Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak

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DEGREE OF

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(VEGETABLE SCIENCE)

BY

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DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

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Dated:
Bhubaneswar

CERTIFICATE I

This is to certify that the thesis entitled **"Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak".** Submitted in partial fulfilment of the requirements for the award of the Degree of **MASTER OF SCIENCE IN AGRICULTURE** (**VEGETABLE SCIENCE**) of the Odisha University of Agriculture and Technology, Bhubaneswar is an authentic record of bonafide research work carried out by **KAMAL LOACHAN PANDA, Adm. No. 08 VSC/17,** 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 evidence and help obtained by him from various sources during the course of investigation has been duly acknowledged.

Dr. C.M. PANDA
(CHAIRMAN)
ADVISORY COMMITTEE

CERTIFICATE II

This is to certify that the thesis entitled "**Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak".** Submitted by **KAMAL LOACHAN PANDA, Adm. No. 08VSC/17** to Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the discipline of **VEGETABLE SCIENCE** has been approved by the students' advisory committee and the external examiner.

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Place: Kamal loachan Panda

Date: Adm. No. 08VSC/16

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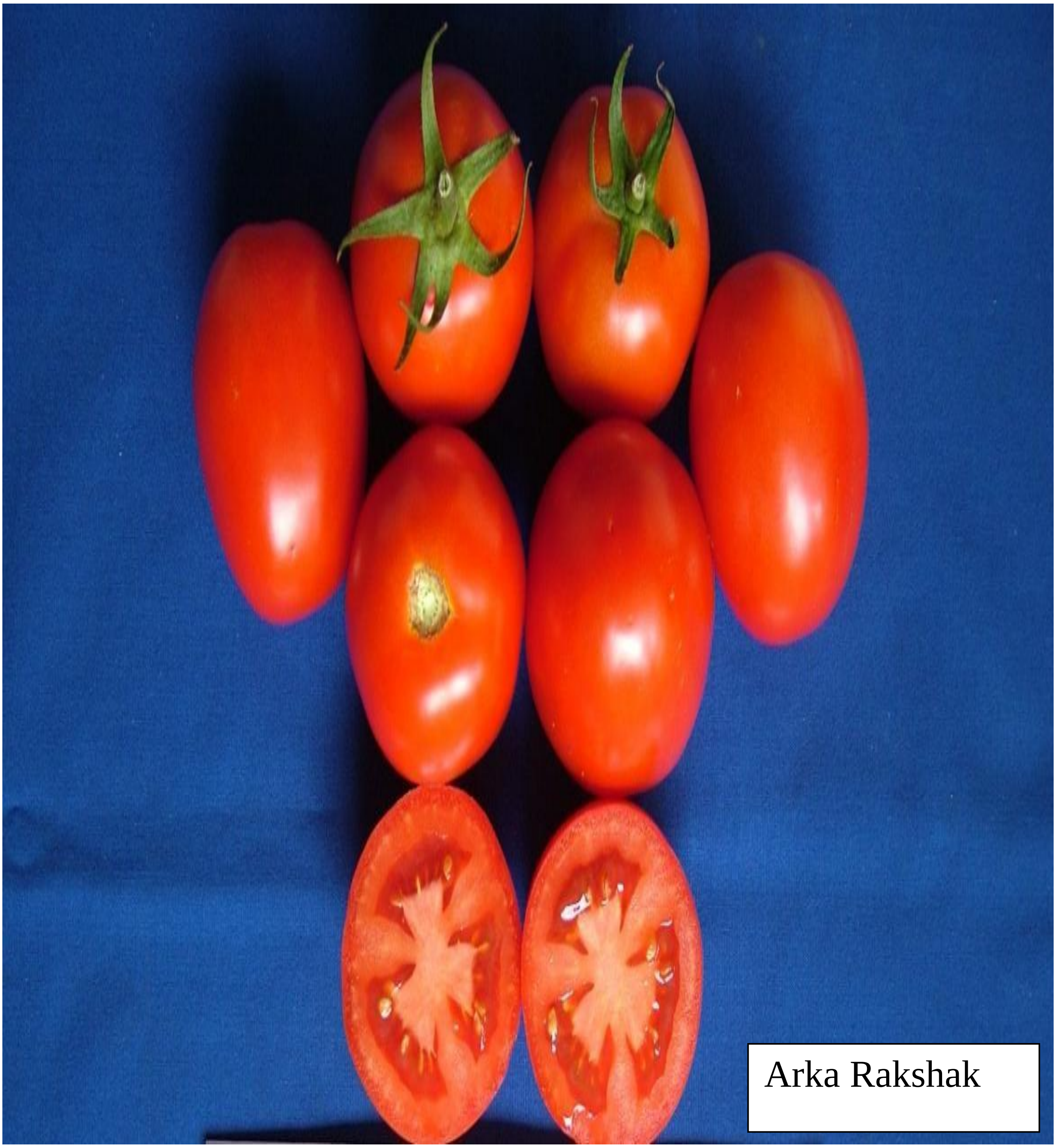
LIST OF ABBREVIATION USED

