

Effect of growth regulator on Growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.):cv. Utkal Gaurav.

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Orissa University of Agriculture and Technology
in Partial fulfillment of the Requirement for the degree of
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(Vegetable Science)*

By

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CERTIFICATE-I

This is to certify that the thesis entitled “**Effect of growth regulator on Growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.);cv. Utkal Gaurav.**” submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **Kanhaiyalal Sanodiya** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled “**Effect of growth regulator on Growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.);cv. Utkal Gaurav.**” submitted by **Kanhaiyalal Sanodiya** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** has been approved by the students’ advisory committee and external examiner.

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ABSTRACT

The present investigation entitled, "Effect of growth regulator on growth, yield and seed quality parameters of okra (*Abelmoschus esculentus*L.):cv. Utkal Gaurav." Was carried out at Central Farm, Breeder Seed Production Unit, College of Agriculture, Bhubaneswar, Odisha, during *Kharif*, season of 2015-2016. The objective was to study the effect of different growth regulator on the foliar spray and seed treatment in respect of growth, yield and quality parameters.

The field experiment consisted of foliar spray of three replication, nine treatments and seed treatment three replication, ten treatments along with control. The different growth regulator used in the experiment (GA_3 @ 50ppm and NAA @ 50 ppm) combination (GA_3 + NAA and NAA + GA_3) and foliar spray at 20, 40 and 60 days after sowing and seed treatment of GA_3 (25 and 50 ppm), NAA (25 and 50 ppm), IBA (25 and 50 ppm) Triacantanol (5 and 10 ppm) water soaked and dry seed control. The experiment was laid out in RBD with three replication in a plot of 2.5m x 2 m with spacing of 45cm x 30cm.

The result revealed foliar spray is significantly positive impact on growth regulator in growth parameters i.e. T_4 (NAA 50 @ppm at 20days spray) was first flowering (31.47 days), 50 per cent flowering (40.40 days), first harvesting (37.02 days), minimum days to fruit maturity (66.02 days), yield parameter T_5 (NAA 50 ppm at 40 days spray) fruit weight (16.47 gm.), dry fruit weight (5.61 gm.), fruit length (16.58 cm), fruit girth (6.46 cm), number of fruit per plant (13.46), fruit yield per plot (4.83 kg), yield per hectare (96.63 q/ha.) and seedling parameter test weight was maximum (8.03 gm.). High germination per cent was recorded in T_1 (GA_3 50 ppm at 20 days spray).

The result revealed seed treatment T_3 (NAA 50 @ppm) was maximum stem girth (5.83cm), first flowering (34.31 days), 50 per cent flowering (44.49 days), first harvesting (40.83 days), minimum days to fruit maturity (69.82 days), high chlorophyll index (21.75), yield parameter such as fruit weight (15.09 gm.), dry fruit weight (4.96 gm.), fruit length (15.32 cm), fruit girth (6.37 cm), number of fruit per plant (14.10), fruit yield per plot (4.48 kg), yield per hectare (89.21 q/ha.). Seedling parameter was maximum significantly was observed in test weight (7.84 gm.) and vigour index- I (2368.23). In early germination, 50 per cent and 100 per cent was recorded in GA_3 treated seeds.

Hence, it may be concluded that application of growth regulator for profitable okra crop. The result indicated that foliar spray of NAA 50 ppm at 40 days with maximum benefit cost ratio (2.96) and seed treatment with NAA 50 ppm not only increased the seedling parameters but also increase the vegetative growth and yield with benefit cost ratio (2.79).

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ABBREVIATIONS USED

%	:	Per cent
/	:	Per
@	:	At the rate
C.D.	:	Critical Difference
Cm	:	Centimeter
DAS	:	Days after sowing
d.f.	:	Degree of freedom
ESS	:	Error sum of square
<i>et al.</i>	:	<i>(et albeit)</i> and elsewhere
PCV	:	Phenotypic co-efficient of variation
GCV	:	Genotypic co-efficient of variation
h^2	:	Heritability in broad sense
GA	:	Genetic advance
GAM	:	Genetic advance over per cent mean
etc.	:	Etcetera
g	:	Gram
ha	:	Hectare
Hrs.	:	Hours
i.e.	:	<i>(Id est.)</i> that is
Kg	:	Kilogram
M	:	Meter
m^2	:	Square meter
Max.	:	Maximum
Min.	:	Minimum
mm	:	Millimeter
MSS	:	Mean sum of square
No.	:	Number
R.H.	:	Relative humidity
RSS	:	Replication sum of square
Tss	:	Treatment sum of square
<i>Viz.</i>	:	<i>(Videlicet)</i> Namely
°C	:	Degree Celsius
dSM^{-1}	:	deci simon per

INTRODUCTION

Okra, lady's finger (*Abelmoschus esculentus* L.), $2n = 2x = 130$ is one of the major vegetable crops of the tropical and subtropical parts of the world. It belongs to the family Malvaceae. It has originated from Tropical Africa and widely grown in tropical and subtropical parts of the world. Okra is an annual herbaceous vegetable crop that is grown for its tender fruits often consumed as vegetable. The plant is a robust, erect, annual herb, ranging 1-2 m in height, with simple leaves, which are alternate and palmately veined. It is often cross-pollinated where the natural cross pollination occurs from 8.75 – 9.61%.

Okra pod contains many nutritional contents which are important for human health. Fresh okra fruit contains 2.1 g protein, 0.2 g fat, 8 g carbohydrate, 36 calories, 1.7 g fiber, 175.2 mg and 88 ml of water per 100 g of edible portion (Tindal, 1983; Berry *et al*, 1988). It is an excellent source of iodine besides other minerals and vitamins.

India had the credibility of producing 162.89 million tons of vegetables in 2013-14 (NHB, 2013-14), being the second among the vegetable producing country in the world. In India, okra cover an area of 533 thousand hectares with productivity of 11.9 MT/ha Production of 6346 MT (NHB, 2013-14).

Okra is an important vegetable crop having good demand throughout the year for its tender fruits. In recent years, scientists have paid due attention to the idea of regulating the plant growth as third most important factor, in improving the growth, yield and quality, with the application of plant growth regulators in various ways.

Growth and yield of okra depend upon various factors including seed quality, nutrition, climatic conditions and cultural practices but chemical substances like plant growth regulators can bring changes in the phenotypes of plants and affect growth, either by enhancing or by stimulating the natural growth regulatory systems from seed germination to senescence (Das and Das, 1995).

Plant growth regulators are the organic substances which are produced naturally in plants, synthesized in one part and usually translocated to other part where every small quantity influence the growth and other physiological function of the plants.

Plant growth regulators are considered as new generation of agro chemicals after fertilizers, insecticides and herbicides. The use of plant growth regulators has led to intensive scientific activity for their commercial exploitation. Since, 1949 several valuable effects of different plant growth regulators have been studied on a number of horticultural crops (Khan *et al.*, 2006).

Although, plant growth regulators have great potential for growth improvement, but their application has to be planned sensibly in terms of optimal concentration, stage of application, species specificity and seasons. Similarly, those are inorganic substances necessary for the normal growth and development of plants and have important role in various enzymatic processes, assimilation, oxidation and reduction reactions and help in increasing the biomass and pod yield.

Okra is a heavy yielder and high remunerative crop but sometimes grower suffer with recurring economic loss due to poor plant vigour, low pod setting and small pod size. Therefore, besides varieties evaluation, standardization of location specific approach is essential to improve productivity of okra. Growth regulator is considered to be a key factor in vegetative growth, flowering, pod setting and high yield in okra (Singh *et. al.* 2012).

The growth regulators and their uses are considered to be the most technical and scientific in crop production. The selection of right hormones, their appropriate concentration and their time and method of application are most essential. Even the same growth regulator in different concentrations brings about the different results. Due to high rise in the prices of chemical fertilizers and also to maintain the eco-system of soil, it has become necessary to use eco-friendly chemicals like GA₃, NAA and IBA.

Foliar spray and seed treatment with plant growth regulator are among one of the most popular methods and have been claimed as effective tools by many workers for improving rate and amount of germination, vigorous vegetative growth, early flowering, fruiting and high yield.

Various aspects of methodology for okra production *viz.*, seed treatment, time and method of sowing, nutritional management, culture practices and stage of harvest were widely studied. But the research on the effect of growth regulators on growth, yield and seedling parameter is limited, with this background, present study entitled “Effect of growth regulator on Growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.) cv. Utkal Gaurav” has been undertaken with following

Objectives.

- I. Response of okra (cv. Utkal Gaurav) to different growth regulators (GA₃, NAA, IBA, Tricentanol) as seed treatment in respect of growth, yield and quality parameters.
- II. Response of okra (cv. Utkal Gaurav) to different growth regulators (GA₃, NAA, & their combination) as foliar spray in respect of growth, yield and quality parameters.
- III. Effect of growth regulators on seed quality parameters.

REVIEW OF LITERATURE

In various physiological and biochemical process in plant, the role of plant growth regulators is well known. The plant growth regulators are known to effect right from seed germination to senescence either by enhancing growth or by reducing the plant height, flowering, fruit development, fruit ripening and seed yield. Various production factors are known to influence growth, yield, and seed quality parameter in okra.

Hence, the reviews on these aspects on related and other crops have also been included along with the reviews on okra.

2.1 Effect of Gibberellic acid (GA₃)

The Gibberellic acid (GA₃) is widely used phytohormone in horticulture and food industry. Gibberellins enhance biological activity in stimulating cell division or cell elongation, early flowering, fruit set, fruit growth, and seed germination etc. today 72 forms of gibberellins are known and commercially available gibberellins are GA₃, GA₄, GA₇ (Taiz, 2010).

2.1.1 Effect of Gibberellic acid (GA₃) on growth parameters

Hilli *et al.* (2010) reported the spraying of GA₃ @ 50 ppm at four leaves stage, flower stage and fruit initiation stage significantly improved the vine length and Maximum vine length and number of branches recorded in ridge gourd.

Bhagure and Tambe (2011) observed application of GA₃ (50 and 100 ppm) at 30 and 45 days after sowing increase the height of plant, number of leaves, number of internodes, induce early flowering, increase number of flowers, fruit set, number of fruits, and high yield per plant in okra.

According to Sure *et al.* (2012) spraying with GA₃ at 25 ppm in four leaf stage at trellis method could be a suitable for enhancing growth and yield in medicinal pumpkin.

The Application of 160 ppm GA₃ resulted in minimum number of days of first flowering (37.13) and days to 50% flowering (41.33) in okra (Singh *et al.*, 2012).

According to Kumar *et al.* (2014) study that gibberellic acid plants treated with the application of GA₃ @ 50 ppm showed an increased plant height, number of leaves, number of fruits, fruit weight, ascorbic acid and total soluble solids in tomato.

According to Thomson *et al.* (2015) effect of plant growth substances on growth, flowering, yield and economics of garden pea, (*Pisum sativum*) L cv. Bonneville. Plants were sprayed with treatments *viz* control, NAA at (25 and 50 ppm), GA₃ at (50 and 100 ppm), the results revealed that the plant growth substance GA₃ at (100 ppm) showed highest growth parameters. Days to first flowering ranged between 48.97 and 52.75. The minimum days (48.97) to first flowering were taken by the treatment GA₃ at (100 ppm) and all other treatments were *statistically at par* for the days taken to first flowering.

In okra reported that increased plant height (89.0 cm), longest petiole (29.0 cm), number of leaves (49.0/plant), leaf area (29.7 cm), and number of branches (5.5/plant) was due to foliar spray of GA₃ 50 ppm (Mehraj *et al.*, 2015).

