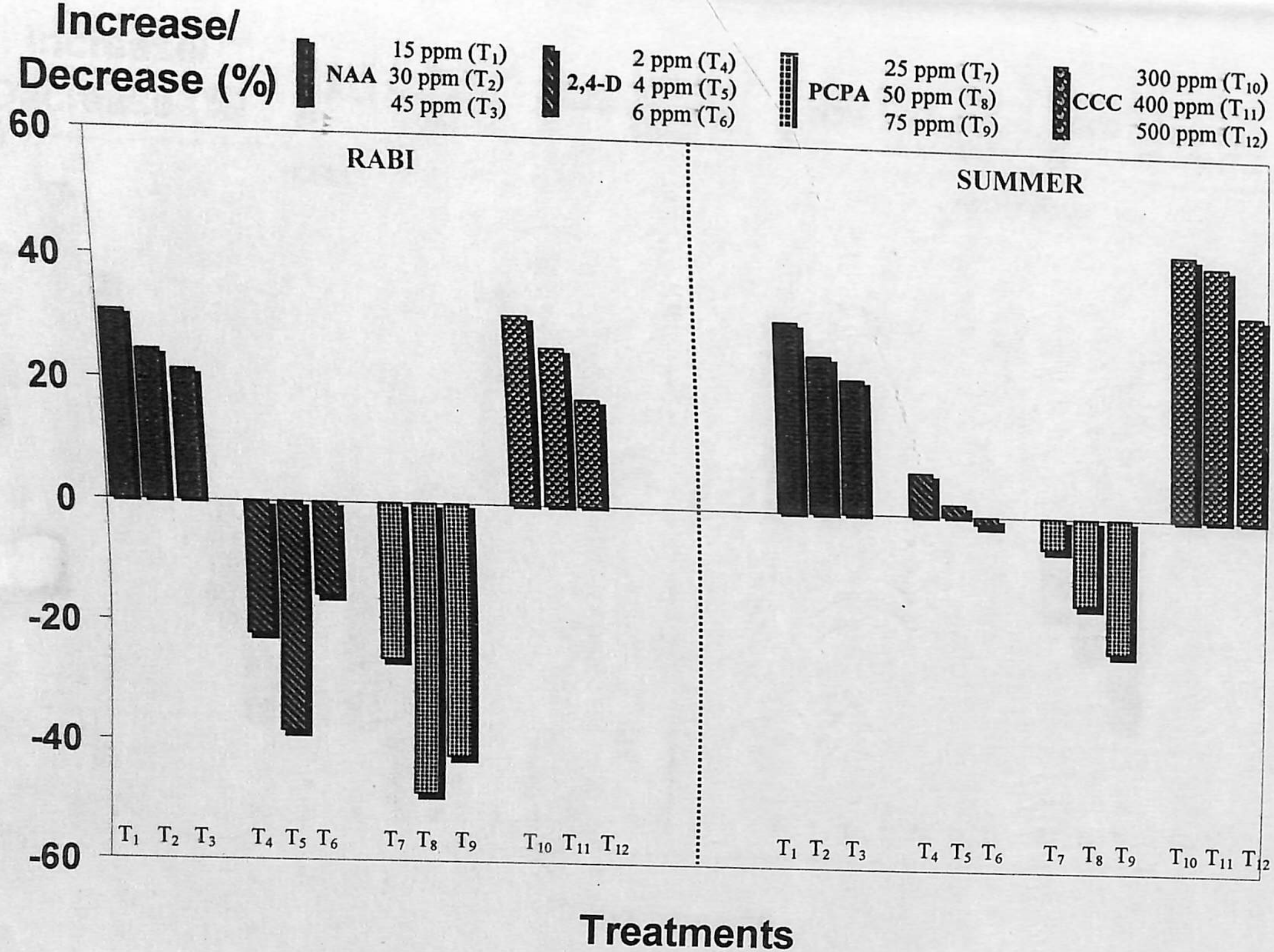


Fig. 5.9. Number of fruits per plot in different treatments over seasons

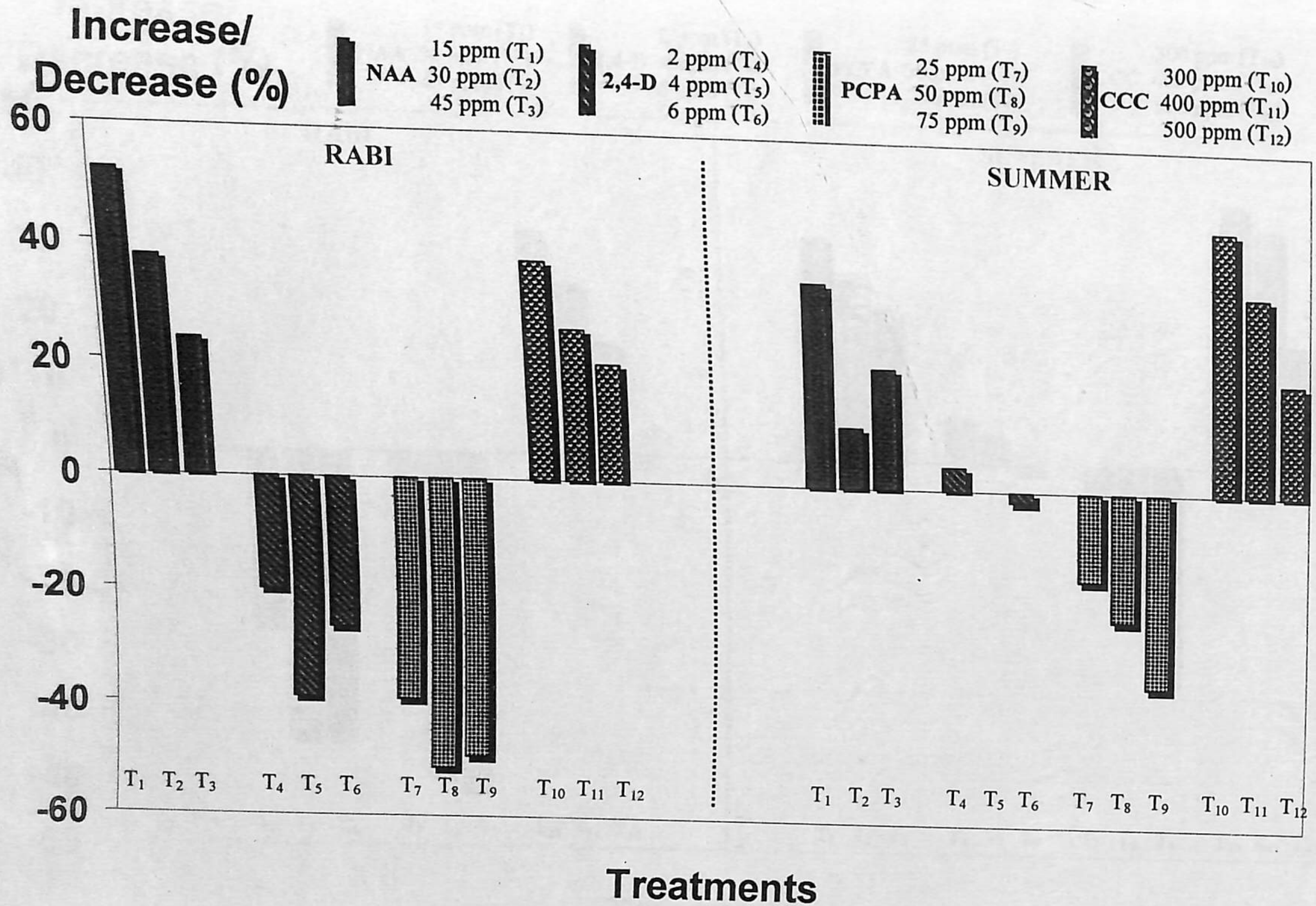


Fig. 5.10. Fruit yield per plant in different treatments over seasons

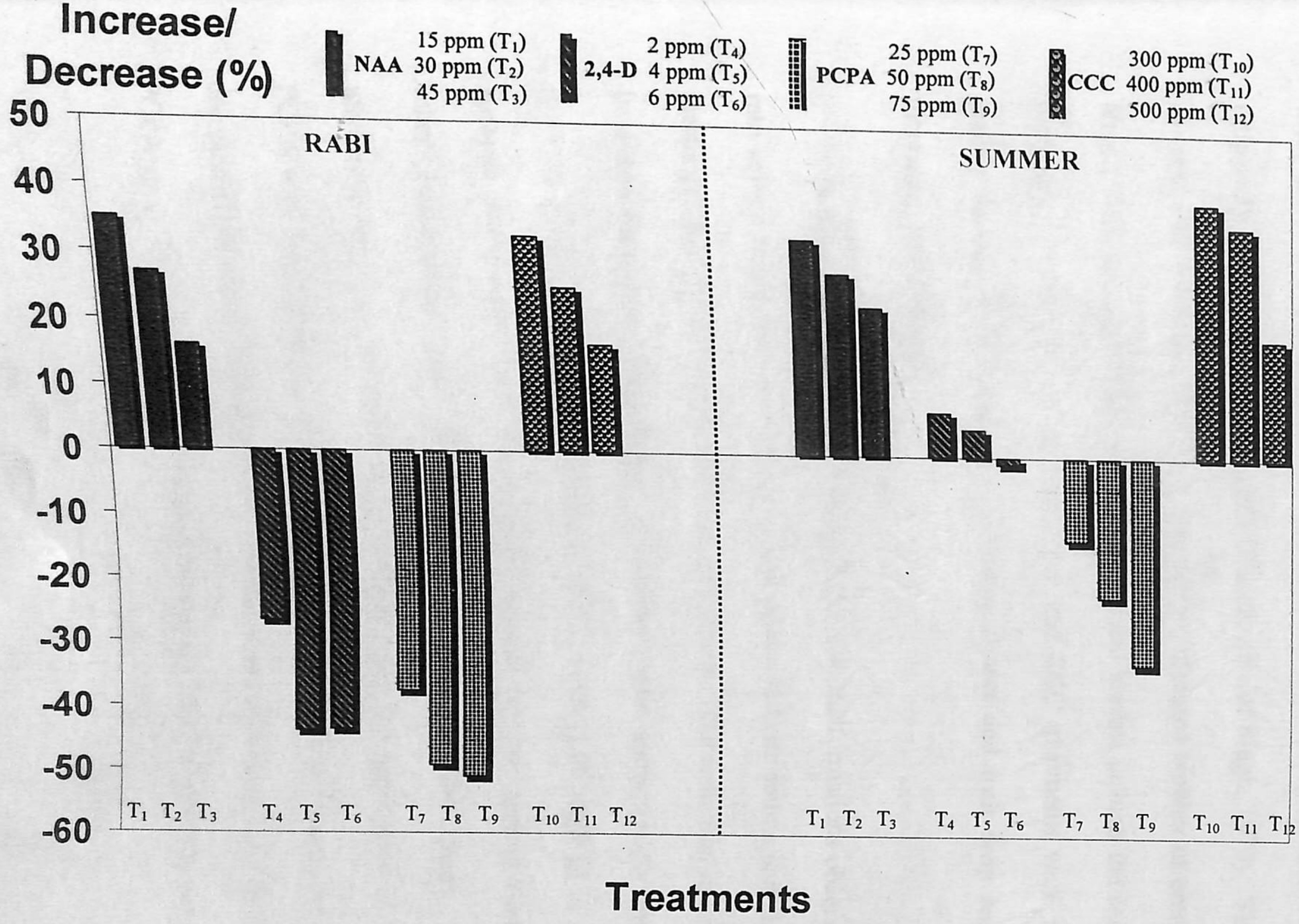


Fig. 5.11. Fruit yield per plot in different treatments over seasons

affected by the application of NAA and CCC compared to 2,4-D and PCPA treatments. Another probable reason is that the plant remained physiologically more active to build up sufficient food stock for the developing flowers and fruits ultimately leading to increased yield (Randhawa and Singh, 1970). The increase in yield with NAA and CCC may also due to increased number of branches, vine length, fruit set percentage, early flowering and harvest in both the seasons. The superiority in productivity of both NAA and CCC treatments were manifested mainly through their influence in reducing flower and fruit drop and there-by increasing fruit number.

