# Controlling seedling height of cowpea (*Vigna unguiculata* (L.) Walp.) transplants using plant growth regulators.

**By**

**Anu Latha Robi**

**(2019-12-017)**


**DEPARTMENT OF VEGETABLE SCIENCE**

COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

**2022**

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**THESIS**

Submitting in partial fulfillment of the requirement for the degree of

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**Faculty of Agriculture**

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**DEPARTMENT OF VEGETABLE SCIENCE**

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VELLANIKKARA, THRISSUR – 680656

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**2022**

## DECLARATION

I, hereby declare that this thesis entitled **"Controlling seedling height of cowpea (*Vigna unguiculata* (L) Walp transplants using plant growth regulators"** 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.

Vellanikkara

Date: 28.04.2022

**Anu Latha Robi.**

(2019-12-017)

## CERTIFICATE

Certified that this thesis entitled **"Controlling seedling height of cowpea *vigna unguiculata* (L.) Walp"** is a bonafide record of research work done independently by **Ms. Anu Latha Robi (2019-12-017)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

28/4/22

Vellanikkara

Date: 28.04.2022

**Dr. C. Narayanankutty**

(Chairman, Advisory Committee)

Professor (rtd)

Kerala Agricultural University

## CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Anu Latha Robi (2019-12-017)**, a candidate for the degree of **Master of Science in Horticulture** with major field in **Vegetable Science**, agree that this thesis entitled **"Controlling seedling height of cowpea *vigna unguiculata* (L.) Walp transplants using plant growth regulators "** may be submitted by **Ms. Anu Latha Robi** in partial fulfilment of the requirement for the degree.

28/4/22

**Dr. C.Narayanankutty**
(Chairman, Advisory Committee)
Professor (rtd)
Kerala Agricultural University, Mannuthy

28/4/22

**Dr. T. Pradeepkumar**
(Member, Advisory Committee)
Professor and Head
Department Vegetable Science
College of Agriculture, Vellanikkara

28/4/22

**Dr. Sangeeta Kutty M**
(Member, Advisory Committee)
Assistant Professor.
Department of Vegetable Science
College of Agriculture, Vellanikkara

28/4/2022

**Dr. Parvathi M Sreekumar**
(Member, Advisory Committee)
Assistant Professor
Department of Plant Physiology
College of Agriculture, Vellanikkara

28/4/22

**Dr. Berin Pathrose**
(Member, Advisory Committee)
Assistant Professor
Department of Vegetable Science
College of Agriculture, Vellanikkara

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***Anu Latha Robi***

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## ABBREVIATIONS

| | | |
|---|---|---|
| % | - | Percent |
| °C | - | Degree Celsius |
| cm | - | Centimeter |
| g | - | Gram |
| KAU | - | Kerala Agricultural University |
| kg | - | kilo gram |
| mm | – | Millimetre |
| mg | – | Milligram |
| PGR | – | Plant growth regulator |
| PBZ | – | Paclobutrazol |
| CC | – | Cycocel |
| ET | - | Ethrel |
| Ha | - | Hectare |
| NAA | - | Naphthalene acetic acid |
| 2, 4 - D - 2, 4 | - | Dichloro phenoxy acetic acid |
| MH | - | Maliec hydrazide |
| ppm | – | Parts per million |
| $GA_3$ | – | Gibberellic acid |
| IAA | – | Indole acetic acid |

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# *INTRODUCTION*

# 1. INTRODUCTION

Legumes are an important source of dietary protein, mainly for people in underdeveloped countries (Wang *et al.,* 2003). Cowpea (*Vigna unguiculata* (L.) Walp is an annual leguminous vegetable crop native to central Africa belonging to the family Fabaceae. It is commercially grown throughout India for its green pods used as a vegetable. Cowpea is also known as niebe, wake, and ewa in West Africa and caupi in Brazil. In the United States, it is also called southern pea, black-eyed pea, field pea, pinkeye or crower. Cowpea is a typical climbing or trailing vine that bear compound leaves with three leaflets. They bear white, purple, or pale-yellow flowers usually grow in pairs or threes at the ends of long stalks. The pods are long and cylindrical and can grow 20–30 cm long, depending on the cultivar. It is a self-pollinated drought tolerant crop well adapted to the tropics. Kashi Kanchan is a bush type cowpea variety (*Vigna unguiculata* (L.) Walp with violet colored flowers and medium sized green pods. Vellayani Jyothika is a trailing type Yard long bean cowpea variety (*Vigna unguiculata* subsp.*sesquipedalis* (L.) Verdcourt) with light green pods. The tender pods are used as a delicious vegetable and it is rich in crude protein (28 %), minerals like iron (2.5 mg /100 g), calcium (80 mg /100 g), phosphorous (74 mg /100 g), vitamin A (941 IU /100 g) and vitamin C (13 mg /100 g) and dietary fibre (2 g /100 g). The tender green leaves are also used as vegetable. Green cowpea seeds are boiled as a fresh vegetable or may be canned or frozen. The beans are nutritious and provide complementary proteins to cereal diets.

Plug production is a commercially adopted method for large scale production of vegetable seedlings. There are several advantages in producing transplants like efficient use of expensive seeds, improved germination, production of pest free quality seedlings which are uniform healthy and to reduce transplanting shock of seedlings. Overextension of hypocotyl leading to lanky growth of vegetable seedlings like cowpea, bhindi and cucurbits grown in polyhouses is an undesirable quality, especially in plugs intended for mechanized planting and long distance transport. Difficulties in mechanical transplanting and field survival are challenges horticultural plant growers face due to increased height of transplants. A common practice to prevent seedling overgrowth is seed treatment with plant growth retardants .The most commonly used plant growth retardants are Paclobutrazol, Cycocel and Ethrel to reduce seedling height

and prevent lodging in crops (Armstrong and Nicol, 1991). Soil, foliar application, seed treatment and direct injection to the trunk are the common methods used to control seedling height. Presowing seed treatment is an alternative approach for delivery of growth regulators to plants. Treating seeds with growth regulators is known to change plant growth and stress resistance (Fletcher *et al.,* 2000). Advantages of seed treatments with plant growth regulators include less usage of active ingredient, lower drift of product and simplicity of application. Seed treatments with growth regulators has been widely used in controlling plug height in marigold, geranium, cosmos, tomato, and pepper (Pasian and Bennett, 2001). Seed priming with growth regulators has been suggested as a possible method for seedling growth control (Pill and Gunter, 2001). However limited studies have been conducted in horticultural crops especially vegetables. Hence the present study was formulated with the objective of controlling seedling height of vegetable cowpea and to assess the field performance of treated seedlings.

# *REVIEW OF LITERATURE*

# 2. REVIEW OF LITERATURE

Cowpea is one of the most popular and cosmopolitan vegetable crop grown in Kerala. It is a rich and inexpensive source of vegetable protein. It enriches soil fertility by fixing atmospheric nitrogen. Because of its quick growth habit it has become an essential component of sustainable agriculture in marginal lands of the tropics. Number of studies have been undertaken on effect of plant growth regulators on controlling seedling height in various horticultural crops, especially in ornamentals crops, fruits and vegetables on horticultural crops are reviewed in this chapter

## 2.1 Plant growth regulators

Plant Growth Regulators (PGRs) are organic or chemical substances applied externally in order to modify several physiological processes like seed germination, seedling growth, and development, flowering, fruit set and ripening as well as to improve storage life. Application of appropriate PGR at specific dosage at specific plant growth stage will controlling the seedling height as well as improve the yield and quality of the crop.

Broadly plant growth regulators are classified in to growth promoters and growth retardants based on their effects

### 2.1.1 Growth promoters

Auxins – 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)

Gibberellins – Gibberellic acid

Cytokinins – Kinetin, Zeatin

Ethylene- Ethylene

#### 2.1.1.1 Auxins

The first auxin was extracted from maize kernels. The compound was indole acetic acid it is the naturally occurring auxin in all higher plants and fungi.

The major functions of auxins in plants is to stimulate cell division and cell enlargement in apical region by increasing the amylase activity and prevention of premature drop of fruits. At higher doses it act as herbicides and lower doses as plant growth regulators

**2.1.1.2 Gibberellins**

Gibberellins are important plant hormones synthesized in immature seeds and young seedlings. It was first extracted from the ascomycetous fungus *Gibberella fujikuroi* . It promotes seed germination, break bud dormancy, delays senescence of fruits, enhance seedless fruits and accelerates flowering in long day plants,

**2.1.1. 3 Cytokinins**

Cytokinins play a key role in the life of higher plants. It is mainly produced in root tips. Some of the important roles of cytokinins are it promotes seed germination and radical growth by breaking dormancy, it helps in cotyledon expansion in immature seedling of dicots, stimulates chlorophyll synthesis , induces cell division and shoots development, delay senescence and induce morphogenesis in cultured cell

**2.2 Growth retardants**

Growth retardants are chemicals that have the effect physiological of slowing of cell division in the sub-apical meristem, thereby limiting stem growth. Leaves, flowers, and fruits continue to form normally. Inhibition of gibberellin production between ent-kaurene and ent-kaurenoic acid causes growth retardation. The important growth retardants are uniconazole, paclobutrazol (P333, Cultar), triapenthenol, flurpirimidol, AMO-1618, CCC, and Phosphon- D

Dormins –Abscisic acid (ABA), Phaseic acid

Synthetic growth retardants – Cycocel (CCC) , AMO 1618

a . Ethylene releasing compound – eg: etacelasil
b, Inhibitors of GA translocation eg: B-9, Maleic hydarzide
c, Inhibitors of GA biosynthesis : includes
( i) Onium type compounds : Cycocel AMO 1618

(ii) Nitrogen with compounds: containing heterocycle: eg: Paclobutrazol

(iii) Cyclohexatrions : cimetocarb

### 2.2.1 Abscisic acid

Abscisic acid (dormins) are growth inhibitory substances inhibiting α –amylase production which is essential for seed germination and inhibits vegetative growth and triggers reproductive growth.

### 2.2.2 Ethylene

Ethylene is the only gaseous plant growth regulator and the main function is the induction of ripening and hastens abscission of plants, it encourages root formation, it acts as a fruit ripening hormone enhances seed germination, induces production of female flowers, male sterility, and inhibits vegetative growth and triggers reproductive growth.

Plant growth regulators are applied to the plants in many ways *viz.,* foliar application and seed treatments. Injections of growth regulators directly into the trunk can also be done for valuable woody ornamental plants .In the case of root treatments, growth regulators are applied directly to the soils. Seed treatment with growth regulators is an alternate method of delivering growth regulators to plants (Fletcher *et al.,* 2000). Seed treatments with plant growth regulators have the advantages of using less active ingredient, having less product drift and being simple to apply (Pasian and Bennett , 2001 and Fletcher *et al.,* 2000). Seeds that have been treated with growth regulators have shown altered plant growth and stress resistance .Seedling emergence is reduced and delayed, which is one of the unintended consequences of using growth regulators on seeds (Giba *et al.,* 1993 and Pill and Gunter, 2001)

## 2.3 Effect of plant growth retardants on seedling vigour characters.

Paclobutrazol treated at a concentration higher than 1mg/$L^{-1}$ showed growth inhibition in pepper transplants. At concentrations of 0.5 and 1mg/$L^{-1,}$ seedling growth was slightly enhanced, whereas at 50 mg/ $L^{-1}$ stem elongation was completely inhibited. At all Paclobutrazol concentrations tested (0.5-50 mg/ $L^{-1}$), The root development was stimulated and leaf chlorophyll was increased (Aloni and Pashkar, 1987)

Seeds treatments with Paclobutrazol reduced seedling height in barley during winter. Increasing Paclobutrazol concentration proportionally reduced shoot growth in barley, but also leads to decreased seed germination when compared to control. Paclobutrazol

treated seedlings were showed reduced seedling height than those treated with chloremequat chloride (Smith and Leibovitch, 1990)

Paclobutrazol treatment of barley and rape (*Brassica napus* L.) seeds resulted in delayed germination and reduced germination percentage (Aufhammer *et al.,* 1993).

Stock (*Matthiola incana* L.) seeds soaked in 50, 100 or 200 mg /$L^{-1}$ of Paclobutrazol solutions for 24 h had a significant reduction in seedling growth, but they also had a decrease in germination and seedling emergence. The same effects were found for seeds treated with 100, 200, or 400 mg/ $L^{-1}$ uniconazole solutions. The treatment with higher concentrations of growth regulators resulted in repression of germination and higher seedling emergence (Grzesik , 1995).

Soaking pea (*Pisum sp*.) seeds in uniconazole solutions for 24 hours delayed the seed germination and resulted in morphological and physiological alterations in seedlings (Hathout, 1995).

Soaking maize (*Zea mays* L.) kernels in 80 or 160 mg / $L^{-1}$ paclobutrazol solutions for 16 hours resulted in a temporary reduction in seedling growth but no reduction in seedling emergence (Dale and Drennan , 1997).

Berova and Zlatev (2000) evaluated the physiological response and yield of paclobutrazol treated tomato plants. Seedlings were treated with soil and foliar applications of paclobutrazol at concentrations of 1.0 and 25.0 mg / $L^{-1}$ respectively. The results revealed that reduced height and the increased thickness of the young plant stems accelerated flowering and fruit formation and there by early fruit yield

Passian and Bennett (2001) studied the effect of seeds soaking of marigold, geranium and tomato in paclobutrazol solutions @ 0, 500, 1000 mg/$L^{-1}$ for 6, 16 or 24 hours. Higher concentration of Paclobutrazol 1000 mg $L^{-1}$ and prolonged soaking increased growth regulation but also inhibited emergence of seedlings. When seeds were imbibed for 6, 16, or 24 hours, growth restriction was 31%, 31 %, and 40 % respectively for tomatoes, 61%, 37%, and 76% respectively for geraniums, and 30 %, 38 %, and 41% respectively for marigolds.

Soaking pepper seeds in uniconazole @ 1-100 mg/$L^{-1}$ for 24, 72, or 120 hours inhibited hypocotyl length and seedling growth considerably (Shin and Jeong, 2002).

Tsegaw *et al.* (2005) treated potato plants with foliar sprays of paclobutrazol @ 0, 45.0 and 65.9 mg of active ingredient per plant at the stage of stolon initiation. Paclobutrazol treated seedlings were found to be short and compact, with thicker stems, root diameter, and darker green leaves. They also had higher chlorophyll content, higher accumulation of starch granules in the cortical cells of the stem root, which resulted in a thicker stem and root diameter.

Tomato seeds were soaked in different concentrations of paclobutrazol 0, 50, 100, 150, 200, or 250 mg/$L^{-1}$ for 1 hour. A concentration of Paclobutrazol at 100 mg / $L^{-1}$showed optimum control of hypocotyl elongation. (Brigard *et al.,* 2006)

Magnitskiy *et al.* (2006) reported that cucumber seeds soaked in 1000 mg / $L^{-1}$ Paclobutrazol solution for 180 minutes had lower averge fruit weight and fruit length than the control.

Ugur and Kavak (2007) studied the effects of Paclobutrazol and Cycocel on controlling the seedling height in tomato. Seeds of (cv. Rio Grande) were soaked in 250 and 500 ppm Paclobutrazol and 500 and 1000 ppm Cycocel solutions for 30, 60 and 120 minutes at 20°C. 250 and 500 ppm Paclobutrazol treatments reduced the seedling height by 55% and 58%, respectively. It was concluded Cycocel treatments were less effective than the Paclobutrazol treatments to control seedling height.

Cho *et al* . (2002) reported that cucumber seeds when soaked in various concentrations of 250 ,500 ,1000 mg /$L^{-1}$ paclobutrazol solutions for 6,12 or 24 h produced seedlings with reduced stem elongation , hypocotyl length , leaf area ,fresh and dry weight .

Ramin (2009) under took studies on effect of paclobutrazol on improving germination performance and chilling tolerance in cucumber seedlings. The studies revealed that hypocotyl length was reduced in seeds treated with 40 mg/$L^{-1.}$ Paclobutrazol seedlings that were treated with paclobutrazol had higher chlorophyll concentrations following 4 days of chilling at 5°C.

Shin *et al*. (2009) conducted studies to identify the appropriate concentration of plant growth retardants and time of soaking required to suppress hypocotyl length and plug seedling height in tomato seedlings. Seedlings soaked in different growth regulators *viz*, daminozide (1000 mg/$L^{-1}$), uniconazole (100 mg/$L^{-1}$) and ethephone (2000 mg/$L^{-1}$)

for one day revealed that uniconazole (100 mg /$L^{-1}$) was suppressed most effective in suppressing hypocotyl length and seedling height.

Ozgur and Mehmet (2011) carried out an investigation on control of hypocotyl elongation in cucumber seedlings. Seeds of cucumber cv. 'Maraton $F_1$ ' were soaked in 500 and 1000 mg/L solutions of Paclobutrazol 7500 mg/$L^{-1}$ and 15000 mg/$L^{-1}$ solutions of daminozide and chlormequat chloride for 12 and 24 hours respectively. Both concentrations of paclobutrazol resulted shortening hypocotyl and epicotyl lengths. The transplant heights were reduced as 63.4% at 500 mg /L and 74.9% at 1000 mg/L.The application of Paclobutrazol for 24 h showed effective seedling height control than that treated for 12 h. They reported that Paclobutrazol was more effective in reducing the seedling height than daminozide and chloromequat chloride.

Seeds of two okra varieties were soaked in varying concentrations (0, 4, 8,10, and 20 mg / $L^{-1}$) of Paclobutrazol solution. Paclobutrazol seed soaking affected the germination rate and maximum reduction in germination rate was observed at 20 mg/ $L^{-1}$ of Paclobutrazol. A gradual decrease in plant height was recorded in Paclobutrazol treated plants as compared to control (Bashir *et al.,* 2021).

**2.4 Effect of Plant growth regulators on Physiological Parameters**

Khali *et al.,* 1990 reported that Paclobutrazol treated plants were reported to be greener than control, it increased chlorophyll concentration per unit area of leaf

Application of Paclobutrazol at the pod formation stage increased chlorophyll content of the ground nut crop, ultimately increased carbon dioxide assimilation rates which inturn higher seed yield (Senno and Isoda ,2003)

Bora *et al.* (2007) treated sixty days old green gram plants with Paclobutrazol (500 µg active ingredient per 10 inch pot) by applying 100 ml of 5 mg/ $L^{-1}$ solution as soil drench to each pot .The plants were placed in the darkness for seven days after drenching, along with control .The chlorophyll content was 36 % higher in treated plants than the control.

Xia *et al*. (2018) reported that plants treated with Paclobutrazol were superior in terms of increased photosynthetic efficiency when compared to untreated control. They

attributed increased leaf greenness of paclobutrazol treated plants to higher leaf chlorophyll content.

Demir and Celikel (2019 ) conducted study on the effect of plant growth regulators on plant height in *Hyacinthus orientalis* The bulbs were soaked into flurprimidol solutions of 0, 10, 20 ppm and paclobutrazol at 0, 100, 200 ppm for 30 minutes before planting. The shortest plant height was obtained Paclobutrazol treatments @ 200 ppm. In fluprimidol the shortest plant height was recorded concentration at 20 ppm. The treatments reduced plant height by 49%, plant height was reduced by 49% in Paclobutrazol and 41% in flurprimidol treatment

**2.5 Effect of Plant growth regulators on Biometric Characters.**

Yadava (1980) reported a higher pod yield (18.7 q ha-1) and seed yield ((12.3q $ha^{-1}$) in vegetable cowpea with foliar application of NAA at 45ppm at flowering stage.

Huang and Zheng (1989) evaluated the effect of Paclobutrazol on growth of watermelon seedlings using different concentrations (200, 300, 400, 500, 1000 and 2000 ppm) in foliar application. It may found that under the higher concentration of 2000 ppm recorded average fruit weight and rind thickness also decreased in watermelon than the control

Patel and Saxeena (1994) found the effect of seed soaking and foliar spray of growth regulators on growth and yield of black gram .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 percent in plants treated with NAA and Kinetin

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

Ruiz *et al.* (1998) carried out an experiment on effectiveness of different growth regulators in enhancing bell pepper yield and fruit quality .The commercial growth regulators used for this study were CCC ( 100 $mg/L^{-1}$ ) , NAA ( 27 mg $/L^{-1}$) ,$GA_3$ (16 $mg/L^{-1}$ ) and bio enzymes. They were sprayed on plants at flower initiation stage .The

results revealed that NAA (30 %) CCC (18%) Bio enzymes (29%) produced marketable fruits per ha than the control and $GA_3$ didn't affected the yield of bell pepper.

Gill *et al*. (2005) investigated the effect of plant growth regulators NAA, MH, CCC and water regimes on growth, yield and quality of bottle gourd cultivar Pusa Summer Prolific Long and revealed that application of CCC 200 ppm at four leaf stage showed the significantly lowest number of male flowers and highest number of female flowers per vine.

Bora and Sarma (2006) soaked pea seeds in $GA_3$ and Cycocel at different concentrations *viz* 10, 100, 250 , 500 and 1000 µg $ml^{-1}$ along with a non-treated control for 12 hours . The seeds of pea were soaked for 12 hours .$GA_3$ @ 250 µg $ml^{-1}$ recorded maximum number of pods (21.83 pods /plant) followed by treatment Cycocel @ 250 ppm (22.07 pods /plant) compared to all other treatments

Chaudhary *et al.* (2006) conducted studies in experiment in effect of PGR in promoting growth and yield of chilli cultivars Jwala and Suryamukhi. Among PGRs, 2,4-D at 2 ppm was better for fruit set, number of fruits per plant, fruit length, number of seeds per fruit, seed weight per fruits, 1000 seed weight and fruit yield where as NAA at 40 ppm gave the highest leaf area index (LAI) . The treatments, 2 ppm 2, 4-D, 5 ppm triacontanol, 40 ppm NAA and 10 ppm $GA_3$ produced 28.75%, 25.70%, 13.61% and 2.30% higher fruit yield over control.

Haque *et al*. (2007) found that Ethrel at 50, 100, 250 and 500 mg / $L^{-}1$ produced a significant positive effect on pyrethrins level, decreased plant height, while 50 and 100 mg / $L^{-1}$ significantly increased fresh and dry flower yield. Chlormequat chloride at 1000 and 2000 mg / $L-^{1}$ and paclobutrazol 80 and 160 mg /$L^{-1}$ increased flower weight and decreased plant height and flower yield.