According to Bello. (2015) revealed that the okra seeds were pre-soaked GA₃ at (100 ppm) for 3-4 hours observed that increase the plant height, number of leaves, leaf Area and dry matter (yield) in okra.

Ravat and Makani (2015) concluded that application of GA₃ @ 100 ppm at different growth stages increased plant height, number of leaves, number of internodes per plant, days to flower initiation, days to 50 % flowering in okra.

According to Rathod *et al.* (2015) reported that the maximum plant height (34.53 cm), plant spread (31.46 cm), number of leaves per plant (15.73) and number of branches per plant (7.66) in treatment where GA₃ at 200 ppm was applied, while minimum plant height (25.93 cm), plant spread (24.70 cm), number of leaves per plant (11.66) and number of branches per plant (5.20) respectively observed in the treatment in Cycocel 200 ppm, in French bean.

According to Njogu *et al.* (2015) reported that foliar application of GA₃ causes significant increase in subsequent germination, enhances vegetative growth, average number of stems, leaflets number and more yields in potato.

2.1.2 Effect of Gibberellic acid (GA₃) on yield parameters

According to Sharma (2006) reported in Brinjal cultivar of Pusa Purple Long produced significantly higher yield at 40 ppm NAA than at GA₃ at 10 ppm and 30 ppm BAP while, the yields at other treatments were at par.

Patil and Patel (2010) observed an okra seed highest percentage of seed germination, number of branches, early flowering, fruit length, fruit weight, fruit yield per plant and fruit yield per hectare. Treatments comprised with GA₃ at 15mg/lit soaking of seeds in distilled water and control (unsoaked seeds).

In okra, it was noticed that significantly minimum number of days required for first flowering (39.67 days) and first harvesting (44.67 days) were recorded in treatment GA₃ at 150 ppm by (Dhage *et al.*, 2011).

Choudhury *et al.*(2013) observed that maximum plant height at 60 DAT (86.01cm), number of flowers cluster per plant (10.60), number of flowers per plant (39.69), number of fruits per plant (36.54), single fruit weight (74.01 g) and yield (28.40 t/ha) were found the minimum for all the parameters in tomato were found in control.

Chowdhury *et al.* (2014) noticed the application of GA₃ (100 ppm) in okra different days of sowing increasing the yield (16.67 t/ha) as compared to control.

According to Prajapati and Varma (2014) reported that application of GA₃ at 50 ppm to the maximum number of branches (5.52) and minimum days taken for initiation of flower (48.50 day) in sweet pepper.

Chandiniraj *et al.*(2016) reported that maximum plant height (75.60 cm), plant spread in north-south direction (46.53 cm), number of days to flowering (47.56) and maximum fruit diameter (1.24 cm) were recorded in GA₃ 60 ppm treated plants in chilli.

Krishnaveni *et al.* (2016) revealed maximum yield attributes like number of pods per plant, length of pod and seed yield per plant were recorded with single pinching at 25 DAS and application of GA₃ 50 ppm in fenugreek.

2.1.3 Effect of Gibberellic acid (GA₃) on seed quality parameters

Application of growth regulators at flowering stage increased the growth and seed yield of chilli. Among them, GA₃ at 100 ppm spray at flowering stage recorded higher fruit and seed yield followed by GA₃ at 50 ppm and NAA at 20 ppm, indicating their utility in enhancing seed production in chilli by (Natesh *et al.*, 2005).

Patil *et al.* (2008) concluded that length of dried pod, weight of seeds per pod, weight of 100 seeds the treatment GA₃ at 50 ppm showed significantly superior performance over remaining control treatment in okra.

Bhagure and Tambe (2011) noticed early germination, highest germination percentage with seed soaking of GA₃ at (50 ppm) compare to control treatment in okra.

Dhoran and Gudadhe (2012) concluded indicates that GA₃ at 50 ppm gave best response of germination rate Asparagus but as the concentration increased above 60 ppm the germination decreased rapidly and vigour index also decreased during light and dark period.

In okra recoded that GA₃ sprayed in early stage of plant growth (3-4 leaves) increase the number of seeds per pod in okra (Mohammadi *et al.*, 2014).

Ravat and Makani (2015) observed the increased growth and seed quality characters *viz.*, average pod weight (g), 100 seed weight (g), seedling dry weight (g) and seedling vigour index-II, while the plants sprayed GA₃ @ 50 ppm was the best result found in okra.

According to Krishnaveni *et al.* (2016) concluded that among the interactions of pinching and plant growth regulators (PGRs), the treatment combination of no pinching with application of GA₃ 50 ppm resulted in maximum test weight and seed yield.

2.2 Effect of Naphthalene Acetic Acid (NAA)

Naphthalene Acetic Acid (NAA) belongs to synthetic forms of Auxins. They play key role in cell elongation, cell division, vascular tissue, differentiation, root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting and flowering (Davies, 1987).

2.2.1 Effect of Naphthalene Acetic Acid (NAA) on growth parameters

Meena and Dhak (2003) reported higher plant height (42 cm) with NNA @ 25 ppm compared to 50 and 75 ppm in brinjal.

According to Gavaskar and Anburani (2004) recorded highest height (91.24 cm) and number of leaves (78.21) with foliar spray of NAA @ 25 ppm compared to NAA @ 50, & 75 ppm and control in brinjal cv. Annamalai.

According to Mohammed *et al.* (2005) Observed that plants sprayed with NAA @ 40 ppm gave more plant height (92.30 cm) when compared to control in chilli cv. K-2.

According to Bose *et al.* (2009) reported growth regulator NAA 50 ppm gave the highest plant height (61.63 cm), number of leaves 10.25), neck diameter (1.98 cm), fresh weight of bulb (78.71 g), bulb diameter (5.08 cm) as compared to NAA 30 ppm over control.

Mandal *et al.* (2012) revealed that maximum plant height and intermodal length with sprayed twice, first at 3-4 leaf stage and second after one month of the first spray NAA 75 ppm in okra.

Arvindkumar *et al.* (2012) reported in bitter gourd application of NAA at 50 ppm produced highest vine length (192.33 and 260.67 cm), leaf area (1.890 and 2.965 cm²/vine), leaf area index (1.969 and 2.760) and leaf chlorophyll content (39.23 and 38.90 SPAD value) at 85 and 100 days after sowing (DAS).

2.2.2 Effect of Naphthalene Acetic Acid (NAA) on yield parameters

Kore *et al.* (2003) observed highest fruit yield per plot (6.69 kg) and yield per hectare (92.90/q) when sprayed with NAA @ 25 ppm compared to NAA @ 50 ppm, and control in okra.

According to Gupta *et al.* (2003) observed higher fruit yield (57.78 t/ha) with NAA @ 75 ppm spray compared to NAA @ 25 ppm in tomato.

Meena and Dhaka (2003) observed higher fruit length (7.06 cm) and fruit yield (23.40 q/ha) with NAA @ 75 ppm foliar spray compared to control in brinjal.

Mohammed *et al.* (2005) observed fruit length (8.04 cm), girth (4.04 cm) and fruit yield (16605 kg/ha) when sprayed with NAA @ 40 ppm compared to control in chilli cv. K-2.

Kokare *et al.* (2006) observed that increase in number of leaves, number of fruits, fruit girth, fruit yield per plant, fruit yield (t/ha) with spray NAA 200 ppm in 30 and 45 days after sowing in okra.

According to Surendra *et al.* (2006) the foliar application of GA₃ (25 and 50ppm) at 60 days after sowing (DAS) registered significantly higher fresh fruit yield over other treatments. The increase is due to increase in yield attributing components *viz.*, total number of flowers, fruits per plant, fruit length, seed number per fruit, seed weight and harvest index in okra.

According to Gour *et al.* (2009) observed that foliar spray of naphthalene acetic acid (NAA) 20 ppm at 25 days after sowing (DAS) and 55 DAS resulted in significantly higher growth and seed yield (17.41 quintal per ha) of fenugreek. The highest benefit: cost ratio (4.20:1) was observed for the treatment, 60 kg phosphorus per ha + NAA 20 ppm.

In tomato recorded that application of NAA at 75 the maximum yield plant per plot (2.47kg) was recorded, treatment while the minimum yield plant per plot (1.23 kg) was recorded from control treatment by (Desai *et al.*, 2012).

Premchand *et al.* (2013) observed that interactions of 8 fruits retained plants sprayed with NAA @ 25 ppm recorded highest fruit length (25.32 cm), fruit width (6.24 cm) and number of seeds per fruit (61.66) in okra.

According to Chandiniraj *et al.* (2016) reported that different treatments maximum number of fruits per plant (94.83), fruit length (6.80 cm), yield per plot (2.72kg/3.2m²) and projected yield per hectare (6.37 t) were observed in plants raised from application of NAA 75 ppm in chilli.

2.2.3 Effect of Naphthalene Acetic Acid (NAA) on seed quality parameters

According to Sultana *et al.* (2006) evaluated the effects of seeds harvested from 10 ppm NAA treated plants showed highest germination percentage followed by 100 ppm Ethephon, Lowest germination percentage of seed was recorded in control. Seedling vigour was highest in 10 ppm NAA followed by 50 ppm NAA and 100 ppm Ethephon in chilli.

Patel *et al.*(2006) concluded that significant effect of growth regulators in chilli found the maximum seed yield per plant (8.30 g), seed yield per fruit (0.35 g), average fresh weight of fruits per plant (39 g) and average dry weight of fruits per plant (19.67 g) were obtained in 40 ppm NAA as against control.

Arvindkumar *et al.* (2012) found that spray of NAA at 50 ppm in bitter gourd (*Momordica charantia*) cv. Pusa Visesh highest seed germination (83.25 %), seedling vigour index – I (1757).

According to Premchand *et al.*(2013) found that interactions of 8 fruits retained plants sprayed with NAA @ 25 ppm recorded highest (29.80 cm, 19.16 cm) shoot, root lengths, seedling dry weight (24.0 mg), vigour index type-I & II (4833 and 2369), field emergence (93%).While lowest parameters were recorded with all fruits retained plants of okra sprayed with distilled water.

Khan *et al.* (2013). Noticed that application of NAA @ 100 ppm is effective in enhancing germination (94.67%) and also results in increasing seed yield (29.78 q/ha) as compared to control in okra.

2.3 Effect of Triacontanol

Triacontanol (TRIA) is a natural component of plant epicuticular waxes, and its potential growth promoting property was first identified by Ries *et al.* (1977). TRIA has been found to enhance the growth and yield of many important cereals, vegetables, horticultural, medicinal and oil crops. Growth promoting effects of TRIA are associated with increased protein content, water and element uptake and photosynthetic CO₂ uptake. Studies till now on triacontanol have concentrated on physiological aspects of crops leading to effects on components of yield.

2.3.1 Effect of Triacontanol on growth parameters

Sarada *et al.* (2008) reported higher plant height, more number of branches and more number of umbellets per umbel of coriander with Triacontanol @ 1.0ml/lit spray.

2.3.2 Effect of Triacontanol on yield parameters

Effect of Triacontanol at 1.0 ppm increasing growth, yield and quality parameter in tomato. According to this experiment, variety Hyb-SC-3 (C1) proved better quality by (Khan *et al.*, 2006).

According to Singh (2010) was observed in fenugreek Maximum plant height (80.47 cm), number of branches per plant (7.04), number of pods per plant (49.09), length of pod (10.82 cm), number of grains per pod (16.90) and yield (1.86 t/ha) was recorded by spraying Triacontanol @ 0.5 ml/l.

In okra it was found that application of Triacontanol @ 4000 ppm highest fruit length was recorded by (Rani *et al.*, 2013).