@	:	At the rate
cm	:	Centimeter
cm^2	:	Centimeter square
C.V.	:	Coefficient of variation
C.D.	:	Critical Difference
cm^2	:	Centimetre square
^{0}	:	Degree
^0C	:	Degree Celsius
d.f.	:	Degree of freedom
SSe	:	Error sum of square
et al.	:	And others
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
hr.	:	Hour
i.e.	:	(*Id est.*) that is
Kg	:	Kilogram
km	:	Kilometer
Max.	:	Maximum
MT	:	Metric Ton
MSS	:	Mean sum of square
m	:	Meter
mm	:	Millimeter
Min.	:	Minimum
Viz.	:	Namely
No.	:	Number
N.B.	:	Nota bene
/	:	Per
%	:	Per cent
R.H.	:	Relative humidity
SSr	:	Replication sum of square
SEm	:	Standard error of mean
t	:	Ton

ABSTRACT

The present research work entitled, "**Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak**" was conducted during *rabi*, 2018-19 at research field of Department of Vegetable Science, Odisha University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in Randomized Block Design (RBD) with thirteen treatments such as T_1 – Control, T_2-NAA (25 ppm), T_3-NAA (25 ppm)1st spray, Triacontanol (.05%EC) 2nd spray, T_4-Boron (0.2%) 1st spray, NAA (25 ppm) 2nd spray,T_5-Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray, T_6-Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray, T_7-Triacontanol (0.05%EC),T_8-Boron (0.2%)1st spray, Triacontanol (0.05%EC) 2nd spray, T_9-Calcium (0.5%) 1st spray, Triacontanol (0.05%EC) 2nd spray ,T_{10}-Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray ,T_{11}-Boron (0.2%),T_{12}-Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray,T_{13}-Calcium (0.5%) which were replicated twice. The results revealed that the maximum values of morphometric characters such as plant height (105.51 cm), number of branches per plant (9.75) and number of leaves per plant (255.20) were recorded with foliar application of Boron (0.2%) as 1st spray, Calcium (0.5%) as 2nd spray, Triacontanol (0.05%EC) as 3rd spray chronologically (T_{10}). Highest yield and yield attributing parameters such as fruit diameter (4.65 cm), fruit weight (72.06 g), fruit yield per plant (4.26 kg) and yield per hectare (60.39 t) were recorded with foliar application of Boron (0.2%) as 1st spray, Calcium (0.5%) as 2nd spray, Triacontanol (0.05%EC) as 3rd spray chronologically (T_{10}) . Similarly highest benefit-cost ratio of (6.22) was observed with foliar application of Boron (0.2%) as 1st spray, Calcium (0.5%) as 2nd spray, Triacontanol (0.05%EC) as 3rd spray chronologically (T_{10}). Whereas the highest yield attributing parameters such as flowers per cluster (9.1), fruit per cluster (8.0) and fruit per plant (59.07) were recorded with foliar application of Boron (0.2%) as 1st spray, Calcium (0.5%) as 2nd spray, NAA (25 ppm) as 3rd spray consecutively (T_6). Thus, in this experiment it was observed that foliar application of Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray consecutively produced better plant height (105.51 cm), maximum number of leaves per plant (255.20), highest fruit diameter (4.65 cm), highest fruit weight (72.06 g), highest yield per hectare (60.39 t) and highest benefit-cost ratio of (2.40) as compared to other treatments in Arka Rakshak hybrid variety of tomato released from IIHR.



Arka Rakshak

INTRODUCTION

The crimson vegetable (*Solanum lycopersicum* L.) popularly referred to as 'wolf apple' is a handsome member of the nightshade family (Solanaceous). During 1893, US Supreme Court declared it as a vegetable for its culinary use although it is a fruit botanically. Marching along with some tropical parts of America, it reached in the Indian subcontinent, acclimatised here and conquered the kitchen from South to North, in such manner that, it is hard to be believed for an exotic vegetable.Gradully its popularity percolated down to earth making it an essential item of every kitchen of the countryside. The patterns of consumption in raw form (salad) as inoculated from the west or in the cooked form (sauce, puree, ketchup, soup) in indigenous type are equally adorable. A decent supply of vitamin A, vitamin C, Ca, Fe, protein, Na, K, Mg (USDA, 2016) antioxidants and carotenoids (Dimasico *et al*., 1989) helps in retarding cancer and degenerative diseases (Giovannucci, 1999). As a recent discovery, the antioxidant lycopene which imparts a red colour to fruit possesses tremendous nutritional property to render it as a "protective food". The well ripe tomato (per 100 g of edible portion) contains water (94.1%), energy (23 calories), calcium (1.0 g), magnesium (7.0 mg), vitamin A (1000 IU), Ascorbic acid (22 mg), thiamine (0.09 mg), riboflavin (0.03 mg) and niacin (0.8 mg). Besides the other pharmacological uses of tomato as a blood purifier, intestinal antiseptic, renal stimulant, anti bronchitic properties are harnessed in present day lifestyle. Owing to its importance in nutritional security, the cultivation of the crop is now gaining momentum. In addition, its photoperiodic insensitiveness fits it as a sandwich crop for climate-resilient cropping system.