Singh and Singh (2009) investigated the effect of gibberellic acid on growth, yield and quality parameters of chilli (*Capsicum annum* L.) The treatments include combinations of gibberellic acid ($GA_3$) 50, 100 and 150 ppm and control. Plant growth regulators were applied at vegetative stage. They observed that application of $GA_3$ @ 150 ppm was significantly superior over other treatments in terms of plant height at 30 days after transplanting (DAT), 60 DAT and at harvest (76.82 cm, 116.14 cm, 141.58 cm), No of branches /plant at 30 DAT and at harvest (28.37 and 50.73), fruit length ( 29.74 cm),

fresh weight of ten fruits of chilli (109.85 g), number of fruits/plant (127.91), fruit yield/plant (636.04 g), fruit yield/ha (25.70 t/ha) and vitamin C content (98.49 mg /100 g) .

Devi *et al.* (2011) worked on the response of soybean variety to salicylic acid @ 50 ppm, Ethrel @ 200 ppm, Cycocel @ 500 ppm and control (water spray) applied as foliar spray at different stages *viz.* flower- initiation (40 DAS), pod-initiation (60 DAS) and flower-initiation and pod-initiation (100 DAS). The study revealed that application of Ethrel @ 200 ppm at both flower-initiation (40 DAS) + pod-initiation (60 DAS) gave higher vegetative growth and yield compare to salicylic acid @ 50 ppm, Cycocel @ 500 ppm and control. However, maximum chlorophyll content and carotenoids were obtained from Cycocel @ 500 ppm treated plants

Mehdi *et al*. (2012) reported that application of ethrel @ 200-400 ppm increased number of fruits and ultimately fruit yield per plant in both the cucumber varieties. Ethrel treatment at the concentration of 300 ppm increased growth and yield parameters in greenhouse.

Udesi *et al.* (2013) soaked seeds of pigeon pea in different concentrations of growth regulators *viz* 0, 100, and 150 mg/$L^{-1}$ concentration of IAA, NAA, Paclobutrazol, Paclobutrazol + IAA and Paclobutrazol + NAA, respectively for 48 hours. The results revealed that the pigeon pea seeds soaked in 100 and 150 mg/$L^{-1}$ Paclobutrazol + NAA gave significantly highest yield when compared to other treatments. They produced the highest number of flowers (144), pods per plant (318.0), seeds per pod (7.00), longest pod (7.27 cm), and highest seed yield per treatment (1.919 kg)

Ghani *et al*. (2013) studied the effect of plant growth regulators on bitter gourd .Three chemicals with different concentrations of $GA_3$ (25, 50 & 75 ppm), Ethrel (400, 500 & 600 ppm), and NAA (50, 100 & 150 ppm) were applied at three different stages namely S1 (2-leaf stage), S2 (2-leaf and flower initiation stage) and S3 (2-leaf, flower and fruit initiation stage). The results showed that application of $GA_3$ @ 25 ppm significantly reduced number of days to first flower (40 days) and first harvest (54 days) when sprayed at two leaf, flower and fruit initiation stage. Similarly male to female flower ratio was lowest (11.83) in plants sprayed with $GA_3$ @ 75 ppm when two leaf stage while fruit set percentage was highest ( 90 %) with similar application at S2 however,

both fruit length and fruit diameter were highest with similar dose in plants sprayed at S2.

Netam and Sharma (2014) tested the efficacy of the of different Plant growth regulators and their combination of naphthalene acetic acid gibberellic acid and dichlorophenoxyacetic acid 1 ppm and 2 ppm sprayed at 30, 60 and 90 days after planting on fruit yield and quality in brinjal. The highest plant height, number of leaves, plant fresh weight and ascorbic acid and higher yield was recorded in $GA_3$ @ 50 ppm

Foliar application of Naphthalene acetic acid (100 ppm) $GA_3$ (300 ppm), Ethrel (500 ppm) & Cycocel (500 ppm) were carried out in 3 times in each month of marigold plants. Application of $GA_3$ @ 300 ppm recorded maximum plant height of (73 cm). Ethrel @ 500 ppm recorded maximum yield per plant (66.25 kg /plant) (Rajalakshmi and Rajasekhar, 2014)

The application of Indole Acetic acid @ 100 ppm increased number of flowers per plant number of pods /plant and number of seeds /plant also increased the percentage of fruit set in crop cowpea (Basuchudhauri *et al* ., 2016)

NAA @ 100 ppm increased significantly increased plant height, number of branches per plant, number of plants per plant and total dry matter content per plant at 30,45,60,75 and 90 days in mustard when compared to Cycocel and Ethrel sprayed at 30,45,60,75 and 90 days after sowing (Kumar *et al*., 2016)

A experiment was conducted with twelve treatment combinations of different concentrations of plant growth regulators such as Salicylic acid @ 100 mg / $L^{-1}$ Ethrel @ 200 mg / $L^{-1}$ and Cycocel 50 mg / $L^{-1}$ applied at flower initiation, pod initiation and flower and pod initiation stage. among them growth regulators Salicylic acid 100 mg / $L^{-1}$ give higher seed yield and higher pods per plant followed by Cycocel 50 mg / $L^{-1}$ and Ethrel 200 ppm (Vaiyapuri *et al.,* 2016)

Wawrzyniak *et al.* (2016) evaluated the effects of Cycocel on plant height in Jerusalem artichoke (*Helianthus tuberosus* L.) The plants were sprayed with 0.75% of Cycocel retardant, after the first week of Cycocel use, 16 % decreased the plant height

A field experiment was conducted to know the effect of growth retardants *viz*, Maleic Hydrazide (MH) and Cycocel (CCC) on growth characters and yield components in

cowpea (cv.Kashi Kanchan). The study revealed that application of growth retardant reduced plant height in the field. The minimum plant height was reduced in MH 50 ppm (33.2 cm) followed by CCC 1000 (36 cm) height. (Suman and John, 2017).

A soyaben variety Phule Agrani was evaluated for foliar sprays of Ethrel @ 150 ppm, 200 ppm, Cycocel @ 500 ppm and 1000 ppm at the time of initiation of flowering and pod formation stage of the crop .Among the treatments sprayed of Cycocel @ 500 and 1000 ppm recorded significantly lower plant height 45 cm also increased yield as compared to rest of the treatments (Bramhankar *et al.*, 2018)

Kumar *et al*. (2018) conducted study on flowering and quality aspects of okra using different growth regulators The experiment consisted of three treatments *viz* Cycocel (200, 400 & 600 ppm), Paclobutrazol (150, 250 & 300 ppm) and Ethrel (150, 250 & 300 ppm) which was sprayed once at 30 DAS .They concluded that the lowest days to first flowering and 50 per cent flowering (45.26) , highest total number of harvest , number of fruits per plant , yield per plant and per hectare (290 g ) were recorded most in CCC @ 600 ppm than the control and other treated one

Jain *et al.* (2010) worked on papaya using different plant growth regulators *viz* NAA 100 ppm ,200ppm, Ethrel 250ppm and 500ppm, Paclobutrazol 250 ppm ,500ppm , CCC 500 ppm and 1000ppm .The maximum fruit length (6.65 cm), maximum yield (63.83 kg/tree) was observed in Paclobutrazol 500 and 200 ppm followed by Cycocel 1000 ppm and 500 ppm

Kropi and Phonglosa (2020) evaluated the plant growth regulators on the fruit yield of brinjal, three plant growth regulators namely $GA_3$, IAA and NAA @ concentration of 25, 50 and 100 ppm 40 days after planting. The results revealed that the highest leaf chlorophyll content index (44.50) was recorded in the treatment with NAA at 50 ppm Foliar application $GA_3$ at 50 ppm exhibited significantly higher total number of flower per plant (38.49), number of fruit per plant (18.56) and fruit yield (1.58 kg/ plant)

Studies were conducted on growth and yield diameters of lab lab (*Dolichos lablab* L).The treatments were used *viz* control , NAA @ 50 and 100 ppm, Ethrel @ 250 and 500 ppm, Cycocel @ 500 and 1000 ppm, Nitrobenzene @ 50 ppm and Nitrobenzene @100 ppm. The foliar sprays were imposed on 30, 60 and 75 days after sowing. Among the different foliar treatments, NAA @ 100 ppm and NAA @ 50 ppm recorded earlier

flowering 44.88 days and 44.07 days respectively followed by Nitrobenzene 50 ppm (45.59) days found to be the best. Application of NAA @100 ppm recorded the highest number of flowers/plant (241.85 flowers/plant) , number of fruits/plant (178.91/plant) and highest yield/plant 0.39 kg /plant) as compared to control (Kumannan *et al.,* 2020)

# *MATERIALS AND METHODS*

# 3. MATERIALS AND METHODS

## 3.1. Experimental site

The present study on "Controlling seedling height of cowpea (*Vigna unguiculata* (L.) Walp.) transplants using plant growth regulators" was conducted at the Centre for Hi-Tech Horticulture and Precision farming, Vellanikkara KAU, Thrissur during the year 2020-2021. The experimental site was located at 760 26‟ E longitude and 10 ˚54 N latitude at an altitude of 22.5 m above MSL.

## 3.2. Treatments

Treatments comprised of three plant growth regulators namely Paclobutrazol, Cycocel and Ethrel with four doses of 25 ppm, 50 ppm, 100 ppm and 200 ppm and control (ordinary water)

$T_1$- Cycocel 25 ppm

$T_2$- Cycocel 50 ppm

$T_3$ - Cycocel 100 ppm

$T_4$- Cycocel 200 ppm

$T_5$- Paclobutrazol 25 ppm

$T_6$ - Paclobutrazol 50 ppm

$T_7$ - Paclobutrazol 100 ppm

$T_8$ - Paclobutrazol 200 ppm

$T_9$ - Ethrel 25 ppm

$T_{10}$- Ethrel 50 ppm

$T_{11}$- Ethrel 100 ppm

$T_{12}$- Ethrel 200 ppm

$T_{13}$- Control

**Table 1. Growth regulators used for the study**

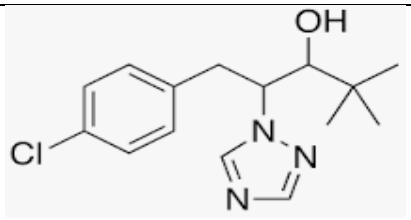
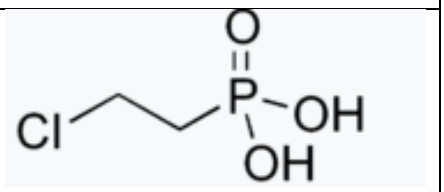
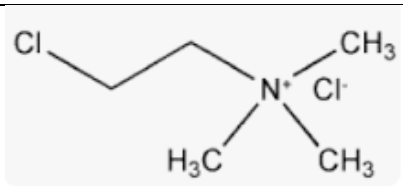
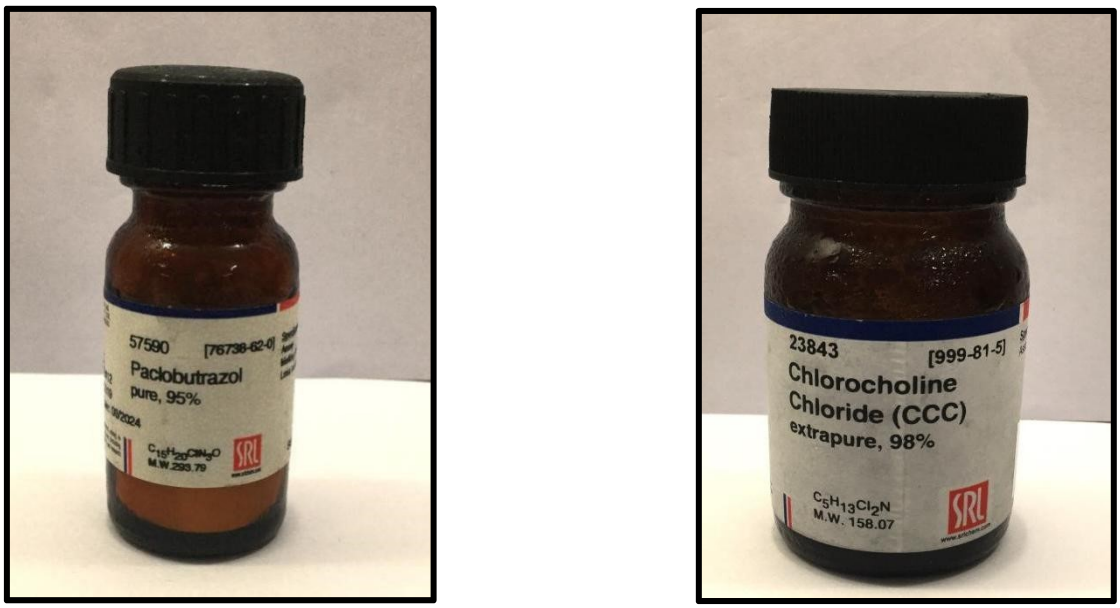
| Common name | Chemical name | Chemical structures |
|---|---|---|
| Paclobutrazol | (2R,3R)-1-(4-Chlorophenyl)-4-4dimethyl-2-(1,2,4-triazol-1-yl)pentane -3-0l |  |
| Ethrel | 2-Chloro ethyl phosphonic acid |  |
| CCC (Cycocel) | 2-Chloro ethyl trimethyl ammonium chloride |  |

**Plate 1. Materials and methods used for the study**




**Growth regulators used for the study**

**Plate 2. Materials and methods used for the study**

**Cowpea genotypes used for the study**

**Plate 3. Materials and methods used for the study**


**Seed treatment with growth regulator solutions**

**Seeds sowing**

**Table 2. Cowpea varieties used for the study**

| Cowpea variety | Source |
|---|---|
| Vellayani Jyothika ( Indeterminate) | KAU, Thrissur |
| Kashi Kanchan (determinate) | IIVR ,Varanasi |

### 3.3 Experimental layout

The investigation was carried out in two sets of experiments

3.3.1. Seedling evaluation

3.3.2 Field evaluation

### 3.3.1. Seedling evaluation

Design: CRD

No. of treatments: 12+1 (control)

No. of replications: 3

No. of plants: 100 per treatment /replication

In this study, seeds of two cowpea varieties Vellayani Jyothika and Kashi Kanchan were soaked for 6 hours in growth regulator solutions. In the case of control, seeds were soaked in ordinary water. After six hours, the soaked seeds were taken out and air - dried and planted into 104 celled pro-trays of 51 cm length and 30 cm width filled with a volume of 700 (g) planting media of coir pith, vermiculite and perlite @ 3:1:1 in each tray. Fertilizers 19:19:19 and $MgSo_4$ were applied into the seedlings @ 3 (g) per liter twice in a week and irrigation done using rose can twice a day.

#### 3.3.1.1 Seedling vigour characters

##### 3.3.1.1.1 Shoot length (cm)

In each treatment, 5 normal seedlings were selected randomly from all replications at 5, 10 and 15 days after germination. The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and expressed in centimeters.

#### 3.3.1.1.2. Root length (cm)

The root length of seedlings selected for measurement of shoot length were recorded at 5, 10 and 15 days after germination and expressed in centimeters.

#### 3.3.1.1.3. Total seedling length (cm)

Total seedling length was measured by adding root length and shoot length of five normal seedlings randomly selected from all replications at 5, 10 and 15 days after germination and expressed in centimeters.

#### 3.3.1.1.4. Weight of shoot (g)

Shoot weight was measured by the weighing above ground parts of the plants in a precision weighing balance.

#### 3.3.1.1.5. Weight of root (g)

The roots of plants were cut at the base level and the adhering media particles were removed from the root and dried at 50$^{o}$ C in a hot air oven for an one day and dry weight was recorded.

#### 3.3.1.1.6. Germination (%)

The percentage of germination was arrived at by counting the number of seeds germinated out of the total number of seeds sown multiplied by 100. It was estimated by using this formula

$$\text{Germination \%} = \frac{\text{No of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

### 3.3.1.2. Morphological observations

**The morphological observations were recorded as described below**

#### 3.3.1.2.1. Number of days for emergence of seedling up to the first node

The number of days taken for the formation of first true leaf from the date of sowing

#### 3.3.1.2.2. Height of seedling up to the first node

Length of shoot measured from the base of the plant till the height at which the first node appeared

#### 3.3.1.2.3. Number of leaves

The number of leaves on the plants were counted at 5 ,10 and 15 days after germination.

#### 3.3.1.2.4. Number of primary branches

The number of primary branches on the plants were counted 15 days after germination and expressed as a number.

#### 3.3.1.2.5. Leaf length

Leaf length of 5 normal leaves were taken randomly by using graduated scale and expressed in centimeter

#### 3.3.1.2.6. Leaf color

Leaf color was determined by using The Royal Horticultural Society Color Chart (RHS COLOUR CHART)

#### 3.3.1.2.7. Girth of seedlings

The girth of shoot was measured at the base of the stem using a Vernier Caliper on 5, 10 and 15 days after germination and it was expressed in mm.

#### 3.3.1.2.8. Physiological parameters

Chlorophyll (a, b and total), carotenoid contents, indole acetic acid, gibberellic acid contents were recorded 10 days after germination.

#### 3.3.1.2.9. Chlorophyll (a, b and total) and carotenoid contents (mg $g^{-1}$FW)

250 mg fresh leaf sample was weighed and macerated with 10 ml of 80 % acetone using a pestle and mortar .The macerated sample was centrifuged for 10 minutes at 3000 rpm. The supernatant liquid was collected and volume made up to 25 ml by using 80% acetone. The absorbance was measured at OD 480, 510, 645 and 663 nm by using a spectrophotometer (Arnon method, 1949)

The pigment contents were calculated using the following formulae

$$\text{Chlorophyll a (mg/g)} = [12.7 \times \text{OD at } 663] - [2.69 \times \text{OD } 645] \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b (mg/g)} = [22.9 \times \text{OD } 645] - [4.68 \times \text{OD } 663] \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll (mg/g)} = [8.02 \times \text{OD}663] + [20.2 \times \text{OD } 645] \times \frac{V}{1000 \times W}$$

$$\text{Carotenoids (mg/g)} = [7.6 \times \text{OD } 480) - [1.49 \times \text{OD } 510] \times \frac{V}{1000 \times W}$$

**3.3.1.2.10. Estimation of IAA content (mg of unoxidised auxin $g^{-1}$ FW)**

500 mg of fresh leaf sample was weighed and macerated with 10 ml of phosphate buffer. The contents were centrifuged for 10 minutes at 5000 rpm.The supernatant liquid was collected and made up to the volume of 25 ml with ice cold distilled water . A mixture of 1 ml aliquot of supernatant liquid, 1ml phosphate buffer and 1ml distilled water was separated in a test tube. The test was kept for an one hour in a dark room. The test tube was kept in hot water bath for 10-20 seconds to stop the reaction, cool the contents and added 8ml of Garden Webber reagent, when the pink color developed .The absorbance was taken at 540 nm. Plotted the sample OD in the standard graph and find out the corresponding concentration (X µg). It was estimated by ( Parthasarathi *et al.,*1970)

$$\text{IAA Content} = \frac{X \times 25 \times 1000\ \mu g}{1 \times 500}$$

Where X = plotted value of OD from the standard graph

### 3.1.3.11. Estimation of Gibberellic acid content ( µg GA $g^{-1}$)

Gibberellic acid content estimated by modified protocol form that described by Sunderberg (1990) and Kojima (1995)

500 mg of fresh leaf sample was grounded with 20 ml of methanol by using pestle and mortar and the sample was kept for 4 hour in fridge .The sample was centrifuged for 10 minutes at 3000 rpm and filtered. The collected supernatant solution was concentrated into water residue at a temperature of 40-50˚C for an 1 hour then take out from the oven and volume was made up to 10 ml with phosphate buffer. The content was poured into separating funnel for separation with 10 ml diethyl ether and stored for 3 minutes. The top portion was discarded and lower phase adjusted the $P^H$ 2.7 with 0.4M hcl. Again partitioned with 10 ml ethyl acetate and lower portion was discarded. After that upper portion collected was again partitioned with 0.4 $NaHCO_3$, lower portion discarded, again top portion adjusted with the $P^H$ 2.5 with 1.6 M hcl, again partitioned with 10 ml ethyl acetate in separating funnel. The top portion was collected 2ml of methanol was added and stored in a glass vial at 4˚C. 5 ml of extract was taken from the test tube and added 2ml of zinc acetate after 5 minutes added 2ml of potassium Ferro cyanide into it. Centrifuged at lower speed for 15minutes then filtered it, again added 5ml of supernatant and 5 ml of 30% hcl .It was kept at 20˚C for 15 minutes , The absorbance was read at 254 nm. Plotted the sample OD in a standard graph and find out the corresponding concentration

GA Content = ( x / 2) × ( 1/1000 )


**Plate 4. General view of field**

**Plate 5. Insecticidal application in cowpea genotype Vellayani Jyothika**

### 3.3.2 Field evaluation

Design: RBD

No of treatments: 13

No of replications: 3

No of plants: 12

Varieties : Vellayani Jyothika, Kashi Kanchan

Spacing : Vellayani Jyothika (trailing type) 1m × 1m

Kashi Kanchan : (Bush type) 60 × 60 cm

### 3.3.3. Preparation of main field

The experimental area was ploughed two or three times with tractor which broke the large clods into powdered fine soil. Before selecting the experimental area (Plot number 1) soil was analyzed (Table no.3) The experimental area was cleared and made into beds of size 41 m × 0.9 m × 15 cm. A spacing of 0.5 m was provided between adjacent beds. The beds were mulched with 30 µ silver black polythene film. Seedlings were transplanted from the pro- trays to the well prepared main field for Vellayani Jyothika planted at a spacing of 1m× 1m and Kashi Kanchan planted at a spacing of 60 cm× 60 cm .The field was laid out in randomized block design with three replications. There were 12 plants per treatment per replication.