2.3.3 Effect of Triacontanol on seed quality parameters

Shivran and Jat (2013) reported that foliar application of Triacontanol @ 1.0 and 0.5 ml/lit. at 40 days after sowing increased umbellets/umbel (6.55), test weight (10.75 g), seed yield (1.47 t/ha) in coriander.

According to Sitingjak and Pandiangan (2014) studied the effect of triacontanol (1.0 ml/lit) significantly affected the growth of seedlings at the age of 14 weeks increase the growth of seedlings, high seedlings, number of leaves, length of leaves, and diameter of stems in cacao seedlings.

2.4 Effect of Indole-3-butyric acid (IBA)

Indole-3-butyric acid (IBA) is a plant growth regulator, used to promote and accelerate root formation of plants and also used on fruit and vegetable crops, field crops and ornamental turf to promote growth development of flowers and fruit and to increase crop yields.

2.4.1 Effect of Indole-3-butyric acid (IBA) on growth parameters

According to Sillu *et al.* (2012) observed that application of IBA 200 ppm was effective in potato maximum germination percent, growth, number of shoots per plant, days taken for physiological maturity, number of tubers harvested per plant and yield of tuber kg/ha.

2.4.2 Effect of Indole-3-butyric acid (IBA) on yield parameters

Amal *et al.* (2009) recorded the effect of IBA at 50 and 100 PPM on pea (*Pisum sativum* L.), the significant increase in 1000 seeds weight and pod parameters (length of pod, number pods / plant, seeds number / pod, pods fresh and dry weights) was recorded by IBA at harvest comparing with control.

According to Singh *et al.* (2012) was observed that spray of IBA at 160 ppm also resulted in maximum pod length (15.73 cm) and pod diameter (2.65 cm), while the least length and pod diameter was recorded with control treatment in okra.

2.4.2 Effect of Indole-3-butyric acid (IBA) on seed quality parameters

Amin *et al.* (2007) reported that foliar application of indole - 3 - butyric acid with different concentrations led to significant increases in vegetative growth onion plant height, number of leaves/plant, fresh and dry weight/ plant, leaf area, leaf area/plant, bulb length, bulb diameter and bulb weight onion.

Sharma and Tyagi (2013) conclude that low concentration of PGRs showed promotory effect on seed germination percentage, radicle and plumule while high concentration of PGRs had inhibitory effect on seedling growth parameters of *Rauvolfia serpentina* (L.) *Benth. ex Kurz*. So this technique will be helpful for farmers to increase the production of medicinally important plant and effect of varying concentration of IAA (Indole Acetic acid) and IBA (Indole Butyric Acid) was ascertained for seed germination and seedling growth of *Rauvolfia serpentina* (L.).

MATERIALS AND METHODS

The present investigation entitled “Effect of growth regulator on growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L) cv. Utkal Gaurav” was carried out during *kharif*, 2015 at Central Farm, Breeder Seed Production Unit College of Agriculture Bhubaneswar, Odisha under Orissa University of Agriculture & Technology, to find out the suitable growth regulators with appropriate concentration for maximum effectiveness in okra and also to response to different growth regulators as foliage spray and seed treatment in respect of growth, yield and seed quality parameters.

3.1 Previous year crop growing of the plot

Kharif	Rabi	Summer
Cowpea	Tomato	Chilli

3.2 Soil

A composite soil sample was taken from a depth of 15 cm surface from the experimental field before raising the crop for investigation. The sample was subjected to laboratory analysis to determine the physical and chemical compositions by following various standard methods. It is observed that the soil of the experimental plot comes under sandy loam (Sand-75.24%, Silt-14.76%, Clay-10.76%) having pH 5.86. The chemical analysis of soil indicated, nitrogen content of 162.5 kg/ha, phosphorous content of 104.2 kg/ha and potassium content of 94.1 kg/ha. The organic carbon content of soil was 1.01% and electrical conductivity was 0.188 dS⁻¹/m.

3.3 Geographical location of the experimental site

Bhubaneswar is located at latitude of 20⁰ 15' N & 85⁰ 52' East longitude. It is about 60 km away from Bay of Bengal and at an altitude of 25.5 meter above mean sea level (MSL).

3.4 Climate

The experimental site comes under the eighteenth agro-climatic region of the country i.e. Eastern Coastal Plain and is termed as sub-humid characterized by warm moist climate with mild winter. The average annual rainfall of Bhubaneswar is

1552mm (Based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September. The average temperature varies from 14⁰C in winter to 40⁰C in summer & relative humidity varies between 49 to 90% from June to December.

Table1: Meteorological data collected during the experimental period (August 2015 to December 2015).

Month	Temperature °C		Relative humidity (%)		Rainfall Daily (mm)	Evaporation (mm)	Wind velocity (Km/hr.)
	Max.	Min.	7 hr.	14 hr.			
Aug. 2015	32.9	25.1	92.4	76.6	297.8	3.7	4.5
Sept. 2015	33.0	25.0	91.3	74.5	151.5	3.3	3.8
Oct. 2015	33.2	23.5	93.0	67.2	75.5	3.4	1.9
Nov. 2015	31.3	20.1	90.8	54.8	3.0	3.6	2.2
Dec. 2015	29.2	17.6	86.5	53.2	14.8	3.4	3.0

3.5 EXPERIMENTAL DETAILS:

Crop : Okra
 Variety : UtkalGourav
 Plot size : 2.5m x 2 m
 Season : *kharif*, 2015
 Design of Layout : Randomized Block Design (RBD)
 Location : Central Farm, Breeder Seed Production Unit,
 College of Agriculture, Bhubaneswar

3.5.1 Foliage spray

Number of Treatments : 9
 Number of Replication : 3

Treatment details

The following treatment combinations involving plant growth regulators viz., Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA₃), each application of foliar spray on 20, 40, 60 days after sowing .

The treatment combinations are below.

T₁ = Foliar spray of 50 PPM GA₃ at 20DAS

T₂ = Foliar spray of 50 PPM GA₃ at 40DAS

T₃ = Foliar spray of 50 PPM GA₃ at 60DAS

T₄ = Foliar spray of 50 PPM NAA at 20DAS

T₅ = Foliar spray of 50 PPM NAA at 40DAS

T₆ = Foliar spray of 50 PPM NAA at 60DAS

T₇ = Foliar spray of GA₃ 20 PPM at 20 DAS + 50 PPM NAA 40 DAS

T₈ = Foliar spray of NAA 20 PPM at 20 DAS + 50 PPM GA₃ 40 DAS

T₉ = Control

3.5.2 Seed Treatment

Number of Treatments : 10

Number of Replication : 3

Treatment details

The following treatment combinations involving plant growth regulators viz., Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA₃), Indole-3-butyric acid (IBA), Triacantanol each at different concentrations applied as seed treatment.

T₁ = Seed treatment with 50 ppm GA₃

T₂ = Seed treatment with 25 ppm GA₃

T₃ = Seed treatment with 50 ppm NAA

T₄ = Seed treatment with 25 ppm NAA

T₅ = Seed treatment with 50 ppm IBA

T₆ = Seed treatment with 25 ppm IBA

T₇ = Seed treatment with 50 ppm Triacntanol

T₈ = Seed treatment with 25 ppm Triacntanol

T₉=Water soaked Seed

T₁₀ = Control dry seed

3.6 Field Operation and Crop Raising

The field was ploughed three times after incorporation of FYM during final land preparation @ 15 Tons/ha and levelled properly. Then the individual plots are laid out of scheduled size as per the plan of layout with required irrigation channel. Seeds of okra cv. Utkal Gaurav are sown during August, 2015, as per the treatments. Sowing was carried out by hand dibbling of two to three seeds in 5 cm deep.

A fertilizer dose of 100 kg N, 50kg P₂O₅ and 50 kg K₂O per ha were applied. The total amount of phosphorous with 20 kg of nitrogen and 10 kg of potash was applied to the soil before sowing. Remaining 80 kg of nitrogen and 40 kg of potash was applied in two-splits, as 40kg of nitrogen along with 20 kg of potash after first weeding, and remaining 20 kg of potash was applied after second weeding and 40kg of nitrogen was applied in 3 consecutive foliar sprays (1% urea) at 10 days interval during fruiting. Subsequently irrigation was provided in the irrigation channel at a interval of 8-10 days during the cropping season.

Manually hoeing followed by weeding, top dressing and earthing up were done followed by irrigation at 25 and 45 days after sowing. The crop was sprayed four time with systemic insecticide (Rogar) at weekly interval starting from 25 days after to control of white flies etc. during fruit development stage Quinolphos was sprayed for the control of fruit borer at weekly interval. Okra fruits were harvested when they were at tender stage and attained marketable size i.e. edible maturity stage. Picking of fruits were done at every alternate day till the last marketable produce.



Fig. 1 An overall view of experimental field



Fig. 2 Vegetative growth and early flowering



Fig. 3 Crop at flowering stage



Fig. 4 Measuring fruit hardness by Penetrometer and chlorophyll index by Spad meter

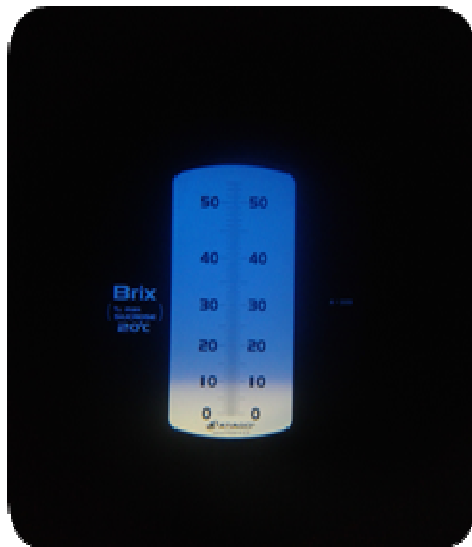


Fig. 5 Measuring TSS by Hand Refractometer



Fig. 6 Effect of foliar spray of growth regulator on different seedling parameter



Fig. 7 Effect of seed treatment of growth regulator on different seedling parameter

3.7 Collection of Experimental Data

Sampling procedure

Ten plants in each treatment and replication were randomly selected and tagged for recording the observation on growth yield and seedling parameters.

3.7.1 No of plants at 2 leaf stage at 10 DAS

This was recorded by counting the number of days taken from sowing to initiation of two leaf stage of plants.

3.7.2 Average Plant height at 25, 40 DAS and final height

The height was measured from ground level to the tip of the main stem on ten earlier tagged plants at 25, 40 and final harvesting stage. The average height was calculated and expressed in centimeter.

3.7.3 Node at 1st flowering starts

Daily counts were made in each plot in each treatment starting which node first flower appeared counted from the base and expressed in number.

3.7.4 Average stem girth

The stem girth was recorded above the groundlevel ten tagged plant and expressed in cm.

3.7.5 Days to first flowering

This was recorded by counting the number of days taken from sowing to initiation of first flower in each plot.

3.7.6 Days to 50% flowering

Daily counts were made in each plot in each treatment & the number of days taken from sowing to the flowering in 50% plants was recorded.

3.7.7 Days to first harvest

This was recorded by counting the number of days taken from sowing to the harvest for marketable yield in each plot.

3.7.8 Days required for fruit maturity

The average number of days taken by the plants in each treatment and replication to reach the physiological maturity based on the visual observation was considered as the number of days taken for maturity. The fruit maturity was decided based on the drying of fruits and development of hairline cracks on the fruits.

3.7.9 Average fresh fruit weight

The ten fruit are harvested from the tagged plants from each treatment and weighed with the help of electronic balance. The mean of ten fruit was calculated and expressed in grams per fruit.

3.7.10 Average fruit length

The length of fruit was measured from the tip of fruit to the point of attachment of the pedicel. The mean of ten fruit was calculated and expressed in centimeter.