In 2,4-D and PCPA applications vegetative malformations observed during rabi season might have reduced the active photosynthetic source and sink for dry matter production and accumulation in rabi season. The reduction in growth may be due to the reduced utilization of translocated sugars and respiratory activities in growing points. The increased chlorophyll *b* content (1.06 mg / g) in the PCPA sprayed plants might have disturbed the normal enzyme, protein synthesis and other biochemical and physiological activities of the plant. Noticable malformations were not observed in summer when the application of 2,4-D and PCPA was delayed from 30 days to 45 days after sowing. Hence, the yield was comparatively higher during summer compared to rabi season crop in 2, 4-D and PCPA spray. And also, other vegetative characters like leaf growth, percentage of fruit set, number of branches, length of vine were found to be low compared to all concentrations of NAA and CCC treatments. Growth retardant like CCC increases the number of branches by breaking the apical dominance. The restricted plant height with application of CCC is due to reduction in plant tissues. This restricted height could bring out greater economical sinks resulting in better growth of auxilliary shoots besides production of more flowers and enhance the yield.

The PCPA applied plants appeared as dark green with total chlorophyll content of 2.6 mg per gram of tissue compared to control plants (2.09mg / g) during rabi season. This increase in total chlorophyll content is due to the production of more chlorophyll *b* content (1.06 mg / g) in the PCPA treated plants compared to untreated plants (0.635 mg / g). This indicates that some stress condition might induced with the application of PCPA during rabi season and have led to reduced number of branches, fruit number, fruit set percentage, pod weight, pod length and there by decreased the crop productivity. While chlorophyll *a* content remain uniform in all the treatments. Yadava and Sreenath (1975) also reported that application of auxins as foliar spray increased the intensity of dark green colour in treated plants compared to control. This darkening may be due to increase in total chlorophyll content. This might have disturbed the normal photosynthesis by disrupting the enzyme system in plants for its normal growth and development (Mayer and Anderson, 1955).

Yard long bean is valued for its tender green pods rich in protein. Protein content was found to be influenced by external application of plant growth regulators and was maximum in CCC 500 ppm (27.27%). CCC at all concentrations (T_{10}, T_{11} and T_{12}) recorded high values for protein content in the pods.

Mosaic, characterized by yellowing and distortion of foliage, is a viral disease causing severe yield reduction in yard long bean especially under high temperatures. Being a viral disease, the spread is very fast and very often difficult to control. Avoiding or minimizing the disease incidence by appropriate cultural practices and technological adoptions is the only practical solution for this dreadful problem. The incidence of mosaic was maximum during summer (24.55 %) compared to rabi season (14.75%). This may be due to high temperature resulting in multiplication of vector population during summer months. Even though, the different plant growth regulators did not impart any considerable reduction in mosaic incidence, minimum mosaic was recorded in all CCC treatments. The CCC applied plants have a mosaic intensity of 14.55 per cent during summer compared to 24.55 per cent in non-treated control.