**Soil testing data of plot No -1 (Table no.3)**

| Parameters | Sample- plot 1 | |
|---|---|---|
| | Quantity | Remarks |
| pH | 5.76 | Moderately acid |
| Electrical conductivity($dsm^{-1}$) | 0.139 | Normal |
| Organic Carbon (%) | 0.99 | Medium |
| Available phosphorous($kg\ ha^{-1}$) | 270. 47 | High |
| Available potassium | 590. 46 | High |
| Available Calcium | 946.5 | Sufficient |
| Available Magnesium | 271.9 | Sufficient |
| Available sulphur | 12.5 | |
| **Micronutrients** | | |
| Iron ($mg\ kg^{-1}$) | 58.93 | Sufficient |
| Manganese($mg\ kg^{-1}$) | 63.28 | Sufficient |
| Zinc ( $mg\ kg^{-1}$) | 4.39 | Sufficient |
| Copper ($mg\ kg^{-1}$) | 3.18 | Sufficient |
| Boron ($mg\ kg^{-1}$) | 0.34 | Deficient |

### 3.3.4 Application of Manures and fertilizers

Fertilizer application was done as per the adhoc package of practices for cowpea. For the main field, land was dug and FYM @ 25t/ha was incorporated into the soil. The crop was irrigated through drip irrigation and fertigation was started one week after planting with a dose of 150 (g ) 19:19:19 , 56 (g) 12:16:0, 318 (g) 13: 0: 45 and 38 (g ) urea per fertigation for Kashi Kanchan .In the case of Vellayani Jyothika fertigation schedule started with 200 (g )19:19:19 , 109 (g) 12:61:0, 551 (g ) 13:0:45 and 74 ( g ) urea . Total number of doses 40 given at the different stages of the crop during the entire crop period.

### 3.3.5. Intercultural operations

Weeding was done in interspaces using a spade three times at regular intervals to keep the field clean. Plant protection measures were adopted to control the pest diseases

incidence in the field like aphids, pod bugs, leaf eating caterpillars, anthracnose and *Cercospora* leaf spots etc.

### 3.3.6. Morphological observations

#### 3.3.6.1 Plant height

Plant height has taken from the base of the stem to the growing tip and it was recorded at 30 days after planting

#### 3.3.6.2. Internodal length (cm)

The internodal length was taken from basal nodes of five plants at 30 days after planting average were taken out and expressed in centimeter

#### 3.3.6.3. Number of primary branches

The primary branches present in the plants were counted at 30 days after planting and expressed as number

#### 3.3.6.4. Days to first flowering

Number of days was taken from the date of sowing to the first flowering in each treatment of three replications were counted and recorded as number of days.

#### 3.3.6.5. Days to first harvest

Number of days from the date of sowing to the first harvest of pods at vegetable maturity was recorded and expressed as number of days

#### 3.3.6.7. Days to last harvest

Number of days from date of sowing to the last harvest of pods at vegetable maturity was recorded and expressed as number of days

#### 3.3.6.8. Pod length (cm)

Ten pods was randomly selected at vegetable maturity from each replication per treatment and length of pods were recorded in centimeter

#### 3.3.6.9. Pod girth (cm)

Girth of ten randomly selected pods taken for measuring pod length was calculated and expressed as centimeter.

### 3.3.6.10. Pod weight (g)

Weight of ten randomly selected pods were measured and expressed as gram (g) at full maturity stage

### 3.3. 6.11. Number of pods per plant (g)

The number of pods harvested at vegetable maturity from 5 randomly selected plants per treatment per replication was recorded in (g)

### 3.3.6.12. Pod yield per plant

Pod yield was computed from the data recorded on number of pods per plant and pod weight was calculated in (g)

### 3.3.6.13. 100 Seed weight

The dry weight of randomly selected 100 seeds selected weighed using an electronic balance and represented in grams

### 3.3.6.14. Incidence of pest and diseases

Pest and diseases incidence on the plants during the entire growth period was recorded.

### 3.3.6.15. Relative growth rate (RGR)

RGR is defined as the increase in dry weight per unit dry material present at any instant time (t) This can be determined by measuring plant dry weight periodically during growth and is commonly represent as mg $g^{-1}$ $day^{-1}$ or g $g^{-1}$ $day^{-}$.

The plants were uprooted from the field on the 15 ,30, 45 , 60 and 75 days after planting and washed out the base of the stem and removed the adherent media and dried under the hot air oven at 50˚C for 24 hours .

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

Where, $W_1$ and $W_2$ are the plant dry weight at times $t_1$ and $t_2$ respectively

### 3.3.6.16. Physiological parameters

Stomatal Index and frequency (on the adaxial surface of leaves)

Third fully opened leaf was selected 30 days after planting from each treatment in three replications for observations

The stomatal index is defined as the percentage of number of stomata as compared to all the epidermal cells in a unit area of the leaf.

A fresh clean leaf was selected from the field, removed all the dust and soil particles adhered to the surface of leaf. A small quantity of quick fix gum was applied on the surface of the leaf and smeared evenly into a thin film layer. After 15-20 minutes the dried thin film layer of the quick fix was removed. This helped to trace out the impression of the epidermal cells, stomatal openings, oil glands and veins. The quick fix film was placed on a glass slide and observed under a microscope and the number of stomata and epidermal cells per unit area of leaf were counted separately. The stomatal index was calculated based on the given formula.

$$\text{Stomatal index} = \frac{S}{E+S}$$

Where S - stomatal number/unit area; E - epidermal cells/unit area.

Stomatal frequency: The number of stomata per unit area of leaf is described as stomatal frequency.

# *RESULTS*

# 4. RESULTS

The present study entitled "Controlling seedling height of cowpea (*Vigna unguiculata* (L.) Walp.) transplants using plant growth regulators" was carried out with the objective of evaluating the role of plant growth regulators in controlling the seedling height of vegetable cowpea and to assess the field performance of the treated seedlings.

**4.1** Experiment No -1 (Seedling evaluation)

**4.1.1** Seedling vigour characters was recorded at 5, 10 and 15 days after germination in the cowpea varieties (Vellayani Jyothika and Kashi Kanchan) following the treatments as given in chapter 3

**4.1.1.1 Shoot length**

In the cowpea genotype Vellayani Jyothika, significantly higher shoot length was recorded on $5^{th}$ (15.0 cm) and $10^{th}$ (19.42 cm ) day after germination in control treatment (Table 4) .On $15^{th}$ day after germination higher shoot length was recorded in treatment with Ethrel @ 100 ppm (21.45cm) but on par with control (21.00 cm). Minimum shoot length was recorded in the treatment receiving Paclobutrazol @ 200 ppm on $5^{th}$ (3.72 cm) $10^{th}$ (4.79 cm) and $15^{th}$ (5.61 cm) day after germination.

In Kashi Kanchan, significantly higher shoot length was recorded on $5^{th}$ (14.56 cm) and $10^{th}$ (15.86 cm) and $15^{th}$ day after germination in control treatment (17. 2 cm). Minimum shoot length was recorded in treatment receiving Paclobutrazol @ 200 ppm on $5^{th}$ (4.3 cm) $10^{th}$ (5.3 cm) and $15^{th}$ (5.8 cm) day after germination which was on par with Paclobutrazol 25 ppm irrespective of the number of days after germination.

**4.1.1.2 Root length (cm)**

Highest root length was recorded in control treatment on $5^{th}$ (15.67cm) day after germination in Vellayani Jyothika. (Table 5) Cycocel 200 ppm was recorded to be superior to all other treatments on $10^{th}$ and $15^{th}$ day after germination (17.36 cm), (18.46 cm) in Vellayani Jyothika Significantly lower root length was recorded in treatment receiving Paclobutrazol @ 200 ppm on $5^{th}$ (10.45cm ), $10^{th}$ (13.4cm) and $15^{th}$ (15.6 cm) day after germination in Vellayani Jyothika.

Significantly higher root length was recorded in treatments receiving Cycocel @ 50 ppm on $5^{th}$ day (13.00 cm) $10^{th}$ (15.43 cm) and $15^{th}$ (16.4 cm) day after germination in

Kashi Kanchan (Table 5). Among the above treatments Cycocel @ 50 ppm was on par with Cycocel @ 100 ppm on 5th (12.53 cm), 10th (14.42 cm) and 15th (15.9 cm) day after germination. Minimum root length was recorded in the treatment receiving Paclobutrazol @ 200 ppm irrespective of the number of days after germination.

**4.1.1.3 Total seedling length (cm)**

In Vellayani Jyothika significantly higher total seedling length was recorded in control treatment on 5th (31.65 cm), 10th ( 35.07 cm) and 15th ( 38.6 cm) day after germination (Table 6). Minimum total seedling length was recorded in seedlings treated with Paclobutrazol @ 200 ppm on 5th (14.16) 10th (18.20 cm) and 15th (21.2 cm) day after germination.

Total seedling length recorded highest in control treatment on 5th (27.3 cm) 10th (29.13cm) and 15th (36.1 cm) day after germination in Kashi Kanchan (Table 6). Minimum seedling length was recorded in Paclobutrazol @ 200 ppm on 5th (16.3 cm) on 10th (19.4 cm) and 15th (20.30 cm) day after germination.

**4.1.1.4 Shoot weight** (g)

Significantly higher shoot weight was recorded in control treatment (0.298 g), but on par with Ethrel @ 25 ppm (0.292 g) Ethrel @ 200 ppm (0.286 g) and Ethrel @ 100 ppm (0.270 g) on 5th day after germination in cowpea genotype Vellayani Jyothika (Table 7). However on 10th day after germination, seedlings treated with Ethrel @ 200 ppm (0.449 g) recorded significantly higher shoot weight. On 15th day after germination, control (0.557 g) treatment recorded significantly superior to all other treatments which was on par with Ethrel @ 200 ppm (0.532 g), Cycocel @ 25 ppm (0.524 g) and Ethrel 100 ppm (0.516 g). Significantly lower shoot weight was recorded in treatment receiving Paclobutrazol 200 ppm (0.148-0.282g) irrespective of the number of days after germination.

Shoot weight was significantly higher in control (0.282 g) but on par with Ethrel @ 50 ppm (0.227 g) and Ethrel @ 100 ppm (0.271 g) . On 10th day after germination, control treatment (0.454 g) recorded significantly higher shoot weight but on par with Ethrel @ 100 ppm (0.433 g) and Ethrel @ 200 ppm (0.418 g) in the genotype Kashi Kanchan (Table 7). Minimum shoot weight was recorded on 5th 10th and 5th day after germination was Paclobutrazol @ 200 ppm (0.139 g), (0.162 g) and (0.264 g) respectively.

#### 4.1.1.5 Root weight (g)

In Vellayani Jyothika significantly higher root weight was recorded in Ethrel @ 25 ppm on 5$^{th}$, 10$^{th}$ day and 15$^{th}$ day after germination (0.276 g), (0.289 g) and (0.335 g) (Table 8). Significantly lower root weight was recorded on 5$^{th}$ and 10$^{th}$ day after germination in treatment receiving Paclobutrazol @ 200 ppm (0.146 g), (0.220 g). On the 15$^{th}$ day, minimum root weight was recorded in treatments with Ethrel @ 200 ppm (0.242 g) which was on par with Paclobutrazol 200 ppm (0.249g)

Significantly higher root weight was recorded in treatment receiving Ethrel 25 ppm on 5$^{th}$ (0.259 g) and 10$^{th}$ (0.287 g) day after germination. Out of the above treatments Ethrel 25 ppm on 10th day after germination was on par with Cycocel 100 ppm (0.295 g) .On 15$^{th}$ day after germination significantly higher treatment was recorded in Cycocel 50 ppm (0.397 g) Minimum root weight was recorded in Paclobutrazol @ 200 ppm irrespective of the number of days after germination (0.124 g), (0.136 g) and (0.195 g) respectively.

#### 4.1.1.6 .Germination percentage

Highest germination percentage was recorded in control treatment on 5$^{th}$ (96.3%) day after sowing. (Table 9) which was statistically on par with Ethrel @ 100 ppm (95%) , Cycocel @ 200 ppm (94.0%), Ethrel @ 50 ppm (93.3%), and Cycocel @ 100 ppm (93.0%) in cowpea genotype Vellayani Jyothika . Minimum germination percentage was recorded in Paclobutrazol @ 200 ppm on 5$^{th}$ (64.3%) and 10$^{th}$ (66.0%) day after sowing in cowpea genotype Vellayani Jyothika. Significantly higher germination percentage was recorded in control treatment (95.65%) on 5$^{th}$ day after sowing (Table 9) but on par with Cycocel @ 25 ppm (95.3%), Cycocel @ 200 ppm (94.66%), Ethrel @ 50 ppm (94.00 %), Ethrel @ 200 ppm (93.33%) in Kashi Kanchan. Significantly lower germination percentage was recorded in treatments receiving Paclobutrazol @ 200 ppm on 5$^{th}$ (70.0%) and 10$^{th}$ (72%) day after sowing. On 15$^{th}$ day after sowing there were no new germination in any treatment in both the genotypes.

**Table. 4 Effect of plant growth regulators on shoot length in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Seedling shoot length (cm) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 13.75$^{b}$ | 16.97$^{c}$ | 18.25$^{e}$ | 13.13$^{b}$ | 14.23$^{c}$ | 15.63 $^{c}$ |
| CC 50 ppm | 12.69$^{d}$ | 16.70$^{cd}$ | 18.22$^{ef}$ | 12.20$^{c}$ | 13.93$^{c}$ | 14.43$^{de}$ |
| CC 100 ppm | 12.20$^{e}$ | 16.85$^{c}$ | 17.67$^{f}$ | 10.70$^{d}$ | 12.80$^{de}$ | 14.00$^{e}$ |
| CC 200 ppm | 12.46$^{de}$ | 17.02$^{c}$ | 19.47$^{c}$ | 12.3$^{c}$ | 13.16$^{d}$ | 14.40$^{e}$ |
| PBZ 25 ppm | 5.68$^{g}$ | 6.55$^{e}$ | 7.97$^{g}$ | 5.53$^{e}$ | 6.80$^{f}$ | 7.43$^{f}$ |
| PBZ 50 ppm | 5.51$^{g}$ | 6.57$^{e}$ | 7.51$^{g}$ | 5.23$^{e}$ | 6.36$^{f}$ | 7.20$^{f}$ |
| PBZ 100 ppm | 4.76$^{h}$ | 5.64$^{f}$ | 6.60$^{h}$ | 4.53$^{f}$ | 5.53$^{g}$ | 5.90$^{g}$ |
| PBZ 200 ppm | 3.72$^{i}$ | 4.79$^{g}$ | 5.61$^{i}$ | 4.36$^{f}$ | 5.33$^{g}$ | 5.83$^{g}$ |
| ET 25 ppm | 13.23$^{c}$ | 17.04$^{c}$ | 18.84$^{d}$ | 11.83$^{c}$ | 12.63$^{e}$ | 14.10$^{e}$ |
| ET 50 ppm | 11.42$^{f}$ | 16.28$^{d}$ | 18.99$^{cd}$ | 11.90$^{c}$ | 13.80$^{c}$ | 14.93$^{d}$ |
| ET 100 ppm | 13.10$^{c}$ | 18.22$^{b}$ | 21.45$^{a}$ | 14.26$^{a}$ | 15.20$^{b}$ | 16.70$^{ab}$ |
| ET 200 ppm | 14.63$^{a}$ | 18.32$^{b}$ | 20.56$^{b}$ | 14.50$^{a}$ | 15.43 $^{ab}$ | 16.30$^{bc}$ |
| Control | 15.01$^{a}$ | 19.42$^{a}$ | 21.00$^{ab}$ | 14.56$^{a}$ | 15.86 $^{a}$ | 17.23$^{a}$ |
| CD | 0.40 | 0.56 | 0.57 | 0.49 | 0.47 | 0.67 |
| CV | 2.24 | 2.45 | 2.20 | 2.82 | 2.4 | 3.1 |
| SE(m) | 0.138 | 0.195 | 0.198 | 0.170 | 0.162 | 0.23 |

**Table. 5 Effect of plant growth regulators on seedling root length in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Seedling root length (cm) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 13.06$^{c}$ | 15.72$^{ef}$ | 16.83$^{bc}$ | 12.20$^{abc}$ | 14.23$^{b}$ | 15.20$^{cdef}$ |
| CC 50 ppm | 12.61$^{cd}$ | 16.03$^{cde}$ | 17.26$^{bc}$ | 13.00$^{a}$ | 15.43$^{a}$ | 16.43$^{a}$ |
| CC 100 ppm | 13.00$^{c}$ | 16.38$^{bcd}$ | 17.40$^{b}$ | 12.53$^{ab}$ | 14.42$^{ab}$ | 15.96$^{ab}$ |
| CC 200 ppm | 12.00$^{de}$ | 17.36$^{a}$ | 18.46$^{a}$ | 10.50$^{e}$ | 12.36$^{de}$ | 14.73$^{def}$ |
| PBZ 25 ppm | 12.70$^{cd}$ | 14.95$^{g}$ | 16.63$^{cd}$ | 10.76$^{de}$ | 14.40$^{ab}$ | 15.36$^{bcd}$ |
| PBZ 50 ppm | 11.63$^{e}$ | 13.38$^{h}$ | 15.93$^{de}$ | 12.20$^{abc}$ | 13.50$^{bc}$ | 14.60$^{ef}$ |
| PBZ 100 ppm | 11.35$^{e}$ | 13.28$^{h}$ | 15.80$^{e}$ | 11.63$^{bcd}$ | 13.63$^{bc}$ | 15.43$^{bc}$ |
| PBZ 200 ppm | 10.45$^{f}$ | 13.41$^{h}$ | 15.66$^{e}$ | 10.16$^{e}$ | 11.66$^{d}$ | 13.23$^{g}$ |
| ET 25 ppm | 12.65$^{cd}$ | 15.32$^{fg}$ | 16.86$^{bc}$ | 11.53$^{cd}$ | 14.20$^{b}$ | 15.60$^{bc}$ |
| ET 50 ppm | 12.62$^{cd}$ | 16.77$^{ab}$ | 17.26$^{bc}$ | 12.23$^{abc}$ | 13.86$^{b}$ | 14.53$^{f}$ |
| ET 100 ppm | 13.27$^{c}$ | 15.83$^{def}$ | 16.96$^{bc}$ | 12.90$^{a}$ | 14.37$^{ab}$ | 15.86$^{abc}$ |
| ET 200 ppm | 14.47$^{b}$ | 15.73$^{ef}$ | 17.20$^{bc}$ | 10.20$^{e}$ | 12.76$^{cd}$ | 15.23$^{cde}$ |
| Control | 15.66$^{a}$ | 16.62$^{bc}$ | 17.23$^{bc}$ | 12.23$^{abc}$ | 13.63$^{bc}$ | 15.93$^{ab}$ |
| CD | 0.67 | 0.62 | 0.70 | 0.93 | 1.07 | 0.67 |
| SE(m) | 0.23 | 0.21 | 0.24 | 0.32 | 0.37 | 0.23 |
| CV | 2.63 | 2.40 | 2.48 | 4.7 | 4.6 | 2.6 |

**Table. 6 Effect of plant growth regulators on total seedling length in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Total seedling length (cm) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 27.54$^{c}$ | 32.69$^{cd}$ | 35.09$^{d}$ | 25.10$^{bc}$ | 27.90$^{c}$ | 30.23 $^{de}$ |
| CC 50 ppm | 25.30$^{e}$ | 32.74$^{cd}$ | 35.49$^{cd}$ | 25.03$^{bc}$ | 28.90$^{a}$ | 32.00 $^{bc}$ |
| CC 100 ppm | 25.20$^{ef}$ | 33.24$^{c}$ | 35.07$^{d}$ | 23.16 $^{cd}$ | 27.13$^{d}$ | 31.23 $^{cd}$ |
| CC 200 ppm | 24.46$^{fg}$ | 34.39$^{ab}$ | 37.94$^{ab}$ | 21.50$^{d}$ | 25.36$^{e}$ | 29.03 $^{e}$ |
| PBZ 25 ppm | 18.21$^{h}$ | 21.51$^{e}$ | 25.14$^{e}$ | 16.82$^{e}$ | 19.80$^{f}$ | 24.56$^{f}$ |
| PBZ 50 ppm | 17.09$^{i}$ | 19.96$^{f}$ | 23.44$^{f}$ | 16.50$^{e}$ | 19.78 $^{fg}$ | 23.50$^{f}$ |
| PBZ 100 ppm | 15.79$^{j}$ | 18.93$^{g}$ | 22.40$^{g}$ | 16.43$^{e}$ | 19.6 $^{fg}$ | 21.79$^{g}$ |
| PBZ 200 ppm | 14.16$^{k}$ | 18.20$^{h}$ | 21.278$^{h}$ | 16.30$^{e}$ | 19.4$^{g}$ | 20.30$^{g}$ |
| ET 25 ppm | 25.88$^{de}$ | 32.36$^{d}$ | 36.044$^{c}$ | 23.33$^{cd}$ | 28.36$^{b}$ | 33.20$^{b}$ |
| ET 50 ppm | 24.054$^{g}$ | 33.05$^{cd}$ | 36.257$^{c}$ | 24.23$^{c}$ | 27.36$^{d}$ | 31.83$^{bcd}$ |
| ET 100 ppm | 26.38$^{d}$ | 34.06$^{b}$ | 38.417$^{ab}$ | 27.20$^{ab}$ | 27.96$^{bc}$ | 32.26$^{bc}$ |
| ET 200 ppm | 29.10$^{b}$ | 34.06$^{b}$ | 37.767$^{b}$ | 23.70$^{cd}$ | 26.97$^{d}$ | 32.36 $^{bc}$ |
| Control | 31.65$^{a}$ | 35.07$^{a}$ | 38.67$^{a}$ | 27.36$^{a}$ | 29.133$^{a}$ | 36.100 $^{a}$ |
| CD | 0.77 | 0.72 | 0.822 | 2.25 | 0.45 | 1.68 |
| SE(m) | 0.26 | 0.25 | 0.28 | 0.77 | 0.15 | 0.578 |
| CV | 1.96 | 1.48 | 1.50 | 6.08 | 1.06 | 3.43 |