3.7.11 Average fruit girth

Ten fruits selected randomly from each plot in a replication for recording of fruit length were also used for noting their girth at the point of maximum thickness which were averaged and expressed in centimeter (cm).

3.7.12 Average Dry fruit weight

The ten physiological dried fruit randomly selected from observation plants, mean value of fruit taken average dry fruit weight in expressed in grams.

3.7.13 Average chlorophyll index

The chlorophyll index on randomly selected ten plants leaves was measured by using chlorophyll content meter.

3.7.14 Marketable fruit yield/plot

The fruit were harvested from each plant from each treatment and weighed with the help of electronic balance and expressed in kg per plot.

3.7.15 Fruit yield per hectare (q/ha)

The fruit yield of tagged plants was added to the fruit yield of net plot area to calculate the fruit yield per hectare and expressed in quintal per hectare.

3.7.16 Average Number of seed per fruit

The seeds from each fruit were separated manually by hand and counted. The mean fruits was calculated and expressed in number.

3.7.17 100 seed weight (g)

The hundred seed from each treatment were count by manually and weighed with the help of electronic balance and expressed in grams.

3.7.18 Seed germination percent

The seed germination test was conducted by adopting rolled paper towel method (Agrawal, 2003). Hundred seeds in three replications were taken at random from each treatment and uniformly placed on germination paper. The rolled paper was kept in the seed germination maintained at room temperature and relative humidity.

3.7.19 Average root length (cm)

Ten normal seedlings in each treatment were randomly selected from the germinated seedling for measurement of root length on seven days. The root length was measured from the collar region to the tip of the root. Average root length of ten seedlings was calculated and expressed in centimeter.

3.7.20 Average shoots length (cm)

The shoot length was measured from the collar region to the point of attachment of cotyledons. The average of ten seedlings was calculated and expressed in centimeter.

3.7.21 Average fresh seedling weight (g)

The fresh seedlings were removed in blotters paper and randomly selected ten seedling weight was recorded and mean of fresh seedling weight.

3.7.22 Average dry seedling weight (g)

A seedling which was used for recording the fresh weight, were packed in a hot air oven maintained at 80 °c. These dried seedlings were removed and cooled in a desiccator for 30 minutes. Then the weight was recorded and their mean was calculated.

3.7.23 Vigour index

The vigour index values were calculated as per the method prescribed by Abdul-Baki and Anderson (1973) and expressed in whole number.

1. Vigour index Type-I = Germination (%) x mean seedling length (cm)
2. Vigour index Type-II = Germination (%) x mean seedling dry weight (g)

3.8 Statistical analysis

The data was analyzed using computer software programmed by the method of variance outlined by Gomez and Gomez (1984). Statistical significance was tested by F value at 5 per cent level of significance. Critical difference at 0.05 level of significance was worked out for field condition, where 1 per cent level of significance CD at 0.01 level of significance was worked out for lab condition.

RESULTS

The result recorded from the study on the “Effect of growth regulator on growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.) cv. Utkal Gaurav” are described in this chapter.

4.1 Foliage Spray

4.2 Seed Treatment

4.1.1 Effect of foliar spray of growth regulators on growth parameters

4.1.1.1 Plant height

On perusal of data tabulated in Table 4.1, it is evident that all the treatments significantly enhanced the plant height as compared to the control. The maximum plant height was recorded under T₂ (107.97 cm) which was statistically at par with T₅ (104.31 cm) and T₇ (103.31 cm). The minimum plant height was recorded under T₉ (95.07 cm)

4.1.1.2 Stem girth (cm)

The data presented in Table 4.1 reveal that the stem girth significantly varied due to the treatments as compared to the control. The stem girth was recorded highest under T₄ (5.68 cm) which was statistically at par with T₇ (5.63 cm). However except T₄ all other treatment showed non-significant variation over control and while lowest (5.22 cm), was recorded with control treatment.

4.1.1.3 Node start first flowering

The data tabulated under Table 4.1 depict that foliar spray of different growth regulator had non-significant effect on initiation of first flower bud from the node. However, initiation of first flower bud was observed from node (2.90) in T₇ while under control treatment it was recorded from 3.22 node. (Fig. 2)

4.1.1.4 Days taken to first flowering

The data on number of days to first flowering presented in the Table 4.1 clearly show that the treatments had a significant effect on days taken to first flowering. According to the results obtained from the statistical analysis of data, days to first flowering was found to be earliest in T₄ (31.47 days) which was statistically at par with T₇ (33.08 days) and T₁ (33.11 days), Maximum days were recorded under T₆ (38.17 days). However, there was a non-significant variation between control (39.04 days) and the treatment T₆ (38.17 days) and T₃ (38.58 days).

Table 4.1: Effect of foliar spray of growth regulators on different growth parameters in Okra cv. Utkal Gaurav

Treatment	Final height (cm)	Stem girth (cm)	Node in which 1 st Flower bud appeared	Days to first flowering	Days to 50 per cent flowering	First harvesting	Days require to fruit maturity
T1- GA₃ @ 50 ppm at 20 DAS	101.32	5.54	2.93	33.11	43.91	40.27	68.51
T2- GA₃ @ 50 ppm at 40 DAS	107.97	5.47	3.13	35.87	45.15	42.24	71.30
T3- GA₃ @ 50 ppm at 60 DAS	98.23	5.26	3.23	38.58	47.94	44.16	72.47
T4-NAA @ 50 ppm at 20 DAS	100.75	5.68	2.94	31.47	40.40	37.02	66.02
T5-NAA @ 50 ppm at 40 DAS	104.31	5.46	3.2	36.04	45.36	43.08	71.13
T6-NAA @ 50 ppm at 60 DAS	97.97	5.37	3	38.17	47.87	44.23	70.90
T7-GA₃ @ 20 ppm at 20 DAS + NAA @ 50 ppm at 40 DAS	103.31	5.63	2.9	33.08	42.05	39.72	68.14
T8-NAA @ 40 ppm at 20 @ DAS + GA₃ @ 50 ppm at 40 DAS	100.24	5.51	2.97	33.96	44.24	40.87	70.23
T9-Control	95.07	5.22	3.22	39.04	49.33	45.14	76.34
Mean	101.02	5.46	3.06	34.59	45.14	41.86	70.56
SEm (±)	1.75	0.13	0.12	0.92	1.12	0.86	0.72
CD 5%	5.24	0.39	N.S.	2.77	3.35	2.57	2.15

4.1.1.5 Days taken to 50 per cent flowering

The data presented in Table 4.1 reveal that the days to 50 per cent flowering significantly varied due to the treatments as compared to control. Days to 50 per cent flowering was found to be earliest in T₄ (40.40 days) followed by T₇ (42.05 days) and T₁ (43.91 days). The control recorded the maximum days to 50 per cent flowering (49.33 days). However, the treatments T₆ (47.87 days) and T₃ (47.94 days) showed non-significant variation over control.

4.1.1.6 Days taken to first harvesting

It is evident from the data tabulated in the Table 4.1 that the days to first harvesting was significantly varied due to the treatments as compared to control. The harvesting was recorded to be earliest in T₄ (37.02 days) followed by T₇ (39.72 days), T₁ (40.27 days) and T₈ (40.87 days). First harvesting was most delayed (45.14 days) in T₉ which was *statistically at par* with T₆ (44.23 days) and T₃ (44.16 days).

4.1.1.7 Days require to fruit maturity

It is evident from the data tabulated in the Table 4.1 that the days to fruit maturity was significantly varied due to the treatments as compared to control. The fruit maturity was recorded to be earliest in T₄ (66.02 days) which was at par with T₇ (68.14 days) and T₁ (68.51 days). Fruit maturity was most delayed (76.34 days) in control.

4.1.1.8 Chlorophyll index

The data on chlorophyll index presented in the Table 4.2 clearly show that the treatments had a significant effect on chlorophyll index. According to the results obtained from the statistical analysis of data, chlorophyll index was found to be highest (22.45) in T₇ followed by T₅ (20.55). Lowest chlorophyll index was recorded under control (17.38). (Fig 4)

4.1.2.9 TSS (Brix)

On perusal of data given in Table 4.2 it is noticeable that TSS was enhanced significantly due to treatments as compared to the control. The maximum TSS was observed in T₇ (9.80) followed by T₄ (8.93), T₁ (8.81) and T₂ (8.67). Whereas, the minimum TSS was recorded under control (6.93). Among the treatments non-significant effects were observed as in case of T₃, T₄ and T₆.(Fig 5)

4.1.2.10 Fruit hardness

A perusal of data in Table 4.2 envisages that fruit hardness significantly decreased over control. The fruit hardness was found to be the minimum in T₂ (95.80) which was statistically at par with T₈ (97.04), T₄ (97.16) and T₁ (97.18). However, maximum hardness of fruit was found in T₉ (105.91),(Fig 4).

4.1.2 Effect of foliar spray of growth regulators on yield parameters

4.1.2.1 Fresh fruit weight

On perusal of data given in Table 4.3 it is noticeable that fresh weight of fruit was enhanced significantly due to treatments as compared to the control. The maximum fresh weight was observed in T₅ (16.47 g) followed by T₇ (15.14g) and T₄ (15.01g). Whereas, the minimum fresh weight of fruit was recorded under control (11.67 g).

4.1.2.2 Dry fruit weight

Data tabulated in Table 4.3 reveal that the dry fruit weight of fruit was superior in all the treatments as compared to control. The dry weight of fruit was observed highest in T₅ (5.61 g) which was significantly higher than all the other treatments combinations. However, the weight of dry fruit was observed lowest under T₉ (4.03 g).

4.1.2.3 Fruit length

On perusal of data given in Table 4.3 it is noticeable that fruit length was enhanced significantly due to treatments as compared to the control. The maximum fruit length was observed in T₅ (16.58 cm) followed by T₇ (14.98 cm), T₁ (14.72 cm) and T₄ (14.38 cm). Whereas, the minimum fruit length was recorded under control (10.89 cm).

4.1.2.4 Fruit girth

Data tabulated in Table 4.3 reveal that the fruit girth was superior in all the treatments as compared to control. The fruit girth was observed maximum in T₅ (6.46 cm) which was significantly at par with T₂ (6.25 cm) and T₇ (5.97 cm). However, the minimum fruit girth was observed under T₉ (4.97 cm). Though most of the treatments had significant differences over the control, but among the treatments there were some non-significant differences as noticed in T₁ (5.75 cm), T₈ (5.68 cm), T₆ (5.62 cm) and in T₃ (5.51 cm).

Table 4.2: Effect of foliar spray of growth regulators on Chlorophyll Index, TSS (Brix), and fruit hardness in Okra cv. Utkal Gaurav

Treatment	Chlorophyll Index	TSS (brix)	Fruit hardness
T₁- GA₃ @ 50 ppm at 20 DAS	18.90	8.81	97.18
T₂- GA₃ @ 50 ppm at 40 DAS	20.54	8.67	95.80
T₃- GA₃ @ 50 ppm at 60 DAS	20.11	7.53	103.74
T₄-NAA @ 50 ppm at 20 DAS	19.68	8.93	97.16
T₅-NAA @ 50 ppm at 40 DAS	20.55	7.80	100.25
T₆-NAA @ 50 ppm at 60 DAS	18.80	7.60	103.92
T₇-GA₃ @ 20 ppm at 20 DAS + NAA @ 50 ppm at 40 DAS	22.45	9.80	102.57
T₈-NAA @ 40 ppm at 20 @ DAS + GA₃ @ 50 ppm at 40 DAS	19.89	8.20	97.04
T₉-Control	17.38	6.93	105.91
Mean	19.81	8.25	100.40
SEm±	0.55	0.28	0.82
CD %	1.64	0.85	2.45

4.1.2.5 Number of fruits per plant

It is obvious from the data (Table 4.3) that the treatments significantly varied over control which recorded the minimum number of fruits per plant. The maximum number of fruits per plant was obtained in T₅ (13.46) which was significantly at par with T₇ (12.97) followed by T₁ (11.73), T₄ (11.03) and T₂ (10.83). Control recorded the minimum number of fruits (9.42) per plant followed by T₃ (9.70) and T₆ (9.90cm).