Commercially it is being cultivated in Bihar, Karnataka, U.P, Odisha, Andhra Pradesh, Maharashtra, Madhya Pradesh and Assam state in the country. The area, production and productivity of tomato in India is estimated as 809 thousand ha, 19697 thousand MT and 24.4 MT/ha respectively (Horticultural statistics at a glance, 2017). In Odisha, the area, production and productivity of tomato is estimated as 91.03 thousand ha, 1311.72 thousand MT and 14.41 MT/ha respectively (Horticultural statistics at a glance, 2017).

Although, tomato is a profitable crop but it's succulent and perishable nature makes it susceptible to various biotic and abiotic stresses, which affects the yield and ultimately the profit. So there is a big question on commercialization and popularity among farmers. So every effort is being made to develop a good hybrid. F1 Hybrid Arka Rakshak released by IIHR, Banglore is considered as a boon for farmers. It is popular among the growers because of its triple disease resistance against Tomato leaf curl virus, Bacterial wilt and Early blight. Besides that, it has better fruit quality attributes like uniform fruit weight, shape, colour and shelf life (18 -20 days). Also fruits are round, deep red, firm and suitable for fresh market. Undeniably the problem of poor fruit set, fruit and flower drop, physiological disorders etc. impair the quality as well as quantity of the crop, hence we are unable to get the potential yield. For which plant growth regulators & micronutrients are considered to be the major factor.

So the plant growth regulators are used extensively in horticulture to enhance growth and improve yield by increasing fruit number, fruit set and size. Also maintain the balance between vegetative and reproductive growth.

The plant growth regulators, Triacontanol (TRIA) [$CH_3(CH_2)_{28}CH_2OH$] is a straight chain fatty alcohol of thirty carbon atoms and has been recognized as a distinguished chemical for various agricultural and horticultural crops (Ries *et al*., 1977; Ries, 1985).

The growth regulator, NAA has an important effect on the fruit retention of several vegetable crops thus increasing the yield substantially (Younis and Tigani, 1977). Application of NAA increases higher fruit set, thereby total yield as well as induces earliness in flowering of tomato.

Supplementation of micronutrients for achieving higher yield potential is essential. Tomato being highly responsive among vegetables to the application of micronutrients thereby increases the yield of fruits. Thus, the application of essential nutrients enhances the uptake and utilization of essential elements (Phillips *et al*., 2004) and decrease nutrient deficiency related disorders. Among the nutrients, boron and calcium are considered an important for tomato.

Calcium is an important secondary macronutrient (Kadir, 2004), which may be deficient in plants either due to low calcium in the soil or low calcium availability due to high soil pH or and low mobility in the plants especially to the fruits (Kadir, 2004; Peter, 2005). Therefore, the endless offer of Ca is needed for leaf development, plant canopy, and vigorous root growth (Delamor and Marcelis, 2006). Calcium is one of the important nutrient used for management of different physiological disorder like blossom end rot (BER). BER is one of the promising physiological disorder which reduces the yield and quality.

The role of boron in carbohydrate metabolism and translocation of sugars has already been well-established and a number of physiological disorders in plants are attributed to boron deficiency. Deficiency in tomato causes distorted young leaves and early death of growing point. Fruit cracking is the most important physiological disorder caused due to boron deficiency. The role of boron in the formation of chlorophyll in plants was well established. Also cracking of tomato is managed effectively by application of boron.

Many nutrients are either associated with or accelerate the production of different aminoacids which act as the precursor of growth regulators. Foliar application of such micronutrients is translocated through the plant system in a complex mechanism to the site of growth regulator synthesis with a particular stimulation called signalling. Thus realizing the significance of the nutrient and plant growth regulators on tomato, the present investigation has been undertaken to know the effect of nutrient (Ca & B), plant growth regulators (Triacontanol & NAA) and combined application of these nutrient and plant growth regulators on the performance of tomato hybrid c.v Arka Rakshak with following objectives:

- To study the effect of plant growth regulators (NAA & triacontanol) and nutrients (Calcium & Boron) on the performance of tomato hybrid Arka Rakshak.
- To study the combined effect on yield and yield attributing character.