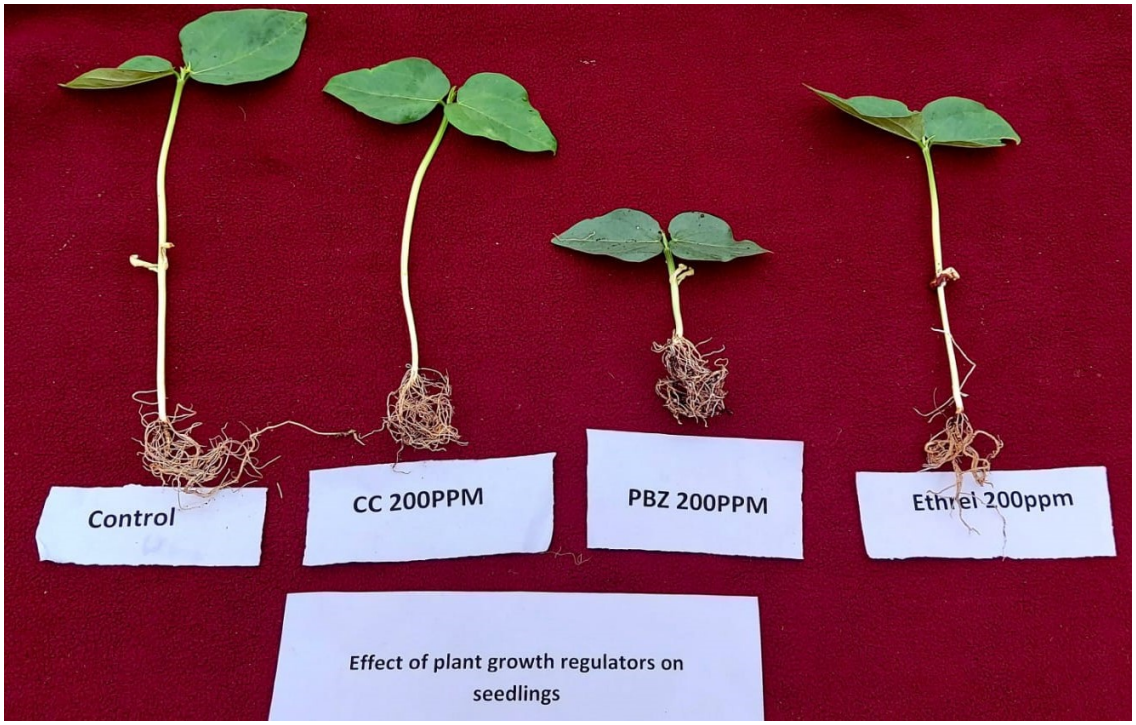



**Plate .6 Effect of plant growth regulators on seedling length**

**Plate .7 Growth regulator treated seedlings kept in polyhouse**

**Table.7 Effect of plant growth regulators on shoot weight in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| Shoot weight (g ) at different days after germination | | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 0.229$^{bc}$ | 0.364$^{c}$ | 0.524$^{abc}$ | 0.242$^{bc}$ | 0.380$^{c}$ | 0.540$^{b}$ |
| CC 50 ppm | 0.227$^{bc}$ | 0.331$^{d}$ | 0.502$^{bc}$ | 0.233$^{cd}$ | 0.309$^{e}$ | 0.533$^{b}$ |
| CC 100 ppm | 0.234$^{b}$ | 0.331$^{d}$ | 0.445$^{de}$ | 0.239$^{c}$ | 0.335$^{de}$ | 0.452$^{c}$ |
| CC 200 ppm | 0.200$^{cd}$ | 0.271$^{ef}$ | 0.327$^{g}$ | 0.185$^{ef}$ | 0.259 $^{f}$ | 0.332$^{d}$ |
| PBZ 25 ppm | 0.173$^{de}$ | 0.249$^{fg}$ | 0.380$^{f}$ | 0.194$^{ef}$ | 0.259$^{f}$ | 0.428$^{c}$ |
| PBZ 50 ppm | 0.167$^{de}$ | 0.233$^{g}$ | 0.406$^{ef}$ | 0.208$^{de}$ | 0.255$^{f}$ | 0.431$^{c}$ |
| PBZ 100 ppm | 0.168$^{de}$ | 0.236$^{g}$ | 0.383$^{f}$ | 0.170$^{f}$ | 0.258$^{f}$ | 0.326$^{d}$ |
| PBZ 200 ppm | 0.148$^{e}$ | 0.198$^{h}$ | 0.282$^{g}$ | 0.139$^{g}$ | 0.162$^{g}$ | 0.264$^{e}$ |
| ET 25 ppm | 0.292$^{a}$ | 0.297$^{e}$ | 0.444$^{de}$ | 0.236$^{cd}$ | 0.305$^{e}$ | 0.423$^{c}$ |
| ET 50 ppm | 0.208$^{bc}$ | 0.281$^{e}$ | 0.485$^{cd}$ | 0.277$^{a}$ | 0.349$^{cd}$ | 0.434$^{c}$ |
| ET 100 ppm | 0.270$^{a}$ | 0.407$^{b}$ | 0.516$^{abc}$ | 0.271$^{a}$ | 0.433$^{ab}$ | 0.520$^{b}$ |
| ET 200 ppm | 0.286$^{a}$ | 0.449$^{a}$ | 0.532$^{ab}$ | 0.269$^{ab}$ | 0.418$^{b}$ | 0.580$^{a}$ |
| Control | 0.298$^{a}$ | 0.397b | 0.557$^{a}$ | 0.282$^{a}$ | 0.454$^{a}$ | 0.598$^{a}$ |
| CD | 0.033 | 0.029 | 0.045 | 0.028 | 0.031 | 0.037 |
| SE(m) | 0.011 | 0.01 | 0.016 | 0.010 | 0.011 | 0.013 |
| CV | 8.71 | 5.59 | 6.05 | 7.30 | 5.83 | 4.831 |

**Table. 8 Effect of plant growth regulators on root weight in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Root weight (g) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 0.219$^{d}$ | 0.260b$^{cde}$ | 0.341$^{a}$ | 0.210$^{bc}$ | 0.256$^{cd}$ | 0.354$^{bc}$ |
| CC 50 ppm | 0.221$^{d}$ | 0.239$^{def}$ | 0.296$^{b}$ | 0.228$^{b}$ | 0.290$^{a}$ | 0.397$^{a}$ |
| CC 100 ppm | 0.221$^{d}$ | 0.256$^{ab}$ | 0.360$^{a}$ | 0.226$^{b}$ | 0.295$^{a}$ | 0.370$^{ab}$ |
| CC 200 ppm | 0.260$^{ab}$ | 0.284$^{ab}$ | 0.363$^{a}$ | 0.216$^{bc}$ | 0.260$^{bc}$ | 0.311$^{de}$ |
| PBZ 25 ppm | 0.213$^{d}$ | 0.242$^{def}$ | 0.273$^{b}$ | 0.181$^{d}$ | 0.219$^{e}$ | 0.324$^{d}$ |
| PBZ 50 ppm | 0.217$^{d}$ | 0.247$^{cde}$ | 0.280$^{b}$ | 0.204$^{bcd}$ | 0.255$^{cd}$ | 0.282$^{ef}$ |
| PBZ 100 ppm | 0.207$^{d}$ | 0.236$^{ef}$ | 0.273$^{bc}$ | 0.179$^{d}$ | 0.228$^{de}$ | 0.278$^{f}$ |
| PBZ 200 ppm | 0.146$^{e}$ | 0.220$^{f}$ | 0.249$^{cd}$ | 0.124$^{e}$ | 0.136$^{f}$ | 0.195$^{g}$ |
| ET 25 ppm | 0.276$^{a}$ | 0.289$^{a}$ | 0.335$^{a}$ | 0.259$^{a}$ | 0.287 $^{ab}$ | 0.329$^{cd}$ |
| ET 50 ppm | 0.226$^{cd}$ | 0.271$^{abc}$ | 0.296$^{b}$ | 0.217$^{bc}$ | 0.267$^{abc}$ | 0.365$^{b}$ |
| ET 100 ppm | 0.249$^{bc}$ | 0.252$^{cde}$ | 0.338$^{a}$ | 0.203$^{bcd}$ | 0.243$^{cde}$ | 0.327$^{cd}$ |
| ET 200 ppm | 0.231$^{cd}$ | 0.260$^{bcde}$ | 0.242$^{d}$ | 0.199$^{cd}$ | 0.226$^{e}$ | 0.285 $^{ef}$ |
| Control | 0.218$^{d}$ | 0.263$^{abcd}$ | 0.296$^{b}$ | 0.214 | 0.245$^{cde}$ | 0.318$^{d}$ |
| CD | 0.025 | 0.027 | 0.030 | 0.026 | 0.029 | 0.029 |
| SE(m) | 0.008 | 0.009 | 0.010 | 0.009 | 0.010 | 0.010 |
| CV | 6.50 | 6.10 | 5.82 | 7.69 | 6.80 | 5.40 |

**Table. 9 Effect of plant growth regulators on Germination percentage in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Germination Percentage ( %) at different days after sowing | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 89.667$^{def}$ | 91.333$^{de}$ | 91.333$^{de}$ | 95.333$^{a}$ | 95.333$^{a}$ | 95.333$^{a}$ |
| CC 50 ppm | 92.000$^{bcde}$ | 92.333$^{cd}$ | 92.333$^{cd}$ | 83.333$^{e}$ | 83.333$^{e}$ | 83.333$^{e}$ |
| CC 100 ppm | 93.000$^{abcd}$ | 93.000$^{bcd}$ | 93.000$^{bcd}$ | 91.333$^{c}$ | 91.333$^{c}$ | 91.333$^{c}$ |
| CC 200 ppm | 94.000$^{abc}$ | 94.000$^{abc}$ | 94.000$^{abc}$ | 94.667$^{ab}$ | 94.667$^{ab}$ | 94.667$^{ab}$ |
| PBZ 25 ppm | 76.333$^{h}$ | 78.333$^{h}$ | 78.333$^{h}$ | 76.333$^{f}$ | 76.333$^{f}$ | 76.333$^{f}$ |
| PBZ 50 ppm | 85.000$^{g}$ | 85.000$^{g}$ | 85.000$^{g}$ | 83.333$^{e}$ | 83.333$^{e}$ | 83.333$^{e}$ |
| PBZ 100 ppm | 89.000$^{ef}$ | 89.333$^{ef}$ | 89.333$^{ef}$ | 86.333$^{de}$ | 86.333$^{de}$ | 86.333$^{de}$ |
| PBZ 200 ppm | 64.333$^{i}$ | 66.000$^{i}$ | 66.000$^{i}$ | 70.000$^{g}$ | 72.000$^{g}$ | 72.000$^{g}$ |
| ET 25 ppm | 87.333$^{fg}$ | 87.333$^{fg}$ | 87.333$^{fg}$ | 87.000$^{d}$ | 87.000$^{d}$ | 87.000$^{d}$ |
| ET 50 ppm | 93.333$^{abc}$ | 93.333$^{bcd}$ | 93.333$^{bcd}$ | 94.000$^{abc}$ | 94.000$^{abc}$ | 94.000$^{abc}$ |
| ET 100 ppm | 95.000$^{ab}$ | 95.000$^{ab}$ | 95.000$^{ab}$ | 92.000$^{bc}$ | 92.000$^{bc}$ | 92.000$^{bc}$ |
| ET 200 ppm | 91.000$^{cde}$ | 91.000$^{de}$ | 91.000$^{de}$ | 93.333$^{abc}$ | 93.333$^{abc}$ | 93.333$^{abc}$ |
| Control | 96.333$^{a}$ | 96.333$^{a}$ | 96.333$^{a}$ | 95.667$^{a}$ | 95.667$^{a}$ | 95.667$^{a}$ |
| CD | 3.35 | 2.563 | 2.563 | 3.191 | 3.191 | 3.191 |
| SE(m) | 1.115 | 0.882 | 0.882 | 1.098 | 1.098 | 1.098 |
| CV | 2.268 | 1.723 | 1.723 | 2.163 | 2.159 | 2.159 |

4.1.2. Morphological observations were recorded at 5, 10 and 15 days after germination.

**4.1.2.1. Number of days for emergence of seedling up to the first node**

Seedlings treated with Paclobutrazol @ 200 ppm recorded significantly more number of days for emergence of seedling up to the first node ( 8.13) and (8.00) in both the genotypes (Table 10) . Minimum number of days for emergence of seedling up to the first node was recorded in both the genotypes when treated with Cycocel @ 50 ppm (4.86) and Cycocel @ 100 ppm (4.86).

**4.1.2.2. Height of seedling up to the first node**

In both the genotypes Cycocel @ 100 ppm recorded significantly higher seedling height up to the first node when compared to all other treatments (10.76 cm), (10.68 cm) but on par with Cycocel @ 50 ppm (10.70 cm), (10.6 cm) (Table 10) .Significantly lower seedling height up to the first node was recorded in treatments receiving Paclobutrazol 200 ppm in both the genotypes (4.09 cm) and (4.03 cm) respectively.

**4.1.2.3. Number of leaves**

Five days after germination, the number of leaves was recorded in both the genotypes was same. (Table 11) .Ten days after germination significantly higher number of leaves was recorded in both the genotypes seedlings treated with Paclobutrazol @ 200 ppm (5.83) and Paclobutrazol 25 ppm (5.7). Out of the above, on $10^{th}$ day after germination, Paclobutrazol @ 200 ppm was on par with Paclobutrazol @ 100 ppm (5.7) and (5.5) respectively and Paclobutrazol 50 ppm (5.58) and (5.50) respectively. Minimum number of leaves were recorded on $10^{th}$ day germination in both genotypes respectively at Cycocel @ 50 ppm (4.8) and (5.08)**.** In both the genotypes, on $15^{th}$ day after germination there were no significant difference in any treatment on number of leaves ranged between 7 to 8.

**4.1.2.4. Number of primary branches**

Two primary branches were observed on the $15^{th}$ day after germination in the both the genotypes .There were no significant differences between the genotypes for this character.

#### 4.1.2.5. Leaf length (cm)

The control treatment recorded significantly higher leaf length on 5th (6.03 cm) 10th (6.15 cm) and 15th (6.60 cm) in the genotype Vellayani Jyothika. (Table 12) Out of the above, control was recorded on 5th, 10th and 15th days after germination was on par with Cycocel @ 100 ppm on 5th (5.90cm),10th (6.22cm), and 15 th (6.53cm) day after germination. Significantly lower leaf length was recorded in treatments receiving Paclobutrazol 200 @ ppm irrespective of number of days after germination( 4.05cm),(4.40cm) and (5.02cm).

Significantly higher leaf length was recorded in treatments receiving Cycocel @ 25 ppm on 5th (5.80 cm) and 10th day (6.32cm) after germination in the genotype Kashi Kanchan (Table 12) .On 15th day after germination , highest leaf length recorded in control treatment (7.06 cm ) which was on par with Cycocel @ 25 ppm (6.88 cm). Significantly lower leaf length was recorded in treatments receiving Paclobutrazol @ 200 ppm on 5th and 10th day after germination (4.41 cm) (4.99 cm) .On 15th day after germination , minimum leaf length was recorded in treatments receiving Paclobutrazol @ 25 ppm (5.59 cm) which was on par with Paclobutrazol 200 ppm (5.76 cm) .

#### 4.1.2.6. Leaf color

Leaf color was recorded on 5th, 10th and 15th days after germination of the seedlings with the help of royal leaf color chart in both the genotypes of cowpea .Seedlings treated with Paclobutrazol showed dark green color and other ones showed variation in green leaf colors .The Leaf color recorded on 5th 10th and 15 days is given as a table (Table 13)

#### 4.1.2.7. Girth of seedlings (mm)

The highest girth of seedlings was recorded in treatments receiving Paclobutrazol @ 200 ppm on 5th, 10th and 15 days after germination ( 3.19 mm), (3.45 mm) and (3.75 mm) in Vellayani Jyothika .(Table 14). Paclobutrazol 200 @ ppm was recorded on 15th day germination was on par with Paclobutrazol @ 25 ppm and 50 @ ppm respectively (3.7 mm), (3.6 mm) .Minimum girth of seedlings was recorded on 5th, 10th day after germination was Cycocel @ 25 ppm respectively (2.08 mm), (2.2 mm) . Significantly lower girth of seedlings was recorded in treatments receiving Ethrel 25 ppm (2.77 mm) on 15th day after germination.

Paclobutrazol 200 ppm was recorded significantly superior than all other treatments in girth of the seedlings on 5th,10th and 15th day after germination respectively at (3.3 mm), (3.4 mm) and 3.8mm) in Kashi Kanchan. (Table 14). Minimum girth of seedlings was recorded on 5th and 10th day after germination was Ethrel @ 25 ppm respectively at (2.5 mm) and (2.6 mm) which was on par with Cycocel @ 50 ppm respectively (2.5 mm) and (2.6 mm). Lowest girth of seedlings was recorded in treatments receiving Cycocel @ 50 ppm (2.7mm) on 15th day after germination.

**Table 10. Effect of plant growth regulators on number of days for emergence of seedling up to the first node and Height of seedling up to the first node in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Vellayani Jyothika | | Kashi Kanchan | |
|---|---|---|---|---|
| Treatments | Number of days for emergence of seedling up to the first node | Height of seedling up to the first node | Number of days for emergence of seedling up to the first node | Height of seedling up to the first node |
| CC 25 ppm | $4.93^{ef}$ | $8.74^{e}$ | $4.86^{e}$ | $8.59^{d}$ |
| CC 50 ppm | $4.86^{f}$ | $10.70^{a}$ | $4.867^{e}$ | $10.66^{a}$ |
| CC 100 ppm | $4.86^{f}$ | $10.76^{a}$ | $4.867^{e}$ | $10.68^{a}$ |
| CC 200 ppm | $5.06^{cdef}$ | $9.82^{c}$ | $5.00^{de}$ | $9.75^{c}$ |
| PBZ 25 ppm | $5.26^{cde}$ | $5.10^{f}$ | $4.86^{e}$ | $5.10^{e}$ |
| PBZ 50 ppm | $5.40^{c}$ | $4.84^{g}$ | $5.40^{c}$ | $4.75^{f}$ |
| PBZ 100 ppm | $7.73^{b}$ | $4.72^{g}$ | $7.60^{b}$ | $4.72^{f}$ |
| PBZ 200 ppm | $8.13^{a}$ | $4.09^{h}$ | $8.00^{a}$ | $4.03^{g}$ |
| ET 25 ppm | $5.20^{cdef}$ | $9.56^{d}$ | $5.20^{cd}$ | $9.56^{c}$ |
| ET 50 ppm | $5.00^{def}$ | $10.24^{b}$ | $5.00^{de}$ | $10.21^{b}$ |
| ET 100 ppm | $5.13^{cdef}$ | $9.62^{cd}$ | $5.06^{de}$ | $9.54^{c}$ |
| ET 200 ppm | $5.33^{cd}$ | $9.61^{cd}$ | $5.33^{c}$ | $9.65^{c}$ |
| Control | $5.00^{def}$ | $10.40^{b}$ | $5.00^{de}$ | $10.60^{a}$ |
| CD | 0.36 | 0.25 | 0.26 | 0.33 |
| SE(m) | 0.12 | 1.81 | 0.091 | 0.11 |
| CV | 3.88 | 0.087 | 2.87 | 2.40 |

**Table 11. Effect of plant growth regulators on number of leaves in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Number of leaves at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 2 | 4.83$^{d}$ | 7.66 | 2 | 5.25$^{bc}$ | 7.33 |
| CC 50 ppm | 2 | 4.83$^{d}$ | 7.33 | 2 | 5.08$^{c}$ | 7.08 |
| CC 100 ppm | 2 | 5.00$^{d}$ | 7.66 | 2 | 5.33$^{bc}$ | 7.66 |
| CC 200 ppm | 2 | 5.08$^{cd}$ | 7.66 | 2 | 5.25$^{bc}$ | 7.33 |
| PBZ 25 ppm | 2 | 5.83$^{a}$ | 7.50 | 2 | 5.75$^{a}$ | 7.16 |
| PBZ 50 ppm | 2 | 5.58$^{ab}$ | 7.41 | 2 | 5.50$^{ab}$ | 7.41 |
| PBZ 100 ppm | 2 | 5.75$^{ab}$ | 8.08 | 2 | 5.58$^{ab}$ | 8.06 |
| PBZ 200 ppm | 2 | 5.83$^{a}$ | 7.58 | 2 | 5.75$^{a}$ | 7.41 |
| ET 25 ppm | 2 | 5.58$^{ab}$ | 7.83 | 2 | 5.58$^{ab}$ | 7.66 |
| ET 50 ppm | 2 | 5.58$^{ab}$ | 7.33 | 2 | 5.50$^{ab}$ | 7.25 |
| ET 100 ppm | 2 | 5.41$^{bc}$ | 7.66 | 2 | 5.41$^{abc}$ | 7.50 |
| ET 200 ppm | 2 | 5.41$^{bc}$ | 7.75 | 2 | 5.41$^{abc}$ | 7.58 |
| Control | 2 | 5.16$^{cd}$ | 7.66 | 2 | 5.25$^{bc}$ | 7.41 |
| CD | NS | 0.397 | NS | NS | 0.38 | NS |
| SE(m) | | 0.13 | 0.22 | | 0.13 | 0.19 |
| CV | | 4.40 | 5.03 | | 4.2 | 4.6 |