4.1.2.6 Fruit yield per plot

The data pertaining to fruit yield presented in Table 4.3 reveal that the character was influenced significantly due to the treatments as compared with control. The maximum fruit yield per plot was recorded in T₅ (4.83 kg) which was statistically at par with T₇ (4.63 kg) and T₂ (4.58 kg). However, the plot yield was found to be lowest (3.97 kg) in T₉.

4.1.2.7 Fruit yield per hectare

Data presented in the Table 4.3 reveal that the fruit yield of okra increased significantly due to various treatments as compared to the control. The maximum yield was obtained in T₅ (96.63 q/ha) and in T₇ (92.6 q/ha) and T₂ (91.5 q/ha). However, the minimum fruit yield (79.37 q/ha) was observed in T₉. It was observe that NAA 50 ppm gave higher benefit cost ratio (2.96) as compare to other treatment data are presented in the table 4.5.

All the treatments showed significant differences over control, but between some treatments non-significant differences were observed as in T₁ (88.62 q/ha), T₆ (87.12q/ha), T₃ (86.56 q/ha) and T₄ (86.44 q/ha).

4.1.3 Effect of foliar spray of growth regulators on seed quality parameter

4.1.3.1 Number of seeds per fruit

Data recorded on number of seeds per fruit are depicted in Table 4.5 it may be inferred from the data that the numbers of seeds per fruit were significantly affected by application of growth regulators. The number of seeds per fruit was found to be maximum in T₇ (59.14) followed by T₅ (57.24), T₄ (56.30), T₁ (55.85) and T₂ (55.62). The minimum number of seeds per fruit was obtained in control (48.40).

Table 4.3:- Effect of foliar spray of growth regulators on different yield parameters in Okra cv. Utkal Gaurav

Treatment	Fruit fresh weight (g)	Dry fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Number of fruit per plant	Fruit yield/ plot (kg)	Yield (q/ha)
T₁- GA₃ @ 50 ppm at 20 DAS	14.47	4.47	14.72	5.75	11.73	4.43	88.62
T₂- GA₃ @ 50 ppm at 40 DAS	14.33	4.53	13.91	6.25	10.83	4.58	91.52
T₃- GA₃ @ 50 ppm at 60 DAS	12.87	4.41	12.72	5.51	9.70	4.33	86.56
T₄-NAA @ 50 ppm at 20 DAS	15.01	4.73	14.38	5.36	11.03	4.32	86.44
T₅-NAA @ 50 ppm at 40 DAS	16.47	5.61	16.58	6.46	13.46	4.83	96.63
T₆-NAA @ 50 ppm at 60 DAS	12.22	4.39	13.07	5.62	9.90	4.35	87.12
T₇-GA₃ @ 20 ppm at 20 DAS + NAA @ 50 ppm at 40 DAS	15.14	4.97	14.98	5.97	12.97	4.63	92.60
T₈-NAA @ 40 ppm at 20 @ DAS + GA₃ @ 50 ppm at 40 DAS	12.67	4.35	13.51	5.68	10.76	4.42	88.40
T₉-Control	11.67	4.03	10.89	4.97	9.42	3.97	79.37
Mean	13.87	4.61	13.86	5.73	11.09	4.428	88.58
SEm±	0.31	0.17	0.34	0.18	0.28	0.13	2.01
CD %	0.94	0.50	1.02	0.55	0.83	0.40	6.02

Table 4.4 Benefit: cost ratio in Okra cv. Utkal Gaurav by foliar spray of different growth regulators

Treatment	Cost of cultivation	Chemical rate	Total cost	Yield (kg)	Sale rate	Total income	Total profit	Benefit cost ratio
T₁- GA₃ @ 50 ppm at 20 DAS	63290	2750	66040	8862	20	177240	111200	2.68
T₂- GA₃ @ 50 ppm at 40 DAS	63290	2750	66040	9152	20	183040	117000	2.77
T₃- GA₃ @ 50 ppm at 60 DAS	63290	2750	66040	8656	20	173120	107080	2.62
T₄-NAA @ 50 ppm at 20 DAS	63290	2087.5	65377.5	8644	20	172880	107502.5	2.64
T₅-NAA @ 50 ppm at 40 DAS	63290	2087.5	65377.5	9663	20	193260	127882.5	2.96
T₆-NAA @50 ppm at 60 DAS	63290	2087.5	65377.5	8712	20	174240	108862.5	2.66
T₇-GA₃ 20 ppm at 20 DAS + NAA @ 50 ppm at 40 DAS	63290	3462.5	66752.5	9260	20	185200	118447.5	2.77
T₈-NAA @ 40 ppm at 20 DAS + GA₃ @ 50 ppm at 40 DAS	63290	4837.5	68127.5	8840	20	176800	108672.5	2.59
T₉-Control	63290	-	63290	7937	20	158740	95450	2.30

4.1.3.2 Test weight

On perusal of data tabulated in Table 4.5, it is evident that all the treatments significantly enhanced the test weight as compared to the control. The maximum test weight was recorded under T₅ (8.03gm) followed by T₇ (7.67gm), T₂ (7.17g) and T₁ (7.00g). The minimum test weight of okra was recorded under control (5.33g).

4.1.3.3 Germination per cent

The data on germination presented in the Table 4.5 clearly show that the treatments had a significant effect on germination per cent. According to the results obtained from the statistical analysis of data, germination per cent was found to be highest in T₁ (91.67 per cent) which was statistically at par with T₇ (87.0 per cent) and T₂ (86.67 per cent). Minimum germination per cent was recorded under control (82.67 per cent).

4.1.3.4 Shoot length

On perusal of data given in Table 4.5 it is noticeable that shoot length was enhanced significantly due to treatments as compared to the control. The maximum shoot length was observed in T₃ (16.95cm) which was statistically at par with T₆ (16.81cm) and T₈ (16.52cm), followed by T₅ (16.33cm), T₂ (15.58cm) and T₁ (15.40 cm). Whereas, the minimum shoot length was recorded under control (13.68cm).

4.1.3.5 Root length

Data tabulated in Table 4.5 reveal that the root length was superior in all the treatments as compared to control. The root length was observed maximum in T₆ (9.40 cm) which was significantly higher than all the other treatments combinations. However, the minimum root length was observed under T₉ (5.21cm). Though all treatments had significant differences over the control, but among the treatments there were some non-significant differences as noticed in T₃ (8.83cm), T₄ (8.67cm), T₂ (8.56cm) and T₁ (8.43cm).

4.1.3.6 Fresh seedling weight

A perusal of data in Table 4.5 investigate that fresh weight of seedling significantly increased over control due to different treatments. The fresh weight of seedling was found to be maximum under T₆ (6.43g) which was statistically at par with T₃ (6.15g), followed by T₅ (6.09 g) and T₇ (6.03 g). The minimum weight was recorded under control (4.75 g) which was significantly lower than all other treatments.

Table 4.5: Effect of foliar spray of growth regulators on different seed quality parameters in Okra cv. Utkal Gaurav

Treatment	No of seed/fruit	Test weight (100 seed g.)	Germination per cent	Shoot length (cm)	Root length (cm)	Fresh seedling weight (g.)	Dry seedling weight (mg.)	Vigour index type - I	Vigour index type - II
T₁- GA₃ @ 50 ppm at 20 DAS	55.85	7.00	91.67	15.40	8.43	5.89	24.33	2184.50	22.30
T₂- GA₃ @ 50 ppm at 40 DAS	55.62	7.17	86.67	15.58	8.56	5.81	24.50	2092.21	21.23
T₃- GA₃ @ 50 ppm at 60 DAS	53.05	6.67	82.33	16.95	8.83	6.15	26.03	2122.47	21.43
T₄-NAA @ 50 ppm at 20 DAS	56.30	6.33	83.00	14.83	8.67	5.69	24.57	1950.50	20.39
T₅-NAA @ 50 ppm at 40 DAS	57.24	8.03	85.68	16.33	8.90	6.09	25.70	2161.71	22.02
T₆-NAA @ 50 ppm at 60 DAS	53.00	6.93	84.33	16.81	9.40	6.43	26.77	2210.29	22.58
T₇-GA₃ @ 20 ppm at 20 DAS + NAA 50 @ ppm at 40 DAS	59.14	7.67	87.00	15.97	7.93	6.03	24.57	2079.30	21.38
T₈-NAA @ 40 ppm at 20 @ DAS + GA₃ @ 50 ppm at 40 DAS	53.03	6.33	85.67	16.52	7.17	5.12	23.27	2029.52	19.94
T₉-Control	48.40	5.33	82.67	13.68	5.21	4.75	19.93	1561.64	16.48
Mean	54.63	6.83	85.44	15.79	8.12	5.77	24.41	2043.57	20.86
SEm±	0.64	0.11	1.34	0.14	0.10	0.07	0.19	50.87	0.44
CD 5%	1.93	0.32	4.01	0.22	0.56	0.43	0.29	152.50	211.99
CD 1%	-	-	5.58	0.30	0.77	0.60	0.40	211.99	1.85

4.1.3.7 Dry seedling weight

The data compiled in Table 4.5 exhibit a highly significant increase in dry weight of seedling under the treatments as compared to control. The maximum dry weight was obtained in T₆ (26.77 mg) which was statistically at par with T₃ (26.03 mg), followed by T₅ (25.70 mg), T₇ (24.57 mg) and T₂ (24.50 mg). However, minimum dry weight of seedling was observed under control (19.93 mg).

4.1.3.8 Vigour index Type-I

The data pertaining to Vigour index Type-I is presented in Table 4.5. It is apparent from the data that most of the treatments had significant variation. Among growth regulators maximum T₆ (2210.29) Vigour index Type-I weight was recorded with NAA @ 50 ppm spray at 60 DAS spray followed by T₁, T₃, while minimum (1561.64) test weight was recorded with control treatment.

4.1.3.9 Vigour index Type-II

A critical evaluation of the results obtained from the data given in Table 4.5 shows that all the treatments significantly increased the vigour index Type-II over control. Among growth regulators maximum T₅ (22.58) vigour index Type-II weight was recorded with followed by T₁ (22.30), T₃ (21.43), while minimum (16.48) test weight was recorded with control treatment.

4.2 Seed Treatment

4.2.1 Effect of seed treatment of growth regulators on growth parameters

4.2.1.1 Days to start germination

The presented data in table 4.6 reveals that days to start germination had a significant effect due to the treatment as compared to control.

The days to start germination was earliest under T₁ (2.07 days) which was statistically at par with T₅ (2.21days), followed by T₆ (2.34days) and T₂ (2.47days). The control (3.67days) recorded maximum days to start germination. However the treatment T₉ (3.51days) and T₁₀ (3.67days) gave the similar response with days to initiate germination.

Table 4.6: Effect on growth parameters in Okra cv. Utkal Gaurav by different growth regulators on seed treatment.