The present study has revealed the possibility of using plant growth regulators like Naphthalene acetic acid and retardants like CCC at low concentrations for enhancing the productivity of yard long bean. The study also disclosed the need for selecting the approptiate growth regulator depending upon the season. Application of CCC 300 ppm (T_{10}) has resulted in an increased yield of 1.82 tonnes per hactare with an additional income of Rs. 12740 per hactare. NAA 15 ppm also has increased the productivity by 1.73 tonnes per hactare with an additional revenue of Rs. 12110 per hactare.The economic analysis of various treatments revealed maximum benefit cost ratio at CCC 300 ppm (1.08) closely followed by NAA 15 ppm (1.06), CCC 400 ppm (1.04) and NAA 30 ppm (1.01).

The vegetative malformations and abnormalities in 2, 4-D and PCPA applied plants reveal the need for studies still at lower concentrations. Delayed application of 2,4-D and PCPA can also be tried instead of applying it in the early vegetative stage.

The two treatments *viz.* NAA 15 ppm and CCC 300 ppm, found promising during rabi and summer seasons, respectively can be further refined in large scale demonstrations in the research stations and in farmers fields with a participatory approach. This will help in the faster adoption of this improved technology by the farming community.

6. SUMMARY

6. SUMMARY

The present investigation was undertaken in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2000-2001. The light green poded yard long bean variety 'Lola' (VS – 13 - 2) was grown for two seasons namely rabi (September, 2000 to January, 2001) and summer (February, 2001 to May, 2001) to study the effect of different plant growth regulators on growth and productivity of the crop.

The experiment was laid out in Randomised Block Design (RBD) with three replications. Four synthetic growth regulators namely NAA, 2,4-D, PCPA and cycocel (CCC) at three concentrations each constituted 12 treatments and were compared with non-treated and water sprayed control. The salient findings of the study are summarized as follows:-

1. All the vegetative, flowering and pod characters exhibited significant variation due to the application of growth regulators during both summer and rabi season. Protein content of fruits were not affected due to the application of plant growth regulators during summer season.

2. Considering the productivity and mosaic incidence, the overall performance of the crop was better in rabi season compared to summer.

3. NAA had a positive effect on vegetative and fruit characters and in the induction of earliness. NAA (15 ppm) sprayed at 30,45 and 60 DAS has increased length of vine (6.56 m), number of branches (18.33 m), percentage of

fruit set (100 %), number of fruits per plant (27.21), number of fruits per plot (572.39), pod yield (7.49 t ha^{-1}) and reduced the number of days taken for flowering (46.33) and harvest (57.00) in rabi season.

4. CCC (300 ppm) sprayed at 20 DAS was found to be more effective during summer and increased number of secondary branches (19.33), mean pod weight (16.89 g), mean pod length (36.86 cm) and protein content (25.59 %) and reduced the days taken for 50 per cent flowering (56.33).

5. 2,4-D when applied at 30, 45 and 60 DAS resulted in severe vegetative malformations in all the three concentrations. These malformations caused reduction in leaf area from 90 cm^2 to 5.6 cm^2 and increased the inter nodal length from 15 cm to 25 cm.This reduction in source area and transpiring area resulted in yield reduction during rabi.

6. In case of PCPA application, vegetative malformations were severe in all the three concentrations (25,50 and 75 ppm) when applied at 30, 45 and 60 DAS during rabi season. But, when the application was delayed to 45 DAS during summer, no such noticable malformations were exhibited. The PCPA applied plants had a high content of chlorophyll *b* (1.06 mg /gm of tissue) than the non-treated plants (0.635 g/ g).

7. During rabi season treatments like NAA 15 ppm (T_1) and CCC 300 ppm (T_{10}) resulted in 100 per cent fruit set. Days to first flowering (39.33) and days to first harvest (46.00) were earliest in T_{10} which received CCC 300 ppm.

8. CCC at 300 ppm resulted in maximum length of pod (37.33 cm) and individual pod weight (17.42 g) in both rabi and summer seasons, which was 26.03 per cent and 19.56 per cent increase over the control. CCC at 400 and 500 ppm and NAA at 15 ppm were also effective for increasing the length of pod and average pod weight.