**Table 12. Effect of plant growth regulators on leaf length in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Leaf length (cm) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | $5.56^{cd}$ | $5.78^{b}$ | $6.11^{cd}$ | $5.80^{a}$ | $6.32^{a}$ | $6.88^{ab}$ |
| CC 50 ppm | $5.03^{f}$ | $5.37^{cd}$ | $5.49^{ef}$ | $5.52^{bc}$ | $6.15^{abc}$ | $6.59^{bcd}$ |
| CC 100 ppm | $5.90^{ab}$ | $6.22^{a}$ | $6.53^{ab}$ | $5.70^{ab}$ | $6.18^{ab}$ | $6.67^{bc}$ |
| CC 200 ppm | $5.38^{de}$ | $6.25^{a}$ | $6.56^{ab}$ | $5.10^{e}$ | $5.85^{cd}$ | $6.30^{d}$ |
| PBZ 25 ppm | $4.38^{g}$ | $5.11^{de}$ | $5.46^{f}$ | $4.50^{g}$ | $5.25^{fg}$ | $5.59^{f}$ |
| PBZ 50 ppm | $4.33^{g}$ | $4.88^{ef}$ | $4.96^{g}$ | $4.81^{f}$ | $5.23^{fg}$ | $5.72^{ef}$ |
| PBZ 100 ppm | $4.51^{g}$ | $4.83^{f}$ | $5.19^{fg}$ | $5.06^{e}$ | $5.44^{ef}$ | $5.80^{ef}$ |
| PBZ 200 ppm | $4.05^{h}$ | $4.40^{g}$ | $5.02^{g}$ | $4.41^{g}$ | $4.99^{g}$ | $5.76^{ef}$ |
| ET 25 ppm | $5.43^{de}$ | $5.50^{c}$ | $5.82^{de}$ | $5.71^{ab}$ | $6.15^{abc}$ | $6.60^{bcd}$ |
| ET 50 ppm | $5.00^{f}$ | $5.35^{cd}$ | $5.95^{cd}$ | $5.23^{de}$ | $5.45^{ef}$ | $5.94^{e}$ |
| ET 100 ppm | $5.75^{bc}$ | $5.79^{b}$ | $6.23^{bc}$ | $5.58^{abc}$ | $5.98^{bcd}$ | $6.70^{bc}$ |
| ET 200 ppm | $5.23^{ef}$ | $5.45^{c}$ | $5.85^{d}$ | $5.36^{cd}$ | $5.72^{de}$ | $6.46^{bcd}$ |
| Control | $6.03^{a}$ | $6.15^{a}$ | $6.60^{a}$ | $5.37^{cd}$ | $5.85^{cd}$ | $7.06^{a}$ |
| CD | 0.27 | 2.95 | 0.33 | 0.23 | 0.32 | 0.31 |
| SE(m) | 0.09 | 0.09 | 0.11 | 0.07 | 0.11 | 0.10 |
| CV | 3.14 | 2.95 | 3.39 | 2.61 | 3.37 | 2.99 |

**Table 13. Effect of Plant growth regulators in leaf color in seedling stage of cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Leaf color at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | **Vellayani Jyothika** | | | **Kashi Kanchan** | | |
| Treatments | 5days | 10 days | 15days | 5days | 10 days | 15days |
| CC 25 ppm | RHS/2015-Green group- 137-Moderate yellow green – C | RHS/2015-Green group-137-moderate yellow green – C | RHS/2015-Green Group -137-Moderate yellow green – C | RHS/2015-Green group -137-Moderate olive green – B | RHS/2015-Green group -137-Moderate olive green –B | RHS/2015-Green group -137 -Moderate yellow green- C |
| CC 50 ppm | RHS/2015-Green group -137-Moderate olive green –B | RHS/2015-Green group- 137-moderate olive green – A | RHS/2015-Green group -137-Moderate yellow green- C | RHS/2015-Green group- 137-moderate olive green-A | RHS/2015-Green group- 137-moderate olive green –B | RHS/2015-Green group- 137 -Moderate olive green-A |
| CC 100 ppm | RHS/2015-Green group moderate -138-yellowish green- A | RHS/2015-Green group-137-Moderate yellow green – D | RHS/2015-Green group -137-Moderate olive green-B | RHS/2015-Green group -137-Moderate olive green-B | RHS/2015-Green group- 137-Moderate yellow green – C | RHS/2015-Green Group -137-Moderate yellow green- C |
| CC 200 ppm | RHS/2015-Green group -137-Moderate olive green –B | RHS/2015-Green group- 137-Moderate olive green – A | RHS/2015-Green group -137 -Moderate olive green – A | RHS/2015-Green Group -137-Moderate yellow green- C | RHS/2015-Green group- 137-Moderate olive green –A | RHS/2015-Green group- 137-Moderate olive green -A |
| PBZ 25 ppm | RHS/2015-Green group -136- Dark green- A | RHS/2015-Green group- 136-Dark green – A | RHS/2015-Green group- 135-Dark green-A | RHS/2015-Green group -136- Dark green – A | RHS/2015-Green group- 136-Dark green –A | RHS/2015-Green group- 135-Dark green -A |
| PBZ 50 ppm | RHS/2015-Green group- 136-Dark green – A | RHS/2015-Green group -136- Dark green- A | RHS/2015-Green group -135 -Dark green A | RHS/2015-Green group- 136-Dark green – A | RHS/2015-Green group- 136-Dark green –A | RHS/2015-Green group- 135-Dark green-A |

| | | | | | | |
|---|---|---|---|---|---|---|
| PBZ 100 ppm | RHS/2015-Green group -136- Dark green – A | RHS/2015-Green group -136- Dark green – A | RHS/2015-Green group- 135 - Dark green A | RHS/2015-Green group- 136- Dark green – A | RHS/2015-Green group- 135 - Dark green A | RHS/2015-Green group- 135- Dark green- A |
| PBZ 200 ppm | RHS/2015-Green group -136- Dark green – A | RHS/2015-Green group -136- Dark green – A | RHS/2015-Green group -136 -Dark green- A | RHS/2015-Green group 136 -Dark green- A | RHS/2015-Green group -136 -Dark green- A | RHS/2015-Green group -136 -Dark green- A |
| ET 25 ppm | RHS/2015-Green group-137 - Moderate yellow green – C | RHS/2015-Green Group -137- Moderate olive green- B | RHS/2015-Green group -137 - Moderate olive green – B | RHS/2015-Green group 137 - Moderate olive green – B | RHS/2015-Green group -137- Moderate yellowish green –D | RHS/2015-Green group -137- Moderate olive green - B |
| ET 50 ppm | RHS/2015-Green group -137 - Moderate yellowish green- D | RHS/2015-Green group -137- Moderate olive green – A | RHS/2015-Green group -137- Moderate olive green – B | RHS/2015-Green group-137- Moderate olive green – A | RHS/2015-Green group -137- Moderate olive green – B | RHS/2015-Green group -137- Moderate yellow green - C |
| ET 100 ppm | RHS/2015-Green group -139- Dark yellowish green- A | RHS/2015-Green group- 137- moderate olive green – A | RHS/2015-Green group -137- moderate yellow green- C | RHS/2015-Green Group -137- Moderate olive green- B | RHS/2015-Green group-137 - Moderate yellow green – C | RHS/2015-Green Group -137- Moderate olive green- B |
| ET200 ppm | RHS/2015-Green group -137- Moderate yellow green – C | RHS/2015-Green group- 137 - Moderate olive green – A | RHS/2015-Green group-137- Moderate yellow green – C | RHS/2015-Green group- 137 - Moderate olive green – A | RHS/2015-Green group 137 - Moderate olive green –B | RHS/2015-Green group – 137- Moderate yellow green -C |
| control | RHS/2015-Green group -137 - Moderate yellowish green- D | RHS/2015-Green group- 137- Moderate olive green- B | RHS/2015-Green group- 137- Moderate olive green- A | RHS/2015 - Green group -137- Moderate yellow green – C | RHS/2015-Green group- 137- Moderate olive green- B | RHS/2015-Green group -137- Moderate olive green- A |

**Table 14. Effect of plant growth regulators on Girth of seedlings on seedling stage in cowpea varieties Vellayani Jyothika and Kashi Kanchan**

| | Girth of seedlings (mm) at different days after germination | | | | | |
|---|---|---|---|---|---|---|
| | Vellayani Jyothika | | | Kashi Kanchan | | |
| Treatments | 5 | 10 | 15 | 5 | 10 | 15 |
| CC 25 ppm | 2.08$^{e}$ | 2.22$^{h}$ | 3.01$^{f}$ | 2.53$^{d}$ | 2.74$^{bcd}$ | 2.90$^{de}$ |
| CC 50 ppm | 2.38$^{cd}$ | 2.48$^{g}$ | 3.37$^{de}$ | 2.52$^{d}$ | 2.62$^{cd}$ | 2.78$^{f}$ |
| CC 100 ppm | 2.32$^{cd}$ | 2.60$^{ef}$ | 3.40$^{de}$ | 2.45$^{d}$ | 2.83$^{b}$ | 3.05$^{d}$ |
| CC 200 ppm | 2.35$^{cd}$ | 2.60$^{ef}$ | 3.55$^{bcd}$ | 2.58$^{cd}$ | 2.80$^{bc}$ | 3.25$^{c}$ |
| PBZ 25 ppm | 2.98$^{b}$ | 3.24$^{b}$ | 3.67$^{abc}$ | 3.05$^{b}$ | 3.26$^{a}$ | 3.49$^{b}$ |
| PBZ 50 ppm | 2.94$^{b}$ | 3.22$^{b}$ | 3.75$^{ab}$ | 3.06$^{b}$ | 3.23$^{a}$ | 3.41$^{bc}$ |
| PBZ 100 ppm | 2.90$^{b}$ | 3.30$^{b}$ | 3.73$^{ab}$ | 3.10$^{b}$ | 3.23$^{a}$ | 3.55$^{b}$ |
| PBZ 200 ppm | 3.19$^{a}$ | 3.45$^{a}$ | 3.77$^{a}$ | 3.34$^{a}$ | 3.48$^{a}$ | 3.81$^{a}$ |
| ET 25 ppm | 2.52$^{c}$ | 2.65$^{e}$ | 2.77$^{g}$ | 2.52$^{d}$ | 2.623$^{d}$ | 2.85$^{ef}$ |
| ET 50 ppm | 2.20$^{de}$ | 2.51$^{fg}$ | 2.79$^{g}$ | 2.46$^{d}$ | 2.70$^{bcd}$ | 2.90$^{de}$ |
| ET 100 ppm | 2.45$^{c}$ | 2.96$^{g}$ | 3.48$^{cde}$ | 2.54$^{d}$ | 2.82$^{b}$ | 3.00$^{de}$ |
| ET 200 ppm | 2.47$^{c}$ | 2.76$^{d}$ | 3.30$^{e}$ | 2.73$^{c}$ | 2.85$^{b}$ | 3.29$^{c}$ |
| Control | 2.17$^{de}$ | 2.55$^{efg}$ | 2.90$^{fg}$ | 2.50$^{d}$ | 2.74$^{bcd}$ | 2.95$^{de}$ |
| CD | 0.21 | NS | 0.21 | 0.15 | 0.17 | 0.18 |
| SE (m) | 0.07 | 0.03 | 0.07 | 0.05 | 0.06 | 0.06 |
| CV | 5.05 | 2.16 | 3.77 | 3.35 | 3.64 | 3.46 |

**Physiological parameters.**

The physiological parameters *viz* chlorophyll a and b content, total chlorophyll content ,carotenoid content, indole acetic acid content and gibberellic acid content were recorded on 10$^{th}$ day after germination.

**4.1.2.8. Chlorophyll a content (mg g$^{-1}$)**

The chlorophyll a content was the highest in seedlings treated with Paclobutrazol @ 200 ppm (0.84 mg) in Vellayani Jyothika (Table 15) and Paclobutrazol @ 200 ppm (0.96 mg) in Kashi Kanchan but on par with Paclobutrazol @ 100 ppm (0.83 mg) in Vellayani Jyothika and Paclobutrazol @ 100 ppm (0.92 mg) in Kashi Kanchan (Table 16). Minimum chlorophyll a content was recorded in the treatments receiving Cycocel 25 @ ppm (0.28 mg) in Vellayani Jyothika and Cycocel 25 @ ppm (0.67 mg) in Kashi Kanchan

**4.1.2.9. Chlorophyll b content (mg g$^{-1}$)**

In Vellayani Jyothika significantly higher chlorophyll b content was recorded in treatments receiving Paclobutrazol @ 100 ppm (0.391mg) but on par with Paclobutrazol 200 ppm (0.381mg) (Table 15). Lower chlorophyll b content was recorded in treatments receiving Cycocel 25 ppm (0.247 mg) but on par with Ethrel 100 ppm (0.250)

Significantly higher chlorophyll b content was recorded in treatments receiving Cycocel 100 ppm (0.629 mg) and Paclobutrazol 200 ppm (0.622 mg) in Kashi Kanchan (Table 16). Significantly lower chlorophyll b content was recorded in treatments receiving Ethrel 200 ppm (0.345 mg) in cowpea genotype Kashi Kanchan.

**4.1.2.10. Total chlorophyll content (mg g$^{-1}$)**

In both the genotypes (Vellayani Jyothika and Kashi Kanchan ) Paclobutrazol @ 200 ppm recorded significantly higher total chlorophyll content when compared to all other treatments respectively (1.22 mg) and (1.44 mg) but was on par with Ethrel @ 25 ppm respectively (Table 15 and 16 ). Minimum total chlorophyll content was recorded in treatments receiving Cycocel @ 25 ppm (0.53 mg) and (1.05 mg) respectively in both the genotypes.

#### 4.1.2.11. Carotenoid content (mg $g^{-1}$)

Highest carotenoid content was recorded in treatments receiving Paclobutrazol @ 100 ppm (0.347 mg) but on par with Paclobutrazol @ 50 ppm and Paclobutrazol 200 ppm (Table 15) in cowpea genotype Vellayani Jyothika .Significantly lower carotenoid content was recorded in treatments receiving Cycocel @ 25 ppm (0.120 mg).

The highest carotenoid content was obtained in Paclobutrazol @ 200 ppm (0.439 mg) in Kashi Kanchan which was on par with Paclobutrazol 100 ppm and Paclobutrazol 25 ppm. Minimum carotenoid content was recorded in Ethrel 200 ppm (0.333 mg) (Table 16)

#### 4.1.2.12. IAA Content (mg of unoxidized auxin $g^{-1}$FW)

The IAA content was the highest in treatments receiving Ethrel 25 ppm (0.220 mg) in Vellayani Jyothika (Table17). Minimum IAA content was recorded in Paclobutrazol @ 200 ppm (0.126 mg) and Paclobutrazol 100 ppm (0.123 mg).

Significantly higher auxin contents were recorded in seedlings subjected to Ethrel @ 200 ppm (0.155) but on par with Paclobutrazol 50 ppm (0.152 mg) in Kashi Kanchan (Table 17) .The minimum content of auxin was displayed in the Paclobutrazol 200 ppm (0.077 mg).

#### 4 .1.2.13. GA Content (ng $GAg^{-1}$FW)

Highest GA content was recorded in treatment receiving control respectively (1.79 ng) and (1.66 ng) respectively (Table 17) in both the genotypes. Minimum content of gibberellic acid was obtained in Paclobutrazol @ 200 ppm (0.819 ng) and (0.730 ng) respectively.

**Table 15. Effect of Plant growth regulators in chlorophyll (a, b and total) and carotenoid content in seedling stage of cowpea varieties of Vellayani Jyothika**

| | Treatments | Vellayani Jyothika | | | |
|---|---|---|---|---|---|
| | | Chlorophyll (a) (mg g-$^{-1}$) | Chlorophyll (b) (mg g$^{-1}$) | Total chlorophyll (mg g$^{-1}$) | Carotenoids (mg g$^{-1}$) |
| 1 | CC 25 ppm | 0.284$^{g}$ | 0.247$^{d}$ | 0.531 $^{i}$ | 0.120$^{h}$ |
| 2 | CC 50 ppm | 0.453$^{f}$ | 0.326 $^{abc}$ | 0.777$^{gh}$ | 0.212$^{fg}$ |
| 3 | CC 100 ppm | 0.443$^{f}$ | 0.301 $^{cd}$ | 0.744$^{h}$ | 0.195$^{g}$ |
| 4 | CC 200 ppm | 0.681$^{bc}$ | 0.310 $^{cd}$ | 0.991 $^{cde}$ | 0.303$^{bc}$ |
| 5 | PBZ 25 ppm | 0.610$^{cd}$ | 0.321 $^{bc}$ | 0.930 $^{def.}$ | 0.230$^{f}$ |
| 6 | PBZ 50 ppm | 0.744$^{b}$ | 0.278$^{cd}$ | 1.024$^{bcd}$ | 0.335$^{ab}$ |
| 7 | PBZ 100 ppm | 0.835$^{a}$ | 0.391 $^{a}$ | 1.083$^{bc}$ | 0.347$^{a}$ |
| 8 | PBZ 200 ppm | 0.847$^{a}$ | 0.381$^{ab}$ | 1.228$^{a}$ | 0.335$^{ab}$ |
| 9 | ET 25 ppm | 0.721$^{b}$ | 0.248$^{d}$ | 1.112$^{ab}$ | 0.312$^{bc}$ |
| 10 | ET 50 ppm | 0.586$^{de}$ | 0.303 $^{cd}$ | 0.889 $^{efg}$ | 0.266$^{de}$ |
| 11 | ET 100 ppm | 0.544$^{de}$ | 0.250$^{d}$ | 0.794 $^{gh}$ | 0.266$^{de}$ |
| 12 | ET 200 ppm | 0.698$^{bc}$ | 0.304$^{cd}$ | 1.00$^{bcde}$ | 0.297$^{cd}$ |
| 13 | Control | 0.517$^{ef}$ | 0.297 | 0.814$^{fgh}$ | 0.242$^{ef}$ |
| | CD | 0.09 | 0.067 | 0.041 | 0.033 |
| | SE(m) | 0.031 | 0.023 | 0.118 | 0.011 |
| | CV | 8.71 | 13.14 | 7.67 | 7.29 |

**Table 16. Effect of Plant growth regulators in chlorophyll (a, b and total), carotenoid content in seedling stage of cowpea varieties of Kashi Kanchan**

| | | Kashi Kanchan | | | |
|---|---|---|---|---|---|
| | Treatments | Chlorophyll (a) (mg $g^{-1}$) | Chlorophyll (b) (mg $g^{-1}$) | Total chlorophyll (mg $g^{-1}$) | Carotenoids (mg $g^{-1}$) |
| 1 | CC 25 ppm | $0.679^{e}$ | $0.372^{ef}$ | $1.051^{h}$ | $0.404^{abc}$ |
| 2 | CC 50 ppm | $0.719^{e}$ | $0.565^{ab}$ | $1.284^{def}$ | $0.345^{def}$ |
| 3 | CC 100 ppm | $0.704^{e}$ | $0.629^{a}$ | $1.332^{cd}$ | $0.338^{ef}$ |
| 4 | CC 200 ppm | $0.703^{e}$ | $0.474^{cd}$ | $1.325^{cd}$ | $0.375^{cde}$ |
| 5 | PBZ 25 ppm | $0.715^{e}$ | $0.489^{bcd}$ | $1.204^{g}$ | $0.414^{ab}$ |
| 6 | PBZ 50 ppm | $0.801^{d}$ | $0.518^{bc}$ | 1.318 | $0.394^{bc}$ |
| 7 | PBZ 100 ppm | $0.925^{ab}$ | $0.522^{bc}$ | $1.434^{ab}$ | $0.419^{ab}$ |
| 8 | PBZ 200 ppm | $0.960^{a}$ | $0.622^{a}$ | $1.447^{a}$ | $0.439^{a}$ |
| 9 | ET 25 ppm | $0.926^{ab}$ | $0.442^{cde}$ | $1.368^{abc}$ | $0.382^{bcd}$ |
| 10 | ET 50 ppm | $0.834^{cd}$ | $0.528^{bc}$ | $1.362^{bcd}$ | $0.353^{def}$ |
| 11 | ET 100 ppm | $0.832^{cd}$ | $0.492^{bcd}$ | $1.324^{cd}$ | $0.393^{bc}$ |
| 12 | ET 200 ppm | $0.884^{bc}$ | $0.345^{f}$ | $1.228^{fg}$ | $0.333^{f}$ |
| 13 | Control | $0.822^{cd}$ | $0.421^{def}$ | $1.243^{efg}$ | $0.401^{abc}$ |
| | CD | 0.069 | 0.081 | 0.08 | 0.039 |
| | SE(m) | 0.024 | 0.031 | 0.027 | 0.013 |
| | CV | 5.07 | 10.70 | 3.65 | 5.99 |

**Table17. Effect of plant growth regulators in auxin and gibberellic acid content in cowpea varieties of Vellayani Jyothika and Kashi Kanchan**

| Sl no | Treatments | Vellayani Jyothika | | Kashi Kanchan | |
|---|---|---|---|---|---|
| | | IAA content ($mg/g^{-1}$) | GA Content($ng/g^{-1}$) | IAA content ($mg/g^{-1}$) | GA content ($ng/g^{-1}$) |
| 1 | CC 25 ppm | $0.136^{j}$ | $1.041^{e}$ | $0.130^{ef}$ | $0.907^{g}$ |
| 2 | CC 50 ppm | $0.166^{f}$ | $1.012^{e}$ | $0.096^{g}$ | $0.987^{f}$ |
| 3 | CC 100 ppm | $0.176^{de}$ | $1.187^{d}$ | $0.141^{cd}$ | $1.160^{e}$ |
| 4 | CC 200 ppm | $0.144^{i}$ | $1.407^{c}$ | $0.147^{bc}$ | $1.350^{c}$ |
| 5 | PBZ 25 ppm | $0.187^{b}$ | $1.046^{e}$ | $0.143^{cd}$ | $0.967^{f}$ |
| 6 | PBZ 50 ppm | $0.151^{h}$ | $0.908^{f}$ | $0.152^{ab}$ | $0.837^{h}$ |
| 7 | PBZ 100 ppm | $0.123^{k}$ | $0.836^{fg}$ | $0.137^{de}$ | $0.983^{f}$ |
| 8 | PBZ 200 ppm | $0.126^{k}$ | $0.819^{g}$ | $0.077^{h}$ | $0.730^{i}$ |
| 9 | ET 25 ppm | $0.220^{a}$ | $1.445^{bc}$ | $0.130^{ef}$ | $1.320^{c}$ |
| 10 | ET 50 ppm | $0.186^{bc}$ | $1.513^{b}$ | $0.145^{bc}$ | $1.283^{d}$ |
| 11 | ET 100 ppm | $0.160^{g}$ | $1.507^{b}$ | $0.124^{f}$ | $1.453^{b}$ |
| 12 | ET 200 ppm | $0.180^{cd}$ | $1.529^{b}$ | $0.155^{a}$ | $1.450^{b}$ |
| 13 | Control | $0.173^{e}$ | $1.791^{a}$ | 0.125 | $1.667^{a}$ |
| | CD | 0.006 | 0.086 | 0.008 | 0.035 |
| | SE(m) | 0.002 | 0.030 | 0.003 | 0.012 |
| | CV | 2.049 | 4.15 | 3.60 | 1.814 |

**Experiment No – 2 Field evaluation**

**4.2. Morphological observations**

Morphological observations *viz* Plant height, Internodal length, Primary branches were recorded on 30$^{th}$ day after planting.