Treatment	Days to start germination	Days to 50 per cent germination	Days to 100 per cent germination	Number of plant two leaf stage at 10 das
T₁ GA₃ @ 50 ppm	2.07	6.59	9.35	45.17
T₂ GA₃ @ 25 ppm	2.47	7.44	11.57	33.39
T₃ NAA @ 50 ppm	2.57	8.11	12.14	29.23
T₄ @ NAA 25 ppm	2.89	8.67	13.37	26.09
T₅ IBA @ 50 ppm	2.21	6.67	10.00	42.32
T₆ IBA @ 25 ppm	2.34	7.00	11.57	40.92
T₇ Tricentanol @ 10 ppm	2.67	8.33	12.69	27.31
T₈ Triacentanol @ 5 ppm	3.05	8.91	13.65	25.42
T₉ water soaked	3.51	11.35	14.34	22.57
T₁₀ Control dry seed	3.67	12.25	15.00	21.71
Mean	2.75	8.53	12.37	31.42
SEm±	0.13	0.44	0.63	1.44
CD 5%	0.39	1.32	1.86	4.27

4.2.1.2 Days to 50 per cent germination

The data tabulated in the table 4.6 clearly shows that the treatments significant effect on days to 50 per cent germination. According to result obtained from statistical data 50 per cent germination was found to the earliest in T₁ (6.59 days) followed by T₅ (6.67 days), T₆ (7.00 days). A maximum day to 50 per cent germination was recorded under control T₁₀ (12.25 days).

4.2.1.3 Days to 100 per cent germination

On perusal of the data presented in table 4.6 it is evident that the treatments had a significant effect on days to 100 per cent germination as compare to control. According to the results obtained from statistical data 100 per cent germination found to be earliest in T₁ (9.346 days) which was statistically at par with T₅ (10.00 days). The control (15.00 days) recorded maximum days to take 100 per cent germination.

4.2.1.4 Number of plants at two leaf stage at 10 days after sowing

The result was recorded 10 days after sowing maximum T₁ (45.17) plant are two leaf stage which was statistically at par with T₅ (42.32), followed by T₆ (40.92). While, minimum number of plants at two leaf stage at 10 DAS was recorded in T₁₀ (21.71).

4.2.1.5 Final height

The data presented in Table 4.7 on plant height reveals that there was significant effect of treatments on plant height as compared to control

The maximum plant height was found in T₁ (102.08cm) which was statistically at par with T₃ (100.24cm) followed by T₂ (99.83cm). The minimum plant height was recorded in T₁₀ (91.50 cm). All the treatments showed significant difference over control except T₉, but between some treatments non-significant differences were observed as in T₂ (99.83 cm), T₄ (99.25 cm), T₅ (98.25 cm) and T₆ (96.04 cm) and in T₇ (95.60) and T₈ (95.22 cm).

4.2.1.6 Node in which first flower bud appeared

It is evident from the data tabulated in the Table 4.7 that the seed treatment by different growth regulator had non-significant effect on initiation of first flower bud from the node. However, initiation of first flower bud was observed from node (2.90) in T₁ while under control treatment it was recorded at 3.50.

4.2.1.7 Stem girth

On perusal of data given in Table 4.7 it is noticeable that the seed treatment had a non-significant effect on stem girth. However, the maximum stem girth was recorded in T₃ (5.83cm) while, minimum stem girth was observed under T₁₀ (4.15cm)

4.2.1.8 Days to first flowering

The data presented in Table 4.7 envisage that the days to first flowering varied significantly with the treatments as compared to the control.

The days to first flowering was earliest observe in T₃ (34.31days) which was statistically at par with T₁ (34.68days), T₂ (34.97 days), T₄ (35.25days), T₇ (36.42 days) and T₅ (36.46 days). While, maximum days to first flowering was recorded in T₁₀ (38.82days) and T₉ (38.51days), Fig 2.

4.2.1.9 Days to 50 per cent flowering

Data recorded on days to 50 per cent flowering are depicted in Table 4.7. It may be inferred from the data that days taken to 50 per cent flowering was significantly affected by growth regulators. Days to 50 per cent flowering was observed earliest in T₃ (44.49 days) which was statistically at par with T₁ (45.49days), followed by T₄ (46.37 days), T₇ (46.38days) and T₈ (46.45days). The maximum days to first flowering was recorded in T₉ (48.75days) which was statistically at par with T₁₀ (48.66 days).

4.2.1.10 Days taken to first harvesting

The statistical analysis of the data presented in Table 4.7 reveal that the days taken to first harvesting was significantly affected by the treatments as compared to control. The days to first harvesting was observed earliest in T₃ (40.83 days) which was statistically at par with T₁ (42.68 days) and followed by T₄ (42.93 days) and T₅ (43.30 days). The maximum days to first harvesting was recorded in T₁₀ (46.68 days). However, among the treatments some non-significant variation was observed as in T₅ (43.30 days), T₂ (43.43 days) and T₇ (43.78 days).

Table 4.7: Effect on growth parameters in Okra cv. Utkal Gaurav by different growth regulators on seed treatment.

Treatment	Final height (cm)	Node in which 1st flower bud appeared	Stem girth (cm)	Days to first flowering	Days to 50% flowering	First harvesting (days)	Days to pod maturity
T₁ GA₃ @ 50 ppm	102.08	2.97	5.54	34.68	45.49	42.68	70.11
T₂ GA₃ @ 25 ppm	99.83	3.17	5.28	34.97	46.96	43.43	71.29
T₃ NAA @ 50 ppm	100.24	2.63	5.83	34.31	44.49	40.83	69.82
T₄ @ NAA 25 ppm	99.25	3.03	5.36	35.25	46.37	42.93	70.93
T₅ IBA @ 50 ppm	98.25	2.87	5.31	36.46	47.15	43.30	71.76
T₆ IBA @ 25 ppm	96.04	3.27	5.28	36.75	47.33	44.14	72.21
T₇ Tricentanol @ 10 ppm	95.60	3.23	5.27	36.42	46.38	43.78	72.65
T₈ Triacentanol @ 5 ppm	95.22	3.32	5.25	37.17	46.45	44.78	73.32
T₉ water soaked	93.28	3.46	4.24	38.82	48.75	46.25	74.17
T₁₀ Control dry seed	91.50	3.50	4.15	38.51	48.66	46.68	74.49
Mean	97.13	3.14	5.15	36.33	46.81	43.88	72.07
SEm±	0.86	0.19	0.35	0.80	0.81	0.69	0.90
CD 5%	2.56	N.S.	N.S.	2.39	2.39	2.06	2.66

4.2.1.12 Days taken to pod maturity

The data presented in Table 4.7 envisage that the days taken to pod maturity varied significantly with the treatments as compared to the control. The days taken to pod maturity was recorded earliest under T₃ (69.82 days). Though the treatments had a significant effect over control, but among the treatments some non-significant variation were observed as in T₁, T₂, T₄ and in T₅. The days taken to pod maturity was delayed most in T₁₀ (74.49days).

4.2.1.8 Chlorophyll Index

The data presented in Table 4.8 reveals that chlorophyll index significantly varied due to the treatments as compared to the control The result was recorded maximum chlorophyll index present in T₃ (21.75) which was statistically at par with T₁ (21.52) followed by T₄ (21.22), T₂ (19.99) and minimum Chlorophyll index was recorded in T₁₀ (17.60).

4.2.2.6 TSS

Data recorded on TSS is depicted in Table 4.8. It may be inferred from the data that TSS was significantly affected by treatment of seeds with growth regulators as compared to control. The maximum TSS result was obtained in T₁ (8.94 brix) which was statistically at par with T₃ (8.54 brix) and followed by T₂ (8.33 brix) and T₅ (8.27 brix). However, minimum TSS was recorded in control (7.53 brix) which was statistically at par with T₉ (7.57 brix).

4.2.2.7 Fruit hardness

The findings obtained on the basis of data presented in Table 4.8 reveal that the treatments had a significant effect on fruit hardness as compared to control. The hardness was recorded lowest in T₁ (98.67) which was statistically at par with T₃ (99.87) followed by T₂ (100.22), T₄ (100.27). Maximum hardness was recorded in control treatment T₁₀ (106.93).

4.2.2 Effect of growth regulators on Yield parameter

4.2.2.1 Fresh fruit weight

A perusal of data in Table 4.9 illustrates that fresh weight of fruit significantly increased over control due to different treatments. The fresh weight of fruit was found to be maximum under T₃ (15.09 g) which was at par with T₄ (14.73g), T₁ (14.65 g), T₂ (14.28 g). The minimum weight was recorded under control (11.47 g) which was at par with T₉ (11.98 g).

Table 4.8: Effect on chlorophyll index, TSS (Brix) & hardness of fruit in Okra (cv. Utkal Gaurav) by different growth regulator on seed treatment.

Treatment	Chlorophyll index	TSS (Brix)	Fruit hardness
T₁ GA₃ @ 50 ppm	21.52	8.94	98.34
T₂ GA₃ @ 25 ppm	19.99	8.33	100.64
T₃ NAA @ 50 ppm	21.75	8.54	99.87
T₄ @ NAA 25 ppm	21.22	8.27	100.21
T₅ IBA @ 50 ppm	19.94	7.86	100.27
T₆ IBA @ 25 ppm	19.82	7.64	104.32
T₇ Tricentanol @ 10 ppm	19.65	7.75	102.47
T₈ Triacantanol @ 5 ppm	19.37	7.68	103.13
T₉ water soaked	18.32	7.57	105.42
T₁₀ Control dry seed	17.60	7.53	106.93
Mean	19.92	8.01	102.16
SEm±	0.51	0.15	0.66
CD 5%	1.52	0.46	1.97

4.2.2.2 Dry fruit weight

The data compiled in Table 4.9 exhibit a highly significant increase in dry weight of fruit under the treatments as compared to control. The dry weight of fruit was found to be maximum under T₃ (4.96g) followed by T₁ (4.71g), T₄ (4.52g) and T₂ (4.42g). The minimum weight was recorded under control (4.03 g) which was significantly lower than all other treatments. It was also inferred that there was non-significant variation between or among the treatments as noticed in T₆, T₈ and T₉.

4.2.2.3 Fruits length

On perusal of data tabulated in Table 4.9 it is evident that all the treatments significantly enhanced the fruit length as compared to the control. The maximum fruit length was observed in T₁ (15.32cm) which was statistically at par with T₃ (14.56cm), followed by T₂ (14.14cm), T₅ (13.93cm) and T₄ (13.89cm). While minimum fruit length was recorded under control (11.56 cm) which was significantly lower than other treatments.

4.2.2.4 Fruit girth

The data presented in Table 4.9, envisage that number of fruit girth was enhanced due to treatments as compared to control. The maximum fruit girth was recorded in T₁ (6.37 cm) which was statistically at par with T₃ (6.28 cm), T₄ (6.22 cm) and T₂ (6.14 cm). However, the minimum fruit girth was recorded in T₁₀ (5.36 cm). All the treatment except T₉ (5.40cm) and T₅ (5.45 cm) showed significant variation over control.

4.2.2.5 Number of fruit per plant

On perusal of data given in Table 4.9 it is noticeable that number of fruits per plant was enhanced significantly due to treatments as compared to the control. The maximum number of fruits per plant was recorded in T₃ (14.10) followed by T₁ (13.04 cm) and T₄ (12.60). Whereas, the minimum number of fruits per plant was obtained in T₁₀ (10.47) which was statistically at par with T₉ (10.66). Among the treatments non-significant effects were observed as in case of T₂, T₄ and T₇.

Table 4.9: Effect on yield parameters in Okra cv. Utkal Gaurav by different growth regulators on seed treatment.