9. During rabi season, the productivity of the crop was maximum at NAA 15 ppm (7.49 t ha^{-1}) closely followed by CCC at 300 ppm (7.37 t ha^{-1}), NAA 30 ppm (7.05 t ha^{-1}) and CCC 400 ppm (6.94 t ha^{-1}). During summer season, productivity was maximum at CCC 300 ppm (6.41 tha^{-1}), closely followed by CCC 400 ppm (6.25 t ha^{-1}) and NAA 15 ppm (6.13 t ha^{-1}). The percentage increase with application of NAA and CCC were 34.01 per cent and 35.62 per cent respectively.

10. In case of number of fruits per plant and number of fruits per plot, the application of CCC at 300 ppm observed maximum values (27.61 and 567.94 respectively), in both rabi and summer seasons.

11. The protein content of the fruits were maximum during rabi season and did not show significant influence during summer season.

12. Incidence of mosaic was more during summer season. The minimum incidence of mosaic was noticed with CCC application in both rabi and summer seasons. The CCC applied plants noticed a mean mosaic incidence of 4.55 per cent during rabi season, compared to non treated plants (20.78 %).

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APPENDICES

APPENDIX Ia.

Weather data during rabi season.

Period	Temperature				Relative humidity(%)		Wind speed (km/hrs)		Sunshine (hrs)		Rain fall (mm)	Evaporation (mm)	
	Max °C		Min °C										
	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Total	Mean	Total
2000 Sept 17 to 23	30.4	213.0	22.90	160.20	92	641	2.9	20.6	3.9	27.1	16.2	3.1	21.7
Sept 24 to 30	30.9	214.7	23.30	162.80	90	628	3.2	22.2	4.6	31.9	150.0	2.7	18.9
Oct 1 to 7	28.9	202.1	22.00	154.20	92	646	2.9	20.1	3.2	22.8	79.3	2.7	18.9
Oct 8 to 14	30.9	216.6	22.10	154.70	91	636	2.7	18.8	7.1	49.9	18.1	3.6	25.3
Oct 15 to 21	30.6	214.1	23.60	164.90	92	641	2.7	19.0	3.7	25.8	160.8	3.1	21.5
Oct 22 to 28	31.7	221.8	19.80	138.60	90	628	2.7	19.2	7.4	51.7	6.8	3.5	24.5
Oct 29 to Nov 4	32.6	228.4	23.30	161.10	88	617	3.3	23.1	8.5	59.8	0.4	3.9	27.3
Nov 5 to 11	33.4	234.1	23.00	161.30	73	509	5.3	37.2	8.3	58.3	a	4.4	30.5
Nov 12 to 18	32.5	227.4	24.10	168.70	67	466	9.1	63.5	7.7	53.9	a	52.0	36.6
Nov 19 to 25	32.6	228.0	23.90	167.00	82	574	4.9	34.3	3.1	21.8	23.1	3.1	21.5
Nov 26 to Dec 2	31.1	217.4	20.80	145.90	86	603	3.9	27.3	6.2	43.4	5.4	3.6	25.0
Dec 3 to 9	31.1	217.6	23.30	162.80	69	486	9.8	68.9	8.5	59.6	a	5.7	40.0
Dec 10 to 16	31.1	217.8	21.20	148.30	65	453	8.7	61.4	9.7	68.1	a	5.7	39.8
Dec 17 to 23	31.5	220.4	22.60	158.30	67	469	8.9	62.0	7.3	51.2	a	5.8	40.5
Dec 24 to 31	30.7	245.4	21.40	171.00	75	597	5.0	39.8	6.8	54.8	8.0	4.2	33.8
2001 Jan 1 to 7	32.1	224.6	23.10	161.40	80	561	6.9	48.9	8.4	58.8	a	5.3	37.0
Jan 8 to 14	37.5	227.2	22.90	160.50	75	525	8.4	58.8	9.0	62.7	a	6.0	42.0
Jan 15 to 21	32.6	228.3	23.00	161.30	63	442	10.7	74.9	8.8	61.6	a	7.4	52.0
Jan 22 to 28	33.5	234.8	23.40	163.90	59	480	7.6	52.9	8.1	56.7	a	6.3	44.0

Source: Department of Agricultural Meteorology, College of Horticulture, Vellanikkara.
a - absent
Date of sowing - 23 September 2000

APPENDIX Ib.