**4.2.1.1. Plant height (cm)**

The plant height was significantly higher in treatments receiving Ethrel @ 50 ppm (161.30 cm). (Table 18) and minimum plant height was recorded in treatments receiving Cycocel @ 50 ppm in Vellayani Jyothika (112.40 cm).

Significantly higher plant height was recorded in all treatments receiving growth regulator Ethrel@ 200 ppm (34.2 cm) but on par with Ethrel @ 25 ppm (33.74 cm) Ethrel @100 ppm (33.07 cm) and Cycocel @ 200 ppm (33.06 cm) in Kashi Kanchan. (Table 20) .The lowest plant height was recorded in treatments receiving Paclobutrazol @ 200 ppm (28.31 cm).

**4.2.1.2. Internodal length (cm)**

In Vellayani Jyothika, significantly higher internodal length was recorded in growth regulator Ethrel @ 100 ppm (3.13 cm) but on par with Ethrel @ 50 ppm (3.04 cm) (Table 18) .The minimum internodal length was recorded in Paclobutrazol @ 200 ppm (2.63 cm) and control (2.64cm). In Kashi Kanchan, internodal length was the highest in treatments that receiving Ethrel 200 ppm (3.34 cm). Minimum internodal length was recorded in growth regulator Cycocel 100 ppm @ ppm (2.53 cm). (Table 20)

**4.2.1.3. Primary branches**

The number of primary branches was the highest in treatments receiving Paclobutrazol @ 200 ppm (5.93) but on par with Paclobutrazol @ 100 ppm (5.63) and Ethrel 100 ppm in genotype Vellayani Jyothika. (Table 18).The minimum number of primary branches was recorded in treatments receiving Cycocel @ 200 ppm (4.4) and control (4.3). In Kashi Kanchan, there was no significant difference between the various treatments for this character (Table 20)

**4.2.1.4. Days to flowering**

The treatments receiving Cycocel @ 200 ppm (41days) was the earliest to flower which was significantly superior to all other treatments in cowpea genotype Vellayani

Jyothika. (Table 18)The treatments receiving Paclobutrazol @ 50 ppm (45.8 days) took maximum number of days to flower.

The treatments receiving Cycocel @ 25 ppm (36.80 days) was the earliest to flower which was on par with Cycocel @ 50 ppm (36.93 days) in Kashi Kanchan. The treatments receiving Paclobutrazol @ 200 ppm (41.66 days) took maximum number days to flower. (Table 20)

**4.2.1.5. Days to first harvest**

Ethrel @ 25 ppm (52.26 days) were the earliest to first harvest but on par with Ethrel @ 50 ppm (51.73 days) and Cycocel @ 200 ppm (51.13 days) in cowpea genotype Vellayani Jyothika. (Table 18) The treatments receiving Paclobutrazol @ 100 ppm (55.13 days) took higher number of days for first harvest but on par with Paclobutrazol @ 200 ppm (54.80 days).

The treatments receiving Cycocel @ 25 ppm (47.93) were the earliest to first harvest in Kashi Kanchan (Table 20).The treatments Ethrel @ 200 ppm (53.93 days) took higher number of days for first harvest but on par with Paclobutrazol 200 ppm (53.40 days)

**4.2.1.6. Days to last harvest**

Treatments receiving Paclobutrazol @ 50 ppm (95.8 days) had the longest crop duration in the field in the genotype Vellayani Jyothika (Table 18) .This was on par with Paclobutrazol @100 ppm (95.3 days), Cycocel 25 ppm (94.6 days), Paclobutrazol 25 ppm (94.6 days). Minimum crop duration was recorded in Cycocel @ 100 ppm (91.5 days) and Ethrel 25 ppm (91.5 days)

The treatments receiving Paclobutrazol @ 100 ppm (79.0 days) recorded maximum crop duration s in cowpea genotype Kashi Kanchan. (Table 20 ) but on par with Paclobutrazol @ 50 ppm (78.61 days) and Cycocel @ 50 ppm (77.06 days) .The crop duration was minimum in growth regulators Ethrel @ 50 ppm (72.40 days), control (72.46 days), and Ethrel 25 ppm (73.6 days).

**4.2.1.7. Pod length (cm)**

Significantly higher Pod length was recorded in treatments receiving Ethrel 100 ppm (52.95 cm) in Vellayani Jyothika (Table 18) but on par with Paclobutrazol 200 ppm

(51.91 cm) .The minimum pod length was recorded in treatments receiving Cycocel 25 ppm (46.40cm) and Cycocel 50 ppm (46.35cm)

Significantly higher pod length was recorded in treatments receiving Ethrel @ 100 ppm (28.12 cm) followed by treatments receiving Paclobutrazol 100 and Paclobutrazol 50 ppm in Kashi Kanchan (Table 20) .The minimum pod length was recorded in the control treatment (25.26 cm).

**4.2.1.8. Pod girth (cm)**

Pod girth was significantly higher in treatments receiving Paclobutrazol @ 100 ppm (3.32cm) followed by Paclobutrazol 200 ppm (3.30cm) while it was minimum in Ethrel @ 50 ppm (2.77cm)

In Kashi Kanchan, significantly higher pod girth was recorded in treatments receiving Paclobutrazol 100 ppm (3.16cm) followed by Paclobutrazol 25 ppm (3.11cm) and Ethrel 100 ppm (3.10cm). Minimum pod girth was recorded in control treatment (2.69cm)

**4.2.1.9. Pod weight (g)**

Pod weight was significantly higher in treatments receiving Paclobutrazol 200 ppm (20.50 g) which was on par with Paclobutrazol 50 ppm (20.267 g) in Vellayani Jyothika. (Table 18) .Minimum pod weight was recorded in the Ethrel 200 (17.7 g)
Significantly higher pod weight was recorded in treatments receiving Ethrel @ 100 ppm (11.23 g) but on par with Ethrel 50 ppm, Paclobutrazol 25 and Paclobutrazol 50 ppm in cowpea genotype Kashi Kanchan (Table 20). Minimum pod weight was recorded in the control treatment (8.42g)

**4.2.1.10. Number of pods per plant**

In Vellayani Jyothika number of pods per plant was recorded highest in Ethrel 100 ppm (64.33) which was on par with Ethrel 50 ppm (57.01). Lowest number of pods was recorded in control treatment (30.15)

In Kashi Kanchan, number of pods was the highest in treatments that receiving Paclobutrazol 100 ppm (161.86) and Ethrel 100 ppm (162.26) .Minimum number of pods was recorded in control treatment (126.20).

#### 4.2.1.11. Pod yield per plant (g)

Significantly higher yield per plant was recorded in Ethrel @ 100 ppm (1273 g) followed by Ethrel 25 ppm (1056.46 g) Vellayani Jyothika (Table 18) .Minimum yield per plant was recorded in control treatment (553. 33 g)

Significantly higher yield per plant was recorded in treatments receiving Ethrel @ 100 ppm (1760) but on par with Paclobutrazol @ 100 ppm (1759 g) in Kashi Kanchan followed by Paclobutrazol 50 ppm (1549 g) (Table 20). Minimum yield per plant was recorded in control treatment (1042.51g)

#### 4.2.1.12 Seed weight (g)

There were no significant differences between the treatments for both the genotypes for this character (Table 18 and 20)

#### 4.2.1.13 Incidence of pest and diseases

Pests like leaf eating caterpillar and pod bug was noticed during the pod formation stage in both the varieties (Vellyani Jyothika and Kashi Kanchan) diseases like anthracnose and leaf spot was observed during vegetative stage of the crop.

**Plate. 8 Effect of plant growth regulator at 30 DAP in cowpea varieties**

**Plate .9 Effect of plant growth regulator on cowpea variety Vellayani Jyothika**



**Plate .10 Effect of plant growth regulator on cowpea variety Kashi Kanchan**

**Plate .11 Pest and disease incidence**

## 4. 3. Physiological parameters

The physiological parameters *viz* chlorophyll a and b ,total chlorophyll ,carotenoids, stomatal frequency and stomatal index were recorded on 30 days after planting from third opened leaf.

### 4.3.1. Chlorophyll a (mg $g^{-1}$)

In Vellayani Jyothika, significantly higher chlorophyll a content was recorded in Paclobutrazol @ 200 ppm (1.79 mg) (Table 19) which was on par with Paclobutrazol @ 100 ppm (1.71 mg). The chlorophyll content recorded minimum in control treatment (0.94 mg).

In Kashi Kanchan, The maximum chlorophyll content was recorded in Paclobutrazol @ 200 ppm (1.54 mg) (Table 21) which was on par with Cycocel @ 50 ppm (1.43 mg) .The lowest chlorophyll content was recorded in control (0.971 mg).

### 4.3.2. Chlorophyll b (mg $g^{-1}$)

Highest Chlorophyll b contents was recorded in treatments receiving Paclobutrazol @200 ppm (0.665 mg) in cowpea genotype Vellayani Jyothika. (Table 19). Lowest value was recorded in treatments receiving Cycocel @ 200 ppm (0.288 mg)

Significantly highest chlorophyll content was recorded in treatments receiving Paclobutrazol 200 @ ppm (0.671 mg) in cowpea genotype Kashi Kanchan (Table 21). Minimum chlorophyll content was recorded in Ethrel @100 ppm (0.402 mg)

### 4.3.3. Total Chlorophyll content (mg $g^{-1}$)

In both the genotypes ,the total chlorophyll content was significantly higher in treatments that receiving Paclobutrazol @ 200 ppm (2.14mg) and (2.06mg) respectively .Significantly lower total chlorophyll was recorded in treatments receiving control treatment (1.61mg) and (1.48 mg) respectively. Total chlorophyll content of the both the genotypes are given in (Table 19 and 21)

### 4.3.3. Carotenoid contents (mg $g^{-1}$)

The treatments receiving Paclobutrazol @ 200 ppm had the highest carotenoid contents in Vellayani Jyothika (0.598 mg). (Table 19). Minimum carotenoid content was recorded in control treatment (0.392 mg)

The highest carotenoid contents was found in Paclobutrazol @ 200 pm (0.675 mg) treatment, whereas the lowest carotenoid content was found in Cycocel @ 25 ppm (0.396 mg) in Kashi Kanchan (Table 21)

### 4.3.4. Stomatal frequency

Significantly higher stomatal frequency was recorded in Paclobutrazol @ 200 ppm (20.00) (Table 19) which was on par with Paclobutrazol @ 25 ppm (19.23), Paclobutrazol @100 ppm (19.00) and Paclobutrazol @ 50 ppm (18.33) in Vellayani Jyothika .Significantly lower stomatal frequency was recorded in Cycocel @ 25 ppm (16.33).

The stomatal frequency was the highest in treatments receiving Paclobutrazol @ 200 ppm (22.0) and Cycocel @ 200 ppm (22.0) in the Kashi Kanchan (Table 21) but on par with Paclobutrazol 100 ppm (21.66) significantly lower stomatal frequency was recorded in treatments receiving Cycocel @ 25 ppm (12.66)

### 4.3.5. Stomatal index

Significantly higher stomatal index was recorded in treatments receiving Paclobutrazol @ 200 ppm (48.27) (Table 19) but on par with Paclobutrazol @ 100 ppm (46.83) in Vellayani Jyothika. Minimum stomatal index was recorded in treatments receiving Cycocel @ 25 ppm (38.8).

The stomatal index was the highest in treatments receiving Paclobutrazol @ 200 ppm (48.12) and Cycocel @ 200 ppm (48.12) in Kashi Kanchan (Table 21) but on par with Paclobutrazol @ 100 ppm (46.0). Minimum stomatal index was recorded in treatments receiving Cycocel 25@ ppm (38.8)

### 4.3.6. Relative growth rate

In Vellayani Jyothika, highest relative growth rate was recorded on 0-15$^{th}$ day, in treatments receiving Paclobutrazol @ 100 ppm (0.072 g) but on par with Ethrel @ 100 ppm (0.072g) (Table 22).The highest relative growth rate was recorded on 15-30$^{th}$ day in treatments receiving Ethrel 100 ppm (0.217g) followed by Paclobutrazol 100 ppm (0.206 g). On 30-45$^{th}$ day ,highest relative growth rate was recorded in treatments receiving Ethrel 100 ppm (0.110 g) followed by Paclobutrazol 100 ppm (0.108 g). Highest relative growth rate was recorded in treatments receiving Paclobutrazol @ 100 ppm (0.0084 g) followed by Ethrel 100 ppm (0.051 g) on 45-60$^{th}$ day

Significantly higher relative growth rate was recorded in treatments receiving Paclobutrazol (0.0052 g) and Paclobutrazol 200 ppm (0.0052 g) but on par with Ethrel 100 ppm (0.043) on 0-15$^{th}$ day in Kashi Kanchan (Table 23). On 15-30$^{th}$ day, highest relative growth recorded in treatments receiving Ethrel @100 ppm (0.184 g) but on par with Paclobutrazol @ 100 ppm (0.177 g). On 30-45$^{th}$ day relative growth rate significantly higher relative growth rate was recorded in Ethrel @ 100 ppm (0.057 g) followed by Paclobutrazol @ 100 ppm (0.051 g). Significantly higher relative growth rate was recorded in Paclobutrazol @ 100 ppm (0.021 g) and Ethrel @100 ppm (0.020 g) on 45-65$^{th}$ day.

**Table 18. Effect of plant growth regulators on morphological characters of cowpea variety Vellayani Jyothika**

| Sl.no | Treatments | Plant height (cm) | Internodal length (cm) | Primary branches | Days to first flowering | Days to first harvest | Days to last harvest | Pod length (cm) | Pod girth (cm) | Pod weight (g) | No of pods per plant | Pod yield /plant (g) | Seed weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CC 25 ppm | 118.70$^{g}$ | 2.96$^{bc}$ | 5.13$^{cde}$ | 42.60$^{cde}$ | 53.60$^{bc}$ | 94.60$^{abc}$ | 46.40$^{de}$ | 3.211$^{f}$ | 18.63$^{de}$ | 48.46$^{bcde}$ | 920.65$^{bcd}$ | 19.933 |
| 2 | CC 50ppm | 112.40$^{h}$ | 2.94$^{bc}$ | 5.26$^{bcd}$ | 42.73$^{cd}$ | 53.46$^{bcd}$ | 94.26$^{bc}$ | 46.35$^{e}$ | 3.200$^{g}$ | 17.90$^{e}$ | 44.49$^{cde}$ | 802.66$^{cd}$ | 19.633 |
| 3 | CC 100 ppm | 122.10$^{g}$ | 2.90$^{bcd}$ | 5.40$^{bcd}$ | 42.93$^{cd}$ | 52.46$^{def}$ | 91.53$^{f}$ | 46.88$^{de}$ | 3.283$^{e}$ | 19.50$^{abcd}$ | 47.33$^{bcde}$ | 910.66$^{bcd}$ | 19.633 |
| 4 | CC 200 ppm | 128.80$^{f}$ | 2.94$^{bc}$ | 4.40$^{f}$ | 41.00$^{f}$ | 51.13$^{g}$ | 92.80$^{def}$ | 47.60$^{cde}$ | 3.178$^{h}$ | 19.26$^{bcd}$ | 39.83$^{ef}$ | 753.33$^{de}$ | 19.933 |
| 5 | PBZ 25 ppm | 136.66$^{d}$ | 2.73$^{ef}$ | 5.00$^{de}$ | 43.06$^{c}$ | 51.93$^{efg}$ | 94.60$^{abc}$ | 48.58$^{bcde}$ | 3.289$^{c}$ | 20.16$^{ab}$ | 41.33$^{def}$ | 855.15$^{bcd}$ | 19.933 |
| 6 | PBZ 50 ppm | 128.00$^{f}$ | 2.78$^{def}$ | 5.46$^{bc}$ | 45.80$^{a}$ | 54.20$^{ab}$ | 95.86$^{a}$ | 50.87$^{abc}$ | 3.272$^{d}$ | 20.26$^{ab}$ | 49.40$^{bcde}$ | 1045.33$^{b}$ | 19.933 |
| 7 | PBZ 100ppm | 131.50$^{ef}$ | 2.90$^{bcd}$ | 5.66$^{ab}$ | 44.33$^{b}$ | 55.13$^{a}$ | 95.20$^{ab}$ | 48.55$^{bcde}$ | 3.328$^{a}$ | 19.93$^{ab}$ | 52.10$^{bcd}$ | 1043.66$^{b}$ | 19.933 |
| 8 | PBZ 200 ppm | 146.00$^{bc}$ | 2.63$^{f}$ | 5.93$^{a}$ | 44.20$^{b}$ | 54.80$^{a}$ | 93.93$^{bcd}$ | 51.91$^{ab}$ | 3.300$^{b}$ | 20.50$^{a}$ | 44.03$^{cde}$ | 899.33$^{bcd}$ | 19.933 |
| 9 | ET 25 ppm | 144.60$^{c}$ | 2.85$^{cde}$ | 5.40$^{bcd}$ | 42.20$^{de}$ | 52.26$^{ef}$ | 91.69$^{f}$ | 50.17$^{abcd}$ | 2.820$^{k}$ | 18.80$^{cde}$ | 54.26$^{abc}$ | 1056.00$^{b}$ | 19.900 |
| 10 | ET 50 ppm | 161.30$^{a}$ | 3.04$^{ab}$ | 5.33$^{bcd}$ | 41.86$^{e}$ | 51.73$^{fg}$ | 92.46$^{ef}$ | 52.12$^{ab}$ | 2.778$^{l}$ | 19.83$^{abc}$ | 57.00$^{ab}$ | 1016.66$^{b}$ | 19.500 |
| 11 | ET 100 ppm | 150.00$^{b}$ | 3.13$^{a}$ | 5.73$^{ab}$ | 44.13$^{b}$ | 54.53$^{ab}$ | 93.40$^{cde}$ | 52.95$^{a}$ | 2.871$^{j}$ | 20.06$^{ab}$ | 64.30$^{a}$ | 1273.00 $^{a}$ | 19.967 |
| 12 | ET 200 ppm | 135.73$^{de}$ | 2.90$^{bcd}$ | 5.46$^{bc}$ | 42.86$^{cd}$ | 52.86$^{cde}$ | 92.60$^{def}$ | 47.41$^{cde}$ | 3.117i | 17.76$^{e}$ | 54.26$^{abc}$ | 973.66$^{bc}$ | 19.767 |
| 13 | control | 135.50$^{de}$ | 2.64$^{f}$ | 4.30$^{f}$ | 42.53$^{cde}$ | 52.33$^{ef}$ | 92.61$^{def}$ | 49.23$^{abcde}$ | 3.261$^{e}$ | 18.67$^{de}$ | 30.15$^{f}$ | 553.33$^{e}$ | 19.933 |
| | CD (0.05) | 4.71 | | 0.45 | 1.10 | 0.38 | 1.34 | 3.80 | 0.007 | 1.18 | 11.86 | 201.08 | N S |
| | SE (m) | 1.614 | 0.055 | 0.21 | 0.27 | 1.11 | 0.46 | 1.30 | 0.002 | 0.38 | 4.06 | 68.80 | 0.183 |
| | CV | 2.075 | 3.28 | 5.14 | 0.80 | 1.24 | 0.855 | 4.59 | 0.13 | 3.43 | 14.60 | 12.81 | 1.596 |

**Table 19. Effect of plant growth regulators on physiological parameters of cowpea variety Vellayani Jyothika**

| Sl.no | Treatments | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Total chlorophyll (mg $g^{-1}$) | .Carotenoid contents (mg $g^{-1}$) | Stomatal frequency | Stomatal Index |
|---|---|---|---|---|---|---|---|
| 1 | CC 25ppm | $1.28^{de}$ | $0.53^{bc}$ | $1.82^{c}$ | $0.40^{f}$ | $16.33^{c}$ | $38.88^{ef}$ |
| 2 | CC 50 ppm | $1.40^{bcd}$ | $0.48^{cd}$ | $1.88^{cd}$ | $0.42^{de}$ | $16.00^{c}$ | $38.028^{f}$ |
| 3 | CC100 ppm | $1.37^{cd}$ | $0.50^{bcd}$ | $1.88^{cd}$ | $0.42^{de}$ | $19.33^{ab}$ | $43.28^{bc}$ |
| 4 | CC 200 ppm | $1.35^{cd}$ | $0.28^{e}$ | $1.92^{c}$ | $0.44^{d}$ | $18.00^{abc}$ | $42.80^{bcd}$ |
| 5 | PBZ 25 ppm | $1.40^{bcd}$ | $0.46^{d}$ | $1.86^{cde}$ | $0.49^{c}$ | $19.33^{ab}$ | $44.15^{b}$ |
| 6 | PBZ 50 ppm | $1.45^{bc}$ | $0.34^{e}$ | $1.80^{de}$ | $0.54^{b}$ | $18.33^{abc}$ | $41.04^{cde}$ |
| 7 | PBZ 100 ppm | $1.71^{a}$ | $0.56^{b}$ | $1.99^{b}$ | $0.57^{a}$ | $19.00^{ab}$ | $46.83^{a}$ |
| 8 | PBZ 200 ppm | $1.79^{a}$ | $0.66^{a}$ | $2.14^{a}$ | $0.59^{a}$ | $20.00^{a}$ | $48.27^{a}$ |
| 9 | ET 25 ppm | $1.54^{b}$ | $0.31^{e}$ | $1.85^{cde}$ | $0.42^{de}$ | $16.00^{abc}$ | $39.67^{ef}$ |
| 10 | ET 50 ppm | $1.27^{de}$ | $0.53^{bc}$ | $1.81^{de}$ | $0.43^{d}$ | $18.00^{bc}$ | $40.58^{de}$ |
| 11 | ET100 ppm | $1.20^{e}$ | $0.44^{d}$ | $1.65^{f}$ | $0.44^{d}$ | $17.00^{c}$ | $40.13^{ef}$ |
| 12 | ET 200 ppm | $1.30^{de}$ | $0.46^{d}$ | $1.76^{e}$ | $0.45^{d}$ | $18.00^{abc}$ | $40.92^{de}$ |
| 13 | Control | $0.94^{f}$ | $0.35^{e}$ | $1.61^{f}$ | $0.39^{f}$ | $17.00^{bc}$ | $40.79^{de}$ |
| | CD (0.05) | 0.13 | 0.06 | 0.10 | 0.02 | 2.61 | 2.30 |
| | SE (m) | 0.04 | 0.02 | 0.03 | 0.01 | 0.89 | 0.78 |
| | CV | 5.93 | 8.83 | 3.49 | 3.57 | 8.67 | 3.25 |