Treatment	Fresh fruit weight (g.)	Dry fruit weight (g.)	Fruits length (cm)	Fruit girth (cm)	Number of fruit per plant	Fruit yield/plot (kg)	Fruit yield (q/ha)
T₁ GA₃ @ 50 ppm	14.65	4.71	15.32	6.37	13.04	4.32	86.05
T₂ GA₃ @ 25 ppm	14.28	4.42	14.14	6.14	12.54	4.20	83.62
T₃ NAA @ 50 ppm	15.09	4.96	14.56	6.28	14.10	4.48	89.21
T₄ @ NAA 25 ppm	14.73	4.52	13.89	6.22	12.60	4.24	84.44
T₅ IBA @ 50 ppm	13.44	4.40	13.93	5.45	12.13	4.17	82.99
T₆ IBA @ 25 ppm	12.78	4.17	13.82	5.97	11.80	4.07	81.15
T₇ Tricentanol @ 10 ppm	12.33	4.36	13.20	6.09	12.03	4.14	82.46
T₈ Triacentanol @ 5 ppm	12.13	4.21	13.25	5.85	11.77	4.06	80.81
T₉ water soaked	11.98	4.13	13.06	5.40	10.66	3.99	80.57
T₁₀ Control dry seed	11.47	4.03	11.56	5.36	10.47	3.96	79.02
Mean	13.29	4.39	13.67	5.91	12.11	4.16	83.03
SEm±	0.28	0.03	0.39	0.09	0.32	0.05	1.44
CD 5%	0.84	0.10	1.154	0.28	0.96	0.15	4.27

Table 4.10 Benefit: cost ratio in Okra cv. Utkal Gaurav by Seed treatment of different growth regulators

Treatment	Cost of cultivation	Chemical rate	Total cost	Yield (kg)	Sale rate	Total income	Total profit	Benefit cost ratio
T₁ GA₃ @ 50 ppm	63290	550	63840	8605	20	172100	108260	2.69
T₂ GA₃ @ 25 ppm	63290	275	63565	8362	20	167240	103675	2.63
T₃ NAA @ 50 ppm	63290	835	64125	8921	20	178420	114295	2.78
T₄ @ NAA 25 ppm	63290	417.5	64041.5	8444	20	168880	104838.5	2.63
T₅ IBA @ 50 ppm	63290	425	63665.75	8299	20	165980	102314.25	2.60
T₆ IBA @ 25 ppm	63290	212.5	63502.5	8115	20	162300	98797.75	2.55
T₇ Tricontanol @ 10 ppm	63290	150	63440	8246	20	164920	101480	2.59
T₈ Triacontanol @ 5 ppm	63290	70	63365	8081	20	165620	102255	2.61
T₉ water soaked	63290	-	63290	8057	20	161140	97850	2.54
T₁₀ Control dry seed	63290	-	63290	7902	20	158040	94750	2.49

4.2.2.8 Fruit yield per plot

The data presented in Table 4.9 reveal that the number of fruit yield per plot significantly varied due to the treatments as compared to the control. The maximum fruit yield per plot was recorded in T₃ (4.48 kg) followed by T₁ (4.32 kg), T₄ (4.24 kg) and T₂ (4.20 kg). While minimum fruit yield per plot was recorded in control (3.96 kg). However, some treatments showed non-significant variation over control as observed in T₉ (4.04 kg), T₈ (4.06 kg) and T₆ (4.06 kg).

4.2.2.9 Fruit yield per hectare

The data on fruit yield per hectare presented in the Table 4.9 clearly show that the treatments had a significant effect on fruit yield. The maximum fruit yield was obtained in T₃ (89.21q/ha) which was statistically at par with T₁ (86.05 q/ha) followed by T₄ (84.44 q/ha) and T₂ (83.62 q/ha). Whereas, the minimum fruit yield was recorded in control (79.02 q/ha). It was observed that NAA 50 ppm gave higher benefit cost ratio (2.78) as compared to other treatment.

4.2.3 Effect of growth regulators on seed quality parameters

4.2.3.1 Number of seeds per fruit

Data recorded on number of seeds per fruit are depicted in Table 4.11, it may be inferred from the data that the number of seeds per fruit were significantly affected by application of growth regulators. The number of seeds per fruit was found to be maximum in T₃ (58.13) followed by T₄ (57.37), T₂ (56.63), T₅ (55.97) and T₁ (54.70). The minimum number of seeds per fruit was obtained in control (50.03).

4.2.3.2 Test weight

It is evident from the data tabulated in the Table 4.11 that the test weight was significantly varied due to the treatments as compared to control. The test weight was recorded to be maximum in T₁ (7.84 g) which was statistically at par with T₃ (7.68g), T₅ (7.54 g) and T₂ (7.35 g). While, the minimum test weight was observed in control (5.33g) which was significantly lower than other treatments.

4.2.3.3 Seed Germination per cent

The data presented in Table 4.11 reveal that the seed germination per cent significantly varied due to the treatments as compared to control. Germination per cent was found to be maximum in T₁ (94.67 per cent) which was statistically at par with T₂ (93.35 per cent), T₅ (91.38 per cent) and T₃ (90.68 per cent). The control recorded the minimum seed germination per cent (81.00 per cent).

4.2.3.4 Seedling shoot length

On perusal of data tabulated in Table 4.11, it is evident that all the treatments significantly enhanced the seedling shoot length as compared to the control. The maximum shoot length was recorded in T₁ (16.24cm) which was statistically at par with T₃ (15.69cm), T₄ (15.32cm) and T₂ (15.27). While, the minimum shoot length was recorded in control (13.70cm) Fig.7.

4.2.3.5 Seedling root length

The data on seedling root length presented in the Table 4.11, clearly show that all the treatments significantly enhanced the seedling root length as compared to control. The maximum root length was obtained in T₅ (9.48cm) which was statistically at par with T₆ (8.61cm), followed by T₃ (8.31cm) and T₁ (8.14cm). While, the minimum root length was recorded in control (5.53cm) which was significantly lower than other treatments. Though all the treatments had significant variation over control but between some of the treatments, there was non-significant difference as it was noticed in T₂, T₄, T₇ and T₈, Fig7.

4.2.3.6 Fresh seedling weight

On perusal of data tabulated in Table 4.11, it is depicted that the fresh weight of seedling was significantly enhanced due to treatments as compared to control. The result was observe in maximum seedling weight T₁ (6.35 g) which was statistically at par with T₃ (6.22 g), followed by T₅ (5.83 g) and T₄ (5.81 g). The seedling weight was found to be lowest in control (4.75 g). Though, all the treatments had significant difference over control, but between or among the treatments, there were non-significant differences as it was noticed in T₂, T₄, T₅, T₆, T₇, T₈ and T₉.

4.2.3.7 Dry seedling weight

The data compiled in Table 4.11, exhibit a highly significant increase in dry weight of seedling under the treatments as compared to control. The maximum dry seedling weight was found to be highest in T₁ (29.50 mg) followed by T₃ (26.60 mg), T₂ (25.57 mg) and T₄ (25.43 mg). The dry seedling weight was recorded lowest in control (19.40 mg). However, the treatments T₁₀, T₉, and T₈ gave the similar response with respect dry weight. Similarly T₂, T₃, T₄ and T₆ produced the similar effect.

4.2.3.8 Vigour index Type - I

The statistical analysis of the data presented in Table 4.11, reveals that all the treatments significantly increased the vigour index type –I over the control. The maximum vigour index type – I was found in T₃ (2368.32) which was statistically at par with T₁ (2308.05), followed by T₅ (2238.81) and T₂ (2165.45). While, the minimum vigour index type – I was recorded in control treatment T₁₀ (1557.63).

4.2.3.9 Vigour index Type - II

The data pertaining to vigour index type –I is presented in Table 4.11, it is apparent from the data that most of the treatments had significant variation. The maximum vigour index type –II found in T₁ (26.89) which was statistically at par with T₂ (23.89), followed by T₃ (22.20) and T₄ (19.60). While minimum vigour index type – II was recorded in control treatment T₁₀ (19.11).

Table 4.11: Effect on seed quality parameters in Okra cv. Utkal Gaurav by different growth regulators on seed treatment.

Treatment	Number of seed per fruit	Test weight (g)	Germination per cent	Seedling shoot length (cm)	Seedling root length (cm)	Fresh Seedling weight (g)	Seedling dry weight (mg.)	Vigour Index Type - I	Vigour Index Type - II
T₁ GA₃ @ 50 ppm	54.70	7.84	94.67	16.24	8.14	6.35	29.50	2368.32	26.89
T₂ GA₃ @ 25 ppm	56.63	7.35	93.35	15.27	7.97	5.75	25.57	2165.45	23.89
T₃ NAA @ 50 ppm	58.13	7.68	90.68	15.69	8.31	6.22	26.60	2308.05	22.20
T₄ @ NAA 25 ppm	57.37	6.88	88.54	15.32	7.85	5.81	25.43	2051.47	19.60
T₅ IBA @ 50 ppm	55.97	7.54	91.38	15.02	9.48	5.83	23.27	2238.81	19.21
T₆ IBA @ 25 ppm	55.63	6.67	89.15	14.95	8.61	5.68	24.03	2100.37	19.08
T₇ Tricantanol @ 10 ppm	53.46	6.97	87.82	14.57	7.65	5.62	22.30	1953.58	16.97
T₈ Triacantanol @ 5 ppm	55.37	6.53	86.92	14.34	7.27	5.58	21.40	1878.34	15.85
T₉ water soaked	53.07	6.22	85.64	13.75	6.75	5.52	20.40	1755.62	14.67
T₁₀ Control dry seed	50.03	5.33	81.00	13.70	5.53	4.75	19.40	1557.63	12.73
Mean	54.14	6.90	88.92	14.88	7.76	5.71	23.79	2037.77	19.11
SEm±	0.95	0.21	1.03	0.25	0.21	0.09	0.57	54.349	0.80
CD 5%	2.83	0.63	3.05	1.03	0.64	0.27	1.70	161.46	2.37
CD 1%	-	-	4.17	0.75	0.87	0.37	2.33	221.17	3.25

DISCUSSION

Okra (*Abelmoschus esculentus* L.) is an important vegetable crop. It is well known that plants produce various growth regulators, which control the physiological and bio chemical process. Several synthetic plant growth regulators were tested to determine how they regulate or modify growth, yield and seed quality of okra. Their application helps in modified germination, flowering, fruiting, yield and seed quality. Present study was carried out to find the best growth regulators concentration for better growth, high yield and seed quality parameters.

5.1 Foliage spray

5.1.1 Effect of growth regulators on growth parameters of okra cv. Utkal Gaurav.

In the present investigation, effect of plant growth regulators significantly influenced the growth parameters.

Growth regulators spray had significant effect on growth parameters at GA₃ @ 50 ppm at 40 DAS (days after sowing) where maximum plant height (107.97cm) was recorded, followed by NAA @ 50 ppm at 20 DAS (100.75cm). Similar results were obtained by (Patil and Patel 2010), where significant plant height (107.3 cm and 110 cm) increase was noticed with GA₃ @ 25 and 50 ppm. Similar finding was reported by Rani *et al.* (2013).

The application of growth promoters increased the plant height due to enhancement in the cell division and cell elongation at shoot apex and such effect was due to increase in photosynthetic efficiency (Taiz and Zeiger 2010).

The highest stem girth (5.20cm) was recorded in treatment NAA @ 50 ppm spray at 20 DAS while lowest (3.48cm), was recorded with control. It may be due to decreased apical growth and increase in translocation of food reserves to stem. Similar result was observed with promoters in onion by Shakhada and Gajipara (1998).

Days to first flowering was found to be earliest in (31.47 days) NAA @ 50 sprays at 20 DAS which was statistically at par with (33.08 days) spray of GA₃ @ 20 ppm at 20 DAS and NAA @ 50 ppm at 40 DAS. Similar result was reported in Chandiniraj *et al.* (2016) where spray of NAA @ 75 ppm had earliest flowering (38.26 days) in chilli. The plants sprayed with NAA remained physiologically more active to build up sufficient food reserve for developing flowers and seed. Similar results have been confirmed by Natesh *et al.* (2005) and Deshmukh (2010) in chilli.