Weather data during summer season

Period	Temperature				Relative humidity(%)		Wind speed (km/hrs)		Sunshine (hrs)		Rain fall (mm)	Evaporation (mm)	
	Max °C		Min °C										
	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Total	Mean	Total
2001Jan 29 to Feb 4	31.9	223.6	23.3	163.0	77	541	6.3	44.3	4.3	30.2	12.2	4.8	33.5
Feb 5 to 11	34.3	239.8	22.1	154.9	81	568	4.5	31.5	7.7	53.6	a	5.2	36.6
Feb 12 to 18	39.9	279.4	22.4	156.7	82	575	5.1	35.4	9.1	64.0	a	5.7	39.7
Feb 19 to 25	35.1	245.5	23.5	164.4	90	633	3.9	27.1	8.7	61.0	a	5.0	34.9
Feb 26 to Mar 4	35.2	246.2	23.7	166.0	85	597	4.7	33.0	8.7	61.0	a	5.9	41.2
Mar 5 to 11	35.0	245.1	23.5	164.3	89	622	3.6	25.3	8.1	56.5	2.2	5.2	36.1
Mar 12 to 18	35.2	24.6	23.4	163.8	88	619	4.1	28.5	8.6	60.0	a	5.5	38.8
Mar 19 to 25	34.3	240.2	24.2	169.7	85	592	3.9	27.2	7.2	50.3	a	5.2	36.5
Mar 26 to Apr 1	34.3	239.8	25.2	176.7	87	606	4.0	27.9	8.0	55.8	2.2	5.5	38.2
Apr 2 to 8	35.7	249.8	25.3	176.8	85	595	3.6	25.5	6.3	44.2	7.1	5.2	36.2
Apr 9 to 15	33.1	231.4	23.4	164.0	90	630	3.6	24.9	5.3	36.9	190.6	3.2	22.6
Apr 16 to 22	33.7	235.7	24.8	171.4	89	621	3.4	23.7	8.4	58.8	44.0	4.3	29.8
Apr 23 to 29	34.3	240.4	25.5	178.8	90	628	3.2	22.7	6.3	43.9	1.4	4.3	30.0
Apr 30 to May 6	33.5	234.7	25.4	177.9	78	545	4.1	29.0	6.0	41.8	13.0	4.3	30.4
May 7 to 13	33.0	231.0	25.5	170.4	62	437	3.4	24.1	7.1	49.6	a	4.7	32.6
May 14 to 20	32.8	229.9	25.0	174.9	64	451	3.4	23.7	8.4	58.9	18.1	4.3	29.8
May 21 to 27	31.4	220.1	23.5	164.7	76	539	3.5	24.2	4.7	32.9	102.9	3.0	20.9
May 28 to Jun 3	30.8	215.6	23.7	165.7	71	500	3.6	25.3	4.7	33.0	44.8	3.8	26.6

Source: Department of Agricultural Meteorology, College of Horticulture, Vellanikkara.
a - absent
Date of sowing -14 February 2001

APPENDIX – II

Cost of various plant growth regulators used

Sl. No.	Chemicals	Quantity (g)	Cost (Rs.)
1	Naphthalene acetic acid (NAA)	75	396.00
2	2,4- dichlorophenoxy acetic acid (2,4–D)	50	3278.00
3	Parachlorophenoxy acetic acid (PCPA)	100	2376.00
4	Cycocel (CCC)	25	364.00

APPENDIX III.

Economics of growth regulator application in yard long bean.