**Table 20. Effect of Plant growth regulators on morphological characters of cowpea variety Kashi Kanchan**

| Sl no | Treatments | Plant height (cm) | Internodal length (cm) | Primary branches | Days to first flowering | Days to first harvest | Days to last harvest | Pod length (cm) | Pod girth (cm) | Pod weight(g) | Number of pods per plant | Pod yield per plant(g) | Seed weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CC 25 ppm | 30.94$^{d}$ | 2.83$^{b}$ | 4.58 | 36.80$^{e}$ | 47.93$^{g}$ | 76.60$^{bc}$ | 26.21$^{f}$ | 2.91$^{h}$ | 8.98$^{f}$ | 154.26$^{ab}$ | 1461.33$^{bc}$ | 11.433 |
| 2 | CC 50 ppm | 30.87$^{d}$ | 2.60$^{cd}$ | 5.16 | 36.93$^{e}$ | 48.40 $^{fg}$ | 77.06 $^{abc}$ | 26.61$^{def}$ | 2.85$^{i}$ | 9.10$^{ef}$ | 138.46$^{cdef}$ | 1281.06$^{d}$ | 11.600 |
| 3 | CC 100 ppm | 31.31$^{cd}$ | 2.533$^{d}$ | 5.08 | 38.73$^{d}$ | 49.86$^{def.}$ | 75.66$^{c}$ | 26.79$^{cde}$ | 3.03$^{e}$ | 9.86$^{cde}$ | 133.86$^{defg}$ | 1369.06$^{cd}$ | 11.600 |
| 4 | CC 200 ppm | 33.06$^{abc}$ | 2.66$^{bcd}$ | 5.06 | 39.60$^{bcd}$ | 49.60$^{ef}$ | 75.66$^{c}$ | 26.38$^{ef}$ | 2.99$^{g}$ | 9.53$^{cdef}$ | 129.53$^{fg}$ | 1287.26$^{d}$ | 11.933 |
| 5 | PBZ 25 ppm | 30.88$^{d}$ | 2.59$^{d}$ | 5.16 | 37.20$^{e}$ | 49.53$^{f}$ | 75.86c | 27.02$^{bcd}$ | 3.11$^{b}$ | 10.80$^{ab}$ | 132.25$^{efg}$ | 1452.73$^{bcd}$ | 12.167 |
| 6 | PBZ 50ppm | 32.46$^{abcd}$ | 2.66$^{bcd}$ | 5.25 | 40.13$^{bc}$ | 51.86$^{c}$ | 78.60$^{ab}$ | 27.50$^{b}$ | 3.00$^{f}$ | 10.73$^{ab}$ | 152.63$^{b}$ | 1549.26$^{b}$ | 11.800 |
| 7 | PBZ 100ppm | 32.15$^{bcd}$ | 2.62$^{cd}$ | 5.58 | 40.96$^{ab}$ | 52.40$^{c}$ | 79.0 $^{a}$ | 27.50$^{b}$ | 3.16$^{a}$ | 10.93$^{ab}$ | 161.86$^{a}$ | 1759.00$^{a}$ | 12.200 |
| 8 | PBZ 200ppm | 28.31$^{d}$ | 2.64$^{bcd}$ | 5.33 | 41.66$^{a}$ | 53.40$^{ab}$ | 75.80$^{c}$ | 26.28$^{ef}$ | 3.06$^{c}$ | 9.78$^{cdef}$ | 145.33$^{bc}$ | 1422.06$^{bcd}$ | 10.933 |
| 9 | ET 25ppm | 33.74$^{ab}$ | 2.66$^{bcd}$ | 4.66 | 39.26$^{cd}$ | 51.13$^{cd}$ | 73.60$^{d}$ | 27.00$^{bcd}$ | 3.05$^{d}$ | 10.13$^{bcd}$ | 142.43$^{cd}$ | 1407.86$^{bcd}$ | 11.600 |
| 10 | ET 50 ppm | 31.92$^{bcd}$ | 2.65$^{bcd}$ | 5.000 | 39.13$^{cd}$ | 51.20$^{cd}$ | 72.40 $^{d}$ | 27.26$^{bc}$ | 3.00$^{f}$ | 10.83$^{ab}$ | 140.80$^{cde}$ | 1523.00$^{bc}$ | 11.833 |
| 11 | ET 100 ppm | 33.07$^{abc}$ | 2.68$^{bcd}$ | 5.583 | 39.66$^{bcd}$ | 51.53$^{c}$ | 75.80$^{c}$ | 28.12$^{a}$ | 3.10$^{b}$ | 11.23$^{a}$ | 162.2$^{a}$ | 1760.00$^{a}$ | 11.567 |
| 12 | ET 200 ppm | 34.21$^{a}$ | 3.34$^{a}$ | 5.417 | 42.20$^{a}$ | 53.93$^{a}$ | 76.93$^{bc}$ | 26.69$^{def}$ | 2.75$^{j}$ | 10.26$^{bc}$ | 136.98$^{cdef}$ | 1382.70$^{bcd}$ | 11.933 |
| 13 | Control | 30.82 $^{d}$ | 2.80$^{b}$ | 5.167 | 39.80$^{bcd}$ | 51.06$^{cde}$ | 72.467$^{d}$ | 25.26g | 2.69$^{k}$ | 8.42$^{f}$ | 126.20$^{g}$ | 1042.51$^{e}$ | 11.933 |
| | CD (0.05) | 1.878 | 0.207 | NS | 1.392 | 1.516 | 2.01 | 0.52 | 0.007 | 0.824 | 9.127 | 172.271 | NS |
| | SE (m) | 0.643 | 0.071 | | 0.674 | 0.52 | 0.843 | 0.178 | 0.002 | 0.282 | 3.127 | 59.021 | 0.263 |
| | CV | 3.502 | 4.556 | 9.231 | 2.097 | 1.768 | 1.573 | 1.152 | 0.136 | 4.832 | 3.792 | 7.108 | 3.87 |

**Table 21. Effect of Plant growth regulators on Physiological Parameters of Kashi Kanchan**

| Sl.no | Treatments | Chlorophyll (a) (mg $g^{-1}$) | Chlorophyll (b) (mg $g^{-1}$) | Total Chlorophyll (mg $g^{-1}$) | Carotenoids (mg $g^{-1}$) | Stomatal Frequency | Stomatal Index |
|---|---|---|---|---|---|---|---|
| 1 | CC 25 ppm | 1.269 $^{cd}$ | 0.579$^{b}$ | 1.847 $^{c}$ | 0.396$^{f}$ | 12.66$^{f}$ | 34.88$^{g}$ |
| 2 | CC 50 ppm | 1.436 $^{ab}$ | 0.577$^{b}$ | 2.013$^{ab}$ | 0.417$^{def}$ | 13.33$^{f}$ | 35.76$^{g}$ |
| 3 | CC 100 ppm | 1.159 $^{de}$ | 0.464$^{cde}$ | 1.623$^{d}$ | 0.438$^{cde}$ | 17.00$^{de}$ | 42.49$^{cde}$ |
| 4 | CC 200 ppm | 1.340 $^{bc}$ | 0.467$^{cde}$ | 1.806$^{c}$ | 0.455$^{cd}$ | 22.00$^{a}$ | 48.12$^{a}$ |
| 5 | PBZ 25 ppm | 1.014 $^{fg}$ | 0.432$^{de}$ | 1.489 $^{de}$ | 0.473$^{c}$ | 16.00$^{e}$ | 39.00$^{f}$ |
| 6 | PBZ 50 ppm | 1.332 $^{bc}$ | 0.548$^{bc}$ | 1.879$^{bc}$ | 0.546$^{b}$ | 18.66$^{cd}$ | 42.40$^{de}$ |
| 7 | PBZ 100 ppm | 1.273$^{cd}$ | 0.512$^{bcd}$ | 1.785$^{c}$ | 0.563$^{b}$ | 21.66$^{ab}$ | 46.06$^{ab}$ |
| 8 | PBZ 200 ppm | 1.548$^{a}$ | 0.671$^{a}$ | 2.063$^{a}$ | 0.675$^{a}$ | 22.0$^{a}$ | 48.12$^{a}$ |
| 9 | ET 25 ppm | 1.345 $^{bc}$ | 0.515$^{bcd}$ | 2.016 $^{ab}$ | 0.424$^{def}$ | 19.33$^{bcd}$ | 43.53$^{bcde}$ |
| 10 | ET 50 ppm | 1.133$^{ef}$ | 0.483$^{cde}$ | 1.616$^{d}$ | 0.434$^{cdef}$ | 21.33$_{ab}$ | 45.00$^{bc}$ |
| 11 | ET 100 ppm | 1.089 | 0.402$^{e}$ | 1.490$^{de}$ | 0.409$^{ef}$ | 20.00$^{abc}$ | 44.77$^{bcd}$ |
| 12 | ET 200 ppm | 1.129$^{ef}$ | 0.466$^{cde}$ | 1.573$^{d}$ | 0.445$^{cde}$ | 18.33$^{cde}$ | 43.63$^{bcde}$ |
| 13 | Control | 0.971$^{g}$ | 0.475$^{cde}$ | 1.403e | 0.406 | 18.33$^{cde}$ | 41.98$^{e}$ |
| | CD (0.05) | 0.121 | 0.085 | 0.146 | 0.04 | 2.57 | 3.615 |
| | SE (m) | 0.41 | 0.029 | 0.05 | 0.014 | 0.862 | 0.884 |
| | CV | 5.822 | 9.99 | 4.99 | 5.046 | 8.193 | 2.58 |

**Table 22. Effect of plant growth regulators on relative growth of cowpea variety Vellayani Jyothika**

| Sl. no | Treatments | 0-15 | 15-30 | 30-45 | 45-65 |
|---|---|---|---|---|---|
| 1 | CC 25 | $0.023^{f}$ | $0.204^{b}$ | $0.101^{d}$ | $0.0035^{def}$ |
| 2 | CC 50 | $0.030^{e}$ | $0.191^{e}$ | $0.106^{c}$ | $0.0038^{de}$ |
| 3 | CC 100 | $0.031^{de}$ | $0.182^{f}$ | $0.107^{bc}$ | $0.0048^{bc}$ |
| 4 | CC 200 | $0.041^{c}$ | $0.173^{h}$ | $0.097^{e}$ | $0.00180^{g}$ |
| 5 | PBZ 25 | $0.072^{a}$ | $0.158^{j}$ | $0.082^{i}$ | $0.0033^{def}$ |
| 6 | PBZ 50 | $0.063^{b}$ | $0.164^{i}$ | $0.105^{c}$ | $0.0035^{def}$ |
| 7 | PBZ 100 | $0.072^{a}$ | $0.206^{b}$ | $0.108^{b}$ | $0.0084^{a}$ |
| 8 | PBZ 200 | $0.033^{de}$ | $0.178^{g}$ | $0.090^{g}$ | $0.0006^{h}$ |
| 9 | ET 25 | $0.035^{d}$ | $0.202^{bc}$ | $0.095^{f}$ | $0.0030^{ef}$ |
| 10 | ET 50 | $0.065^{b}$ | $0.199^{cd}$ | $0.091^{g}$ | $0.0036d^{ef}$ |
| 11 | ET 100 | $0.072^{a}$ | $0.217^{a}$ | $0.110^{a}$ | $0.0051^{b}$ |
| 12 | ET 200 | $0.043^{c}$ | $0.171^{h}$ | $0.079^{j}$ | $0.0027^{f}$ |
| 13 | Control | $0.041^{c}$ | $0.197^{d}$ | $0.085^{h}$ | $0.0040^{cd}$ |
| | CV | 5.193 | 1.263 | 1.059 | 14.843 |
| | SE(M) | 0.002 | 0.001 | 0.001 | 0 |
| | CD | 0.005 | 0.004 | 0.002 | 0.001 |

**Table 23. Effect of plant growth regulators on relative growth rate of cowpea Kashi Kanchan**

| Sl.no | Treatments | 0 – 15 | 15 -30 | 30 - 45 | 45 - 65 |
|---|---|---|---|---|---|
| 1 | CC 25 | 0.023 $^{c}$ | 0.172$^{bc}$ | 0.049$^{bc}$ | 0.014$^{bcd}$ |
| 2 | CC 50 | 0.015$^{c}$ | 0.164 $^{cdef}$ | 0.047$^{cd}$ | 0.009$^{fg}$ |
| 3 | CC 100 | 0.024$^{c}$ | 0.162$^{cdefg}$ | 0.050$^{bc}$ | 0.015$^{cde}$ |
| 4 | CC200 | 0.041$^{b}$ | 0.160$^{efg}$ | 0.051$^{b}$ | 0.014$^{ef}$ |
| 5 | PBZ 25 | 0.043$^{ab}$ | 0.161$^{defg}$ | 0.049$^{bc}$ | 0.011$^{ef}$ |
| 6 | PBZ 50 | 0.041$^{b}$ | 0.165$^{cdef}$ | 0.051$^{b}$ | 0.014$^{bcd}$ |
| 7 | PBZ 100 | 0.052$^{a}$ | 0.177$^{ab}$ | 0.045$^{de}$ | 0.021$^{a}$ |
| 8 | PBZ 200 | 0.052$^{a}$ | 0.153$^{g}$ | 0.043$^{ef}$ | 0.017$^{b}$ |
| 9 | ET 25 | 0.040$^{b}$ | 0.158$^{fg}$ | 0.041$^{f}$ | 0.007$^{g}$ |
| 10 | ET 50 | 0.041$^{b}$ | 0.163$^{cdefg}$ | 0.044$^{de}$ | 0.009$^{fg}$ |
| 11 | ET 100 | 0.043$^{ab}$ | 0.184 $^{a}$ | 0.057$^{a}$ | 0.020$^{a}$ |
| 12 | ET 200 | 0.036$^{b}$ | 0.171$^{bcd}$ | 0.045$^{de}$ | 0.013$^{de}$ |
| 13 | Control | 0.034$^{b}$ | 0.169$^{bcde}$ | 0.044$^{ef}$ | 0.016$^{bc}$ |
| | CV | 0.01 | 3.745 | 4.174 | 11.763 |
| | SE(m) | 0.002 | 0.004 | 0.001 | 0.001 |
| | CD | 0.01 | 0.01 | 0.003 | 0.003 |

# *DISCUSSION*

# 5. DISCUSSION

Cowpea (*Vigna unguiculata* L.) Walp is an annual leguminous vegetable crop native to Central Africa belonging to the family Fabaceae. It is commercially grown throughout India for its green pods used as a vegetable. In India, cowpea is grown almost in all states, but the largest cultivating states are Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala and Orissa. The tender pods are good source of minerals *viz* calcium (80 mg), phosphorus (74 mg), iron (2.5 mg), vitamins (A, B, and C), carbohydrates (8 g), proteins (4.3 g), fats (0.6 g) and fiber (2 g) per 100 g of edible portion (Davis *et al.,* 2000). Pro- tray seedlings grown in soil less medium are widely used for commercial cultivation of vegetables. Over extension of hypocotyl leading to lanky growth of seedlings is a serious problem in plugs of cowpea, cucurbits and bhindi especially in polyhouses. Lanky growth of the seedlings makes them unsuitable for mechanized planting and long distance transport. Plant growth retardants are widely used to control plant growth in many fruit crops and ornamental plants .The present investigation was undertaken with the objective of controlling seedling height of vegetable cowpea using plant growth retardants and to assess the field performance of treated seedlings. The results of the study are briefly discussed in this chapter

### 5.1.1. Seedling vigour characters

Seeds of two cowpea genotypes *viz* Vellayani Jyothika and Kashi Kanchan treated with three plant growth retardants Paclobutrazol, Cycocel and Ethrel each with four doses *viz* 25, 50, 100 and 200 ppm and an untreated control were used in the present research work. In both the cowpea genotypes, highest germination percentage was recorded in control treatment on $5^{th}$, $10^{th}$ and $15^{th}$ day after sowing compared to growth retardant treated seedlings. Paclobutrazol treatments significantly delayed and reduced germination percentage of cowpea seedlings. These findings are in agreement with the studies conducted by Passian and Bennet (2001) in marigold and geranium. They reported that higher concentration of plant growth regulator and longer times of soaking inhibited emergence of marigold and geranium. Maginitskiy *et al .,* (2006 ) also reported that seeds soaked in higher Paclobutrazol concentration of 500 mg /$L^{-1}$ for 180 minutes reduced seedling emergence in Verbena seedlings.

Number of days taken for emergence of seedling up to the first node is directly related to the germination percentage. Paclobutrazol @ 200 ppm took the highest number of days for emergence of seedlings in both the genotypes .It may be due to the delayed germination and inhibitory actions of the Paclobutrazol. (Cho *et al.,* 2002) in terms of retardations of GA induced elongation growth.

Plant growth retardants *viz* Paclobutrazol and Cycocel play a very crucial role in controlling seedling height in vegetable crops. The possible effect of plant growth retardants may be blocking the gibberellic acid synthesis or slowing down the metabolic activity in the plant. In general, all treatments with plant growth retardants recorded significantly lower seedling height than the control treatment. In both the cowpea genotypes, significantly lower shoot length was recorded in Paclobutrazol @ 200 ppm irrespective of the number of days after germination. Similar results were reported by Ugur and Kavak, (2007) in tomato. They reported that seeds of tomato treated with Paclobutrazol @ 500 ppm recorded 58% height reduction but duration of timing had no effect on height reduction.

Height of seedling up to the first node was directly linked to shoot length. In both the genotypes of the cowpea, significantly lower shoot length was recorded in treatments receiving Paclobutrazol. Control treatment recorded significantly higher seedling height up to the first node compared to growth regulator treatments. The highest dose of Paclobutrazol @ 200 ppm recorded the lowest seedling height. Paclobutrazol induced seedling height reduction in marigold seedlings treated at a higher concentration (1000 ppm) has been reported by Pill and Gunter (2001).

Growth retardants in general reduce root growth, shoot weight and root weight of the seedlings. In both the genotypes significantly lower root length, shoot weight and root weight was obtained in Paclobutrazol treatments compared to untreated control. Triazole compounds significantly influence root growth, either by inhibiting the root growth or stimulating root growth depending upon the plant and the concentration of triazole compound used (Davis *et al.,* 1988).

Paclobutrazol treated seedlings had dark green leaves when compared to other growth regulators and control treatment. The increased dark green color in Paclobutrazol treated seedlings is due to the higher chlorophyll content and other photosynthetic

pigments. Xia *et al.*, (2018) reported that Paclobutrazol enhanced the endogenous levels of cytokinin in leaves which in turn enhanced chlorophyll biosynthesis and prevented further degradation of photosynthetic pigments in leaves. Khalil *et al*., (1990) found that triazole compounds increased the chlorophyll and carotenoid content per unit weight of maize seedlings.

Paclobutrazol treated seedlings were short, compact with increased stem girth. In both the cowpea genotypes, when compared to other growth retardant and control treatment highest stem girth of the seedlings was recorded in treatments receiving Paclobutrazol @ 200 ppm. Tsegaw *et al.,* (2005) reported that in potato, Paclobutrazol treatment increased cortex thickness by 58 % in potato. The treated seedlings had larger vascular bundles with large and wider pith cells. Paclobutrazol application also increased the accumulation of starch granules in the pith cells and cortical cells of stem and root, resulting in short and compact seedlings with increased stem girth.

There was no significant difference in the number of leaves on $5^{th}$, $10^{th}$ and $15^{th}$ day after germination. However on $10^{th}$ day after germination higher number of leaves were recorded in plants treated with Paclobutrazol @ 200 ppm .Similar results have been reported by Berova and Zlatev (2000) in foliar application of tomato seedlings with Paclobutrazol @ 1.0 $mg/L^{-1}$ and 25.0 $mg/L^{-1}$

In Vellayani Jyothika leaf length was the highest in control treatment when compared to growth retardant treatments. On $5^{th}$ and $10^{th}$ day after germination growth retardant Cycocel recorded maximum leaf length and on $15^{th}$ day control treatment recorded maximum leaf length. In both the cowpea genotypes, minimum leaf length was recorded in treatment Paclobutrazol @ 200 ppm irrespective of the number of days after germination. Gomathinnayakam *et al.* (2007*)* reported that inhibition of leaf area was more in triazole treated plants compared to non-treated control in tapioca seedlings. Tekalign and Hammes (2004) found that, Paclobutrazol application @ 90.0 mg active ingredient per plant reduced leaf length by 50 % than the control treatment in potato seedlings.

Chlorophyll and carotenoid are two plant pigments that absorb light energy during the process of photosynthesis in plants. There are two main chlorophyll (Chl) pigments in higher plants (Chl a and Chl b) and several hundred different carotenoids (Esteban *et*

*al.,* 2015) .Chlorophyll a and b contents were recorded highest in Paclobutrazol treatments in both the genotypes. These findings are in agreement with (Tsegaw *et al.,* (2005) who found that Paclobutrazol treated potato plants exhibited a dark green color due to higher amount of chlorophyll a and b contents .The increase in chlorophyll content was attributed to an enhanced chlorophyll synthesis or more densely packed chloroplasts per unit leaf area.

Significantly higher chlorophyll and carotenoid contents were recorded in the treatments receiving Paclobutrazol @ 100 ppm but on par with Paclobutrazol @ 200 ppm .The dark green color of leaves of Paclobutrazol treated seedlings increased due to higher total chlorophyll content and more dense photosynthetic pigments. (Soumiya, 2017).

Paclobutrazol is a cell elongation and internode extension inhibitor that retards plant growth by inhibition of gibberellins biosynthesis which in turn results in compact and short sturdy seedlings (Desta and Amare, 2021) .In both the genotypes, minimum gibberellic acid content and auxin contents were recorded in Paclobutrazol @ 200 ppm. Aly and Latif (2011) reported that Paclobutrazol treatment lowered gibberellic acid and auxin contents in wheat seedlings. In almond seedlings free IAA content decreased when treated with Paclobutrazol. This could be indirectly due to the endogenous gibberellin reduction caused by Paclobutrazol since it is known that gibberellin inhibits auxin biosynthesis and inhibits the action of IAA oxidase (Koukourikou., 1996) Paclobutrazol was found to restrict gibberellin biosynthesis in plants by inhibiting the activity of ent-kaurene oxidses and cytochrome p - 40 oxidase thus restricting the oxidation of ent – Kaurene to ent – kaurenoic acid (Dalziel and Lawrence, (1984).