5.1.2 Effect of growth regulators on yield parameters of okra cv. Utkal Gaurav.

Significant highest fruit length (16.58 cm), fruit girth (6.46 cm) and fruit weight (16.47gm) were recorded in the treatment sprayed with NAA @ 50 ppm at 40 DAS, followed by combined spray of GA₃ @ 20 ppm at 20 DAS and NAA @ 50 ppm at 40 DAS. Regarding NAA, similar results were reported by Chattopadhyay and Sen (1974), where NAA @ 50 ppm resulted in maximum fruit length and width.

The increased fruit length, girth may be due to the increase in number of leaves resulting in increased photosynthesis and maximum distribution of assimilates. These results have been reported by Kore *et al.* (2003) where sprayed NAA @ 50 ppm sprayed at pre blooming stage and observed the maximum fruit length and girth.

Fruit yield of 4.83 kg/plot and 96.63 (q/ha) fruit yield per hectare was recorded in NAA @ 50 ppm at 40 DAS followed by combined spray of GA₃ @ 20 ppm at 20 DAS and NAA @ 50 ppm at 40 DAS were superior to control.

It is a well-established fact by several workers that increased yield is product of increased yield parameters like fruit length, width and number of seeds. The increased yield with NAA is due to greater mobilization of reserved food materials to fruit and seed, which ultimately increase the fruit length, width and number of seeds. Regarding NAA similar results were reported by Chattopadhyay and Sen (1974), Kishan *et al.* (2001).

5.1.3 Effect of growth regulators on seedling parameters of okra cv. Utkal Gaurav.

Among the growth regulator, test weight was highest (8.03gm) in NAA @ 50 ppm at 40 DAS followed by combined spray of GA₃ @ 20 ppm (7.67gm) at 20 DAS and NAA @ 50 ppm at 40 DAS. Similar results were found in two foliar application of NAA @ 50 ppm, which increased pod per plant and 1000 seed weight in fenugreek as reported by Godara *et al.* (2013). This may be due to better diversion of photosynthesis to the fruit and better accumulation of food reserves in the seeds. Similar results have been confirmed by Reddy and Bhat (1997).

Growth regulator improved the seed quality parameters over control. NAA @ 50 ppm spray at 60 DAS recorded maximum root length (9.40cm), seedling weight (6.43 g) and dry seedling weight. Vigour index type-I & II maximum was recorded with (2210.29 and 22.58) NAA @ 50 ppm spray at 60 DAS followed by (2184.50) GA₃ @ 50 ppm at 20 DAS spray.

Seeds become more viable and vigorous due to proper development of embryo and endosperm by proportionate use of growth regulators. Similar was recorded in Khan *et al.* (2013) where maximum vigour index (2593.01) was recorded with application of NAA @ 100 ppm as compared to control which recorded least vigour index (2309.48). These results are in conformity with that of Baruah & Paul (1997), Velumani & Ramaswamy (1977).

5.2 Seed treatment

5.2.1 Effect of growth regulators on growth parameters of okra cv. Utkal Gaurav

The Minimum number of days require for germination is GA₃ @ 50 ppm (2.07 days) start germination, (6.59 days) 50% germination, (9.35 days) full germination. Similar result was reported by Dhoran & Gudadhe (2012), where GA₃ was highly effective of germination in Asparagus seeds superior over the control. GA₃ increases the activity of hydrolytic enzymes during germination process. Hydrolytic enzymes get diffused into endosperm, where they catalyse the digestion of stored food material into sugar amino acid etc. these product are used during germination and seedling emergence (Sinha 2014).

The maximum plant height was found in GA₃ @ 50 ppm (102.08cm) which was statistically at par with NAA @ 50 ppm (100.24cm) sows superior over the control. This increase in plant height is due to its effect on stem elongation by rapid cell elongation and multiplication of cells in sub-apical meristem. The rapid growth that occurs is a result of both the greater number of cells formed and elongation of individual cells. The increase in plant height by GA₃ application has also been reported by Patel (1998), Naruka and Paliwal (1999), Sorte *et al.*(2001) in brinjal and Natesh *et al.* (2005) in chilli.

5.2.2 Effect of growth regulator on yield parameters of okra cv. Utkal Gaurav.

Fruit girth and fruit length was significantly influenced by different growth regulator treatments. Maximum fruit length (15.32 cm) and fruit girth (6.37 cm) was reported GA₃ @ 50 ppm. Similar result was observed in Patil and Patel (2012) where maximum fruits girth (4.77 cm) and fruit length (13.80 cm) was higher in GA₃ treatment followed by NAA. The increase in the size of fruit i.e. length and diameter may be a result of cell enlargement and cell elongation, which is caused by the supply of growth regulators within the plants. These results were supported by Singh and Kumar (1998) and Pawar *et al.*(1977).

Among the growth regulator maximum fruit weight (15.09 g), dry fruit weight (4.96 g) fruit yield per plot (4.48kg) and yield per hectare (89.21) was observe. Similar result was observed in Prasad *et al.* (2013). The fruit yield per hectare significantly increased with the application of NAA and GA₃ as compared to control. The maximum fruit yield (483.6 q/ha) was obtained with application GA₃ @ 80 ppm closely followed by NAA @ 1000 ppm (474.2 q/ha). The possible reason for increasing in fruit yield per hectare is due to increase in number of fruits per plant, average fruit weight and fruit yield per plant in tomato. These results are in conformity with the finding of Akhtar *et al.* (1996) and Soha *et al.* (2009).

5.2.3 Effect of growth regulator on seedling parameters of okra cv. Utkal Gaurav.

Among the growth regulators, highest test weight (7.84 g) was observed with GA₃ @ 50 ppm with germination percentage (94.67 per cent). Similar result was reported in Ravat and Makani (2015) where higher 100 seed weight (6.65 g) was under (GA₃ @ 50 ppm) as compared to control and rest of the treatments.

The increase in seed quality parameters obtained due to spraying of (GA₃ @ 50 ppm) might be due to higher percentage of bolder seeds coupled with the higher test weight of seeds and due to increased translocation and assimilation of photosynthates from source to the sink (seeds). Similar findings were also reported by Balakumar and Balsubramanian (1988), Singh and Lal (1995).

SUMMARY AND CONCLUSION

The investigation “Effect of growth regulator on growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.) cv. Utkal Gaurav” was conducted at Central Farm, Breeder Seed Production Unit College of Agriculture, Bhubaneswar, Odisha from August, 2015 to December, 2015. The salient findings of the experiments are summarized in this chapter.

1. The growth regulators significantly improved the plant height of okra. Maximum plant height was recorded when sprayed with (107.32) GA₃ @ 50 ppm 40 days after sowing.
2. The effect of foliar spray of different growth regulators on the node in which first flower bud appeared found to be non-significant.
3. NAA @ 50 ppm at 20 days after sowing proved to be most effective in improving the stem girth (5.68 days), days taken to first flowering (31.47 days), days to 50 per cent flowering (40.40), days to first harvesting (37.02), and days to pod maturity (66.02 day).
4. Chlorophyll index (22.45) of leaves and TSS (9.80 brix) of fruit was maximum with foliar spray of GA₃ @ 20 days after sowing + NAA @ 50 ppm 40 days after sowing.
5. The yield attributing characters were significantly increased by all treatment combination in comparison to control. However, fresh fruit weight (16.47 g.), dry fruit weight (5.61 g.), fruit length (16.58 cm), fruit girth (6.46 cm), and fruit yield (96.63 q/ha) were maximum with foliar spray of NAA @ 50 ppm at 40 days after sowing.
6. Number of seeds per fruit was enhanced significant by foliar spray of growth regulator at various intervals over control. However, application of GA₃ @ 20 ppm at 20 days after sowing + NAA @ 50 ppm at 40 days after sowing production maximum number of seeds per fruit.
7. Seed germination per cent was recorded highest (91.67 per cent) with foliar spray of GA₃ @ 50 ppm at 20 days after sowing. While seedling shoots length was longest (16.95 cm) with foliar spray of GA₃ @ 50 ppm at 60 days after sowing.

8. The foliar spray of growth regulators resulted in significant improvement in various seedling parameters when compared with control. Application of NAA @ 50 ppm at 60 days after sowing proved to be most effective in improving the root length (9.40 cm), fresh seedling weight (6.43 g.), dry seedling weight (26.77 g.), vigour index type – I (2210.29) and vigour index type – II (22.58).
9. The foliar spray of NAA @ 50 ppm at 40 days after sowing resulted in height B:C ratio (2.96), as compared to control (1.50).
10. Seed treatment with different growth regulators significantly enhanced the seed germination, 100 per cent germination and number of plant at 2 leaf stage at 10 DAS and plant height. Earliest 100 per cent germination (9.35 days) was recorded with GA₃ @ 50 ppm same treatment also resulted in maximum number of plants at 2 leaf stage at 10 DAS (45.17) and plant height (102.08), all these parameters were minimum in control.
11. Effect of seed treatment with different growth regulator on stem girth and node at which first flower bud appeared found to be non-significant over control.
12. Days taken to first flowering (34.31), days to 50 per cent flowering (44.49), days to first harvesting (40.83), days to pod maturity (69.82) were recorded to be earliest with NAA @ 50 ppm.
13. The chlorophyll of leaves was significantly increased by all treatments compared to control. However, maximum chlorophyll index (21.75) was obtained when seeds were treated with NAA @ 50 ppm followed by GA₃ @ 50 ppm.
14. TSS and fruit hardness showed significant variation due to various treatments. TSS (8.94 brix) of fruit was maximum and the fruit hardness (98.34) was lowest in treatment involving seed treatment with GA₃ @ 50 ppm. However, the minimum TSS and maximum fruit hardness was recorded in control.
15. Various yield attributing parameters *viz*, fresh fruit weight, dry fruit weight, number of fruit per plant and fruit yield were significantly enhanced by use of different growth regulators as compared to control. Fresh fruit weight (15.09), dry fruit weight (4.96), number of fruit per plant (14.10) and fruit yield (89.21), were recorded to be maximum with NAA @ 50 ppm. All these parameters were minimum in control.
16. Seed treatment with GA₃ @ 50 ppm proved to be most efficient in enhancing the fruit length (15.32) and fruit girth (6.37).

17. Different seedling parameters were significantly improved by use of growth regulators for seed treatment as compared to dry and water soaked seeds. However, test weight (7.84 g.), seed germination per cent (94.67 per cent), seedling shoot length (16.24 cm), fresh seedling weight (6.35 g.), dry seedling weight (29.50 mg.), vigour index type- I (2308.05), vigour index type- II (26.89 g.) were recorded maximum with GA₃ @ 50 ppm. All these parameters were recorded to be minimum in control.
18. Number of seeds per fruit (58.13) and seedling root length (8.31) was recorded to be maximum when seeds were treatment NAA @ 50 ppm. However, minimum number of seeds per fruit and seedling was obtained in control.
19. Seed treatment with NAA @ 50 ppm resulted in highest B:C ratio (2.78) as compared to control (2.49).

Conclusion

The results obtained during the present investigation reveals that use of growth regulators either as foliar spray or seed treatment enhanced the growth, yield quality and seed parameters of okra. So, it can be concluded that foliar spray of NAA @ 50 ppm 40 days after sowing is most effective in enhancing the yield of okra. While seed treatment with NAA @ 50 ppm is most efficient in improving the yield. These treatments were found to be beneficial for cultivation of okra cv. Utkal Gaurav under Bhubaneswar condition. The same treatments can be recommended to the okra farmers of Odisha both of these treatments gave high B:C ratio (2.96 and 2.49 respectively) as compared to conventional okra farming.

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