Treatments	Average fruit yield (t/ha)	Total returns (Rs. /ha)*	Additional cost with different treatments (Rs. /ha)	Total production cost (Rs/ha)	Benefit Cost ratio
1. NAA 15 ppm	6.80	47,600.00	1017.33	44,817.33	1.06
2. NAA 30 ppm	6.46	45,220.00	1134.66	44,934.66	1.01
3. NAA 45 ppm	6.05	42,350.00	1251.99	45,051.99	0.94
4. 2,4-D 2 ppm	4.49	31,430.00	1094.25	44,894.25	0.70
5. 2,4-D 4 ppm	3.95	27,650.00	1288.50	45,088.50	0.61
6. 2,4-D 6 ppm	3.85	26,880.00	1482.75	45,282.75	0.59
7. PCPA 25 ppm	3.73	26,110.00	1779.99	45,579.99	0.57
8. PCPA 50 ppm	3.20	22,400.00	2659.99	46,459.99	0.48
9. PCPA 75 ppm	2.90	20,300.00	3539.99	47,339.99	0.42
10. CCC 300ppm	6.89	48,230.00	600.61	44,400.61	1.08
11. CCC 400ppm	6.59	46,130.00	650.00	44,450.00	1.04
12. CCC 500ppm	5.95	41,650.00	701.85	44,501.85	0.93
13. Water spray	5.22	36,540.00	300.00	44,100.00	0.83
14. Control (No spray)	5.07	35,490.00	-	43,800	0.81

* Returns @ Rs. 7 per kg

EFFECT OF PLANT GROWTH REGULATORS ON GROWTH AND PRODUCTIVITY IN YARD LONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt.)

By

RESMI, R.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the award of the Degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF OLERICULTURE
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR - 680656
KERALA, INDIA

2001

ABSTRACT

Studies on the "Effect of plant growth regulators on growth and productivity in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was conducted at the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during rabi (September, 2000 to January, 2001) and summer (February, 2001 to May, 2001) seasons using the variety 'Lola'. Four plant growth regulators (NAA, 2,4-D, PCPA and CCC) at three concentrations each, constituted twelve treatments excluding water spray and non-treated control. The experiment was laid out in a Randomised Block Design (RBD) with three replications. NAA (15, 30 and 45 ppm) was sprayed thrice at 30, 45 and 60 days after sowing (DAS) and CCC (300, 400 and 500 ppm) at 20 DAS in both rabi and summer seasons. During rabi season 2,4-D (2, 4 and 6 ppm) and PCPA (25, 50 and 75 ppm) were applied at 30, 45 and 60 DAS and during summer at 45 and 60 DAS.

NAA and CCC at lower concentrations (15 ppm and 300 ppm respectively) were effective for the growth and productivity in both the seasons. In case of vegetative characters, NAA at 15 ppm produced maximum vine length (6.58 m) and CCC at 300 ppm produced maximum number of secondary branches (18.67). CCC (300ppm) application resulted in early flowering (39.33 days) and harvest (46 days) during rabi. NAA and CCC at lower concentrations were equally effective for increasing the fruit set by reducing the flower and pod shedding in both rabi and summer seasons.

Spraying of 2,4-D and PCPA at all concentrations resulted in vegetative malformations like curling, cupping and strap shaped leaves without any leaflets, long internodes, funnel shaped leaves with bushy and stunted appearance when

applied at 30, 45 and 60 DAS. This adversely affected the growth and productivity of the crop during rabi. The perfomance of 2,4-D and PCPA treated plants were better without any noticable vegetative malformations when applied at 45 DAS during summer.

NAA at 15 ppm increased productivity of cowpea by 35.19 per cent yielding 7.49 tonnes per hactare compared to 5.54 tonnes in control during rabi season. During summer, the productivity of the crop was maximum (6.41 t ha^{-1}) in CCC 300 ppm which was due to more number of fruits per plot (561.95), length of fruit (36.86 cm) and mean fruit weight (16.89 g). The crude protein content was higher in all CCC treatments. Mosaic incidence was also less (4.55 %) in CCC treated plants compared to control plants (24.55 %) during summer season.