### 5.2.2. Morphological Observations in the field

In case of plant height significant variation could be observed due to the application of plant growth retardants. In both the cowpea genotypes, plant growth regulator Ethrel recorded maximum plant height where as in Vellayani Jyothika minimum plant height was recorded in the treatments receiving Cycocel @ 50 ppm .In Kashi Kanchan lowest plant height was recorded in the treatment Paclobutrazol @ 200 ppm Triazole compounds *viz* Cycocel and Paclobutrazol has strong antigibberellin activity resulting in decreased plant height in the both the genotypes. The reduction in plant height was

greater at higher concentrations of Paclobutrazol. Plants treated with Paclobutrazol solutions of 10 or 20 µg ml-$^{1}$ 'decreased plant height in *Brassica carinata*. The plants exhibited lower stem extension and shortened lower internodes which were thicker. The inhibition of stem height with Paclobutrazol is consistent with the reported mode of action of this chemical as a suppressor of gibberellin acid biosynthesis (Setia *et al*., 1995). Similar results were reported by Dani *et al.* (2010) in marigold and Jagdale *et al* . (2017) in chrysanthemum.

In Vellayani Jyothika highest intermodal length was recorded in Ethrel @ 100 ppm and Ethrel @ 50 ppm and minimum was recorded in Paclobutrazol @ 200 ppm. In the genotype Kashi Kanchan maximum intermodal length was recorded in Ethrel @ 200 ppm and minimum was recorded in Cycocel @ 100 ppm. The antigibberellic effect of Cycocel which reduces the nodes and intermodal length due to the inhibition of IAA synthesis which ultimately resulted in the suppression of apical growth of the plant.

More number of primary branches was recorded in treatments receiving Paclobutrazol @ 100 ppm and Paclobutrazol @ 200 ppm compared to control. In Kashi Kanchan there were no significant differences found between the treatments in the number of primary branches. These findings was agreement with the study conducted by Sahu *et al*., (2021) where it was found that in Marigold. Paclobutrazol @ 90 ppm produced significantly higher number of primary branches than the control. More number of primary branches may be due to the suppression of apical dominance which promotes growth of axillary buds into new shoots.

In both the cowpea genotypes maximum chlorophyll a, b and total chlorophyll content and carotenoid contents were recorded in treatments receiving Paclobutrazol @ 200 ppm but on par with Paclobutrazol @ 100 ppm. This findings are in conformity with Kumar *et al*., (2012) who reported that chlorophyll content was higher in plants treated with Paclobutrazol compared to control. Higher chlorophyll content resulted in darker green leaves which were assumed to be photo synthetically active for a longer period and facilitated higher photo assimilation and better photosynthetic leaf exchange characteristics, which facilitate more number of flowers and inturn more number of pods per plant.

Highest stomatal frequency and stomatal index was recorded in treatments receiving growth regulator Paclobutrazol @ 200 ppm in both the cowpea genotypes. Paclobutrazol application reduced leaf size and water loss which subsequently demands for an increase in conduits for gas exchange as reflected higher stomatal index and frequency (Yim *et al.,*1997) .Similar results have been reported by (Tari., 2003) in beans .This in turns have a positive effect on photosynthetic capacity there by leading to higher pod yield in Paclobutrazol treated plants

Growth retardants had significant effect on the days to first flowering, days to first harvest and crop duration. Early flowering results in early harvesting of pods. In both the genotypes, Cycocel treatments recorded earliest flowering in the field, as has been reported by Kumar *et al*., (2019) in case of Cycocel @ 2500 ppm early flowering was induced in nerium. The early flowering due to the application of plant growth retardants may be due to higher accumulation of food reserves in initial stages of growth in treated plants. The reserve foods could have been utilized for the reproductive growth with a restriction in vegetative growth which was evident in the plants treated with Cycocel. Murali and Gowda (1988) also reported that Cycocel treated jasmine plants came to flowering earlier because of the anti-gibberellin activity of the triazole compound.

In both the genotypes delayed flowering and maximum crop duration was recorded in Paclobutrazol treatments. Application of Paclobutrazol resulted in production of more number of lateral branches. Number of flowers per plant is related to number of lateral branches. Production of more number of branches in Paclobutrazol treated plants resulted in increased number of flowers. One of the most important effects of Paclobutrazol is suppression of senescence in the plant tissue by decreasing ethylene production resulting in an increase in crop duration These results were in accordance with the studies of Kumar *et al* ., (2015) in China Aster and Suradinata *et al.,* (2013) in Begonia .

Pod length and pod girth are directly related to the pod weight. In both the genotypes significantly higher pod length and pod girth were recorded in high yielding treatments such as Paclobutrazol treatments followed by Ethrel treatments compared to control treatment.

Arora *et al.* (1987) reported that application of Ethrel increased cell division and cell enlargement resulting in increased fruit length and fruit girth in ridge gourd.

In both the genotypes significantly higher yield was recorded in Ethrel treatments followed by Paclobutrazol treatment. Significantly lower yield was recorded in both the genotypes in control treatment. In both the cowpea genotypes Ethrel @ 100 ppm recorded highest pod yield per plant which may be due to the highest number of nodes per plant, which consequently resulted in more number of flowers and pods per plant. In both the genotypes Ethrel @ 200 ppm recorded lowest pod yield which may be due to the inhibitory effect of higher dosage of growth retardant Abbas, (1991) found that ethylene hormone released from Ethrel reduced the levels of abscission of flowers, pod shedding and increased the translocations of sugars to the point of auxiliary buds which resulted in highest number of pods and consequently increased yield per plant in chick pea. Adkine *et al*. (2011) found that in soybean plants Ethrel treatment reduced excessive vegetative growth resulting from diversion of the metabolites towards the reproductive growth there by stimulating flowering and increased fruiting of plants which in turn resulted in higher pod yield per plant and reduced premature abscission of flowers . Ethrel application at low and medium concentrations at pre-flowering and mid flowering stages was useful in eliminating flower abscission in chickpea (Saxeena *et al.,* 2007). Similar results has been reported by Khan *et al*., (2000) in mustard.

In bush type variety Kashi Kanchan Paclobutrazol treatment @ 100 ppm recorded highest pod yield but was on par with Ethrel@ 100 ppm. In the trailing type cowpea variety Vellayani Jyothika highest yield was recorded in Paclobutrazol treatments @ 50 and 100 ppm compared to control treatment. Ethrel treatment recorded higher yield although it was not effective on controlling seedling height. On the other hand the sturdiness of the seedlings obtained by Paclobutrazol treatment was coupled with higher yields in the field. Hence seed treatment with growth retardant Paclobutrazol @ 100 ppm can be effective to obtain short and compact seedlings with higher yield in vegetable cowpea.

Triazole compounds lowers the levels of ethylene in the plants by inhibiting the conversion of aminocyclopropane -1- carboxylate to ethylene which in turn reduces abscission of flowers and there by increased the fruit set and number of fruits and yield

in cucumber (Abbas *et al*., 1989).They also increase $CO_2$ fixation and carbon allocation to reproductive sinks which resulted in higher yield (Fletcher and Hofstra, 1974)

There were no significant differences in seed weight in both the cowpea genotypes due to growth regulator treatments. Iqbal *et al*., (2020) reported that Paclobutrazol treatment 80 ppm did not affect the seed weight of okra plants.

In both the genotypes highest relative growth rate was recorded in Ethrel 100 ppm followed by Paclobutrazol 100 ppm. Ethylene is a multifunctional hormone which regulates growth and senescence depending upon the concentration time of application and plant species. (Iqbal *et al.,* 2017) .The action of ethylene on growth may be auxin-dependent. Auxin biosynthesis is increased by ethrel application which leads to cell elongation and cell division in plants. Higher concentration of Ethrel 200 ppm reduced relative growth rate. Similar results have been reported by Grewal *et al.,* 1993 in *Brassica napus* they reported that higher doses of Ethrel showed determinantal effect.

In the present study Ethrel 100 ppm treatment recorded higher yield in both the cowpea genotypes although it was not effective on controlling seedling height. Paclobutrazol treatment 100 ppm treatment was effective in obtaining higher yield in the field and to control seedling height in the nursery.

# *SUMMARY*

# 6. SUMMARY

The present study was carried out at the Centre for Hi-Tech Horticulture and Precision farming, Vellanikkara KAU, Thrissur during the year 2020-2021 with the objective to evaluate the role of plant growth regulators in controlling seedling height of vegetable cowpea and to assess the field performance of the treated seedlings of cowpea varieties of Vellayani Jyothika and Kashi Kanchan. Seedling evaluation was done in completely randomized design in a polyhouse and growth retardant treated transplants were raised in randomized block design with three replications in field evaluation. The salient findings of the study are summarized below.

Two cowpea varieties *viz* Vellayani Jyothika and Kashi Kanchan were subjected to, thirteen treatments comprising of three growth regulators namely Paclobutrazol, Cycocel and Ethrel at four doses of (25 , 50 100 and 200 ppm) and an untreated control. Seedling vigour characters and physiological parameters *viz* total chlorophyll, auxin and gibberellic acid content were recorded at seedling stage in a naturally ventilated polyhouse and morphological characters like plant height, intermodal length, days to flowering, pod yield etc of cowpea were recorded in the field.

Significantly lower germination percentage was recorded in Paclobutrazol treatments compared to other treated seedlings and control in both the genotypes. The treatment receiving Paclobutrazol @ 200 ppm recorded significantly higher germination percentage in both the genotypes irrespective of the number of days after germination. On 15$^{th}$ day after germination there were no new germinated seedling recorded on both the genotypes.

Significantly lower shoot length was recorded in treatments Paclobutrazol 200 ppm .The reduction of shoot length is associated with inhibition of gibberellin biosynthesis of triazole compound Paclobutrazol .Growth retardants in general reduced root growth, shoot weight and root weight of the seedlings. In both the genotypes (Vellayani Jyothika and Kashi Kanchan) significantly lower root length, shoot weight and root weight was obtained in Paclobutrazol treatments compared to other treatments and non-treated control. Girth of the seedlings was highest in Paclobutrazol 200 ppm in both the cowpea genotypes. There were no significant difference found in the number of leaves on 5$^{th}$ and 15$^{th}$ day after germination in Vellayani Jyothika and Kashi Kanchan. There

were no significant difference in the number of primary branches on 15th day after germination in both the genotypes. Paclobutrazol treated seedlings had dark green color compared to control and other growth retardant treatments.

Total chlorophyll content was the highest in treatments receiving Paclobutrazol @ 200 ppm in both the genotypes. Carotenoid content was highest in treatments received Paclobutrazol @100 ppm and Paclobutrazol @ 200 ppm in both the genotypes.

Minimum IAA content was recorded in Paclobutrazol 200 ppm (0.126 mg) and Paclobutrazol 100 ppm (0.123 mg) in Vellayani Jyothika .Minimum IAA content was recorded in treatments receiving Paclobutrazol 200 ppm (0.077 mg) in Kashi Kanchan.

Paclobutrazol treatments significantly lowered the gibberellic acid contents in the plants which resulted in increased intermodal elongation short sturdy and compact plants. Minimum content of gibberellic acid contents recorded in treatments receiving Paclobutrazol 200 ppm (0.819 ng) and (0.730 ng) respectively in both the genotypes.

Minimum plant height was recorded in Cycocel @ 50 ppm in Vellayani Jyothika (112.40cm) where as in the Kashi Kanchan lowest plant height was recorded in treatments receiving Paclobutrazol @ 200 ppm (28.31 cm).

Lowest intermodal length was recorded in treatments receiving Paclobutrazol 200 ppm (2.63 cm) in Vellayani Jyothika where as in the Kashi Kanchan minimum intermodal length was recorded in Cycocel 100 ppm (2. 53) in Kashi Kanchan.

There were no significant differences between the treatments for the number of primary branches in Kashi Kanchan. The number of primary branches was the highest in treatments receiving Paclobutrazol @ 200 ppm and Paclobutrazol @ 100 ppm in the genotype Vellayani Jyothika.

In both the genotypes, total chlorophyll content was significantly higher in treatments that receiving Paclobutrazol @ 200 ppm (2.14 mg) and (2.06 mg) respectively.

The highest carotenoid contents was recorded in treatments receiving Paclobutrazol @ 200 ppm in both the genotypes (0.598 mg) and (0.675 mg) respectively.

Significantly higher stomatal frequency was recorded in Paclobutrazol treatments receiving in Vellayani Jyothika. The stomatal frequency was the highest in treatments receiving Paclobutrazol treatments in the Kashi Kanchan.

Significantly higher stomatal index was recorded in treatments receiving Paclobutrazol @ 200 ppm in both the genotypes. In Kashi Kanchan Cycocel 200 ppm treatment also recorded significantly higher stomatal index

Growth retardants had significant effect on days to first flower opening, days to first harvest and crop duration in vegetable cowpea. Early flowering results in early harvesting of pods. The treatment Cycocel @ 200 ppm was earliest to flower and took minimum number of days to first harvest in Vellayani Jyothika. In Kashi Kanchan Cycocel @ 25 ppm recorded minimum number of days to first flowering and first harvest.

The longest crop duration in the field was recorded in treatments receiving Paclobutrazol 100 ppm and 50 ppm in both the genotypes. Significantly higher pod length was recorded in treatments receiving Ethrel @ 100 ppm in both the genotypes. Pod weight was recorded highest in treatments receiving Paclobutrazol @ 200 ppm but on par with Ethrel @ 50 ppm and Ethrel @ 100 ppm in Vellayani Jyothika where as in Kashi Kanchan highest pod weight was recorded in Ethrel @ 100 ppm.

In Vellayani Jyothika number of pods per plant was the highest in Ethrel @ 100 ppm (64.33) which was on par with Ethrel 50 ppm (57.01). Lowest number of pods was recorded in control treatment (30.15).

In Kashi Kanchan, number of pods was the highest in treatments that receiving Paclobutrazol 100 ppm (161.86) and Ethrel 100 ppm (162.26) .Minimum number of pods was recorded in control treatment (126.20).

Significantly higher pod yield per plant was recorded in Ethrel @ 100 ppm (1273 g) followed by Ethrel 25 ppm (1056 .46 g) in Vellayani Jyothika .Minimum yield per plant was recorded in control treatment (553 .33 g) .Significantly higher pod yield per plant was recorded in treatments receiving Ethrel @ 100 ppm (1760 g) but on par with Paclobutrazol @ 100 ppm (1759 g) in Kashi Kanchan followed by Paclobutrazol 50 ppm (1549 g). Minimum yield per plant was recorded in control treatment (1042.51g)

There were no significant difference between the treatments for hundred seed weight in both the genotypes.

In both the genotypes highest relative growth was recorded in treatments receiving Ethrel 100 ppm and Paclobutrazol 100 ppm on 0-15$^{th}$, 15-30 $^{th}$, 30-45 $^{th}$, and 45-65 $^{th}$ stages.

In general, Ethrel treatments recorded higher yield although it was not effective in controlling seedling height. Paclobutrazol treatment was effective in obtaining higher yields in the field conditions and also to control seedling height of vegetable cowpea .Hence Paclobutrazol @ 100 ppm can be recommended for controlling seedling height and to obtain higher yield in vegetable cowpea.

**Table no 23- Impact of best PGR treatment- Comparison among indeterminate and determinate types**

| **Observations** | **Best treatments** | |
|---|---|---|
| **Seedling evaluation** | Vellayani Jyothika (Indeterminate) | Kashi Kanchan (Determinate) |
| Shoot length | PBZ 200 ppm | PBZ 200 / PBZ 100 ppm |
| Root length | PBZ 200 ppm | PBZ 200/ PBZ 100 ppm |
| Total seedling length | PBZ 200 ppm | PBZ 200 / PBZ 100 ppm |
| **Field evaluation** | | |
| Days to first flowering | CC 200 ppm | CC 25 ppm |
| Days to first harvest | CC 200 ppm | CC 25 ppm |
| Days to last harvest | PBZ 100 /PBZ 50 ppm | PBZ 100/ PBZ 50 ppm |
| Number of pods | ET 100 ppm / ET 50 ppm | ET 100 ppm/ PBZ 100 ppm |
| Pod yield per plant | ET 100 ppm | ET 100 ppm /PBZ 100 ppm |

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# REFERENCES


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# Controlling seedling height of cowpea (*Vigna unguiculata* ( L.) Walp.) transplants using plant growth regulators

**By**

**Anu Latha Robi**

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ABSTRACT OF THE THESIS

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**VELLANIKKARA, THRISSUR -680656**

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**Abstract**

Cowpea (*Vigna unguiculata* (L.) Walp) is an annual leguminous vegetable crop. It is grown throughout india for its tender green pods used as vegetable. Green cowpea seeds are boiled as a fresh vegetable or may be canned or frozen. The beans are nutritious and provide complementary proteins to cereals diets.

Seedlings like cowpea, cucurbits having lanky growth growing in polyhouses is an undesirable quality, especially in plugs intended for mechanized planting and long distance transport. Seed treatment with growth retardants is an effective method for controlling seedling height .However limited studies have been conducted in vegetable crops

The present study was undertaken with the objectives of controlling seedling height of vegetable cowpea and to assess the field performance of treated seedlings. The experiment was conducted at the Centre for Hi-Tech Horticulture and Precision farming, Vellanikkara KAU, Thrissur during the year 2020-2021

In seedling stage, highest germination was recorded in control treatment on 5$^{th}$ and 10$^{th}$ days after sowing (89%) and (91%) respectively in Vellayani Jyothika. Minimum germination percentage was recorded in Paclobutrazol @ 200 ppm on 5$^{th}$ and 10$^{th}$ day after sowing (64.3%) and (66.0%) respectively in cowpea genotype Vellayani Jyothika. Significantly lower germination percentage was recorded in treatments receiving Paclobutrazol @ 200 ppm on 5$^{th}$ and 10$^{th}$ day after sowing (70.0%) (72%) in the genotype Kashi Kanchan. In both the genotypes there were no significant difference between the treatments on 15$^{th}$ days after sowing. Paclobutrazol treatment took more number of days for emergence of seedling up to the first node compared to control treatment ie Paclobutrazol @ 200 ppm (8.13) and (8.00) respectively in both the genotypes.

Highest shoot length was recorded in control treatment on 5$^{th}$, 10$^{th}$ and 15 $^{th}$ days after germination in both the genotypes. Significantly lower shoot length was recorded in treatments receiving Paclobutrazol @ 200 ppm irrespective of the number of days after germination. Growth retardants in general reduce root growth, shoot weight and root weight of the seedlings. In both the genotypes (Vellayani Jyothika and Kashi Kanchan) significantly lower root length, shoot weight and root weight was obtained in Paclobutrazol treatments compared to non-treated control. Height of seedling up to the

first node was directly linked to shoot length. In both the genotypes of the cowpea significantly lower shoot length was recorded in treatments receiving Paclobutrazol @ 200 ppm (4.09) and (4.03) respectively. Paclobutrazol treated seedlings had dark green leaves when compared to other growth regulator and control treatments on $5^{th}$ ,$10^{th}$ and $15^{th}$ days after germination. In both the cowpea genotypes, when compared to other growth retardant and control treatments highest stem girth of the seedlings was recorded in treatments receiving Paclobutrazol @ 200 ppm on $5^{th}$ (3.19 mm) $10^{th}$ (3.45mm) and $15^{th}$ (3.7mm) in Vellayani Jyothika and on $5^{th}$ (3.3mm ) $10^{th}$ (3.4mm) and $15^{th}$ (3.8mm) in Kashi Kanchan. There were no significant difference between the treatments on $5^{th}$ (2) and $15^{th}$ days (7-8) after germination in both the genotypes. The total chlorophyll content and carotenoid content was recorded highest in treatments receiving Paclobutrazol treatments on seedling stage. Minimum auxin content and gibberellic acid contents were observed in Paclobutrazol treatments.

In the field experiment, in both the cowpea genotypes, plant growth regulator Ethrel recorded maximum plant height where as in Vellayani Jyothika minimum plant height was recorded in Cycocel@ 50 ppm (112.40 cm) .In Kashi Kanchan lowest plant height was recorded in Paclobutrazol @ 200 ppm (33.06 cm) in Kashi Kanchan. In vellayani Jyothika highest internodal length was recorded in Ethrel @100 ppm (3.13 cm) and Ethrel @50 ppm (3.04 cm). Minimum was recorded in Paclobutrazol@ 200 ppm (2.63 cm). In the genotype Kashi Kanchan maximum internodal length was recorded in Ethrel@ 200 ppm (3.34 cm) and minimum was recorded in Cycocel @ 100 ppm (2.53cm). Highest number of primary branches was recorded in treatments receiving Paclobutrazol @ 200 ppm which was on par with Paclobutrazol @ 100 ppm compared to control in Vellayani Jyothika. In Kashi Kanchan there were no significant differences found between the treatments. Growth retardants had significant effect on the *viz* days to first flowering, days to first harvest and crop duration. Early flowering results in early harvesting of pods. Plant growth retardant Cycocel @ 200 ppm (41day) and Cycocel @ 25 ppm (36.80 days) recorded earliest flowering in the field in both the genotypes. In both the genotypes delayed flowering and maximum crop duration was recorded in Paclobutrazol treatments. Pod length and pod girth are related with pod weight. Ethrel treatment had highest pod length and pod girth compared to control .The higher number of flowers, pod girth and pod length contributed to production of more number of pods which in turn resulted in higher yield per plant. In both the cowpea

genotypes, highest number of pods per plant and yield per plant was recorded in Ethrel treatments (Ethrel 100 ppm) in Vellayani Jyothika followed by Paclobutrazol treatment (Paclobutrazol 100 ppm) where as in Kashi Kanchan Paclobutrazol 100 ppm was on par with Ethrel 100 ppm. From the above study it could be concluded that, Paclobutrazol 100 ppm seed treatment was effective in controlling seedling height as well to obtain good yield in vegetable cowpea.