◈◈◈◈◈◈◈

REVIEW OF LITERATURE

The literature has relevance to the "**Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.)hybrid Arka Rakshak**" is briefly discussed below. In this chapter, similar work done on the crops has been reviewed to understand the effect of different treatments.

2.1 Effect of plant growth regulators on morphomatric characters

Gupta and Gupta (2000) conducted an experiment by application of auxins (IAA and NAA) at 25 and 50 days after transplanting (DAT) at 25 ppm and 75 ppm, respectively on tomato cv. Krishna. The maximum plant height at 75 DAT was 82 cm and a maximum number of branches (30) at 60 DAT was significantly ($P<0.05$) observed with 75 ppm application of IAA. The early flower initiation (28 days) was significantly observed with 25 ppm NAA application compared to the control. The minimum days for fruit setting in the plant were 42 DAT, observed significantly with the treatment of 25 ppm NAA application.

Singh and Lal (2001) found that a reduction in plant height, branches per plant, fruit per plant, fruit yield, fruit dry matter and weight per fruit due to application of 40 ppm NAA and 10 PPM GA_3, as compared to 20 ppm NAA and 5 ppm GA_3 in tomato.

Singh and Sant (2005) observed the effect of different levels of bioregulators (25 and 75 ppm IAA, 25 and 75ppm NAA), micronutrient mixture and their interaction on plant growth, number of branches and yield. Application of 25 ppm NAA recorded an increase in the numbers of branches. Flowering and first fruiting were also significantly increased by the IAA and NAA application.

Bakrim *et al.* (2007) observed the effect of phytohormones: gibberellic acid (GA3), naphthalene acetic acid (NAA), benzyl aminopurine (BAP) application on some morphological and biochemical parameters of tomato. NAA treatment recorded in a reduction in shoot length. GA_3 treatment promoted maximal shoot elongation. BAP affected negatively shoot length only at late stages. NAA inhibited root elongation all along the test period. GA_3 treatment had no effect on root length, whereas BAP showed strong inhibition on root elongation all along the test period.

Khan *et al*. (2009) studied influence of potassium and TRIA alone as well as in combination on growth, yield and quality of the tomato. The treatments included T_0 (K0+deionized water), T_1 (K0+TRIA 1 μM), T_2 (K30+TRIA 1μM), T_3 (K60+TRIA 1 μM), T_4 (K90+TRIA 1 μM) and T_5 (K120+TRIA 1 μM). Three-week-old seedlings of tomato were transplanted to pots. The TRIA was sprayed on plants four times at 10 days intervals starting after 40 days of transplantation. Compared to control (T_0), all the treatments showed significant increases in the plant height, number of leaves, area per leaf, fresh and dry weights of plant, leaf chlorophyll and carotenoids content, leaf-N, P and K contents, fruit yield, fruit ascorbic acid and fruit-lycopene contents. The combination K90+TRIA 1 μM resulted enhanced fruit yield, ascorbic acid, lycopene and β-carotenoids content by 57.6, 6.7, 9.5 and 8.3%, respectively over the control. Thus, along with soil application of potassium (90 kg K/ha), very dilute foliar sprays of TRIA (1 μM) could be used successfully for the amelioration of growth, yield and quality of tomato crop.

Uddain *et al.* (2009) observed significantly highest plant height at 75 DAT and a maximum number of branches at 60 DAT with 75 ppm NAA along with 2000ppm NAA application as compared to control. A minimum day for fruit setting in the plant was 42 DAT, observed significantly with the treatment of 25 ppm NAA along with Humaur (P_3M_2).

Naeem *et al*. (2011) observed that the TRIA-mediated improvement in growth, yield, photosynthesis, protein synthesis, uptake of water and nutrients, nitrogen-fixation, enzymes activities and contents of free amino acids, reducing sugars, soluble protein, and active constituents of essential oil in various crops. Expectedly, TRIA enhances the physiological efficiency of the cells and, thus, exploits the genetic potential of the plant to a large extent.

Singh and Singh (2011) reported the effect of different doses of NAA (N_0 0 ppm, N_1 50 ppm, N_2 100ppm and N_3 120 ppm) on vegetative growth, yield and quality of three tomato cultivars *viz*., NUN-1560 (V_1), NUN-964 (V_2) and NUN-963 (V_3). At NAA 50 ppm in all the three cultivars resulted the highest plant height (cm), number of branches per plant, number of fruit clusters per plant, number of fruits per plant, fruit length (cm), fruit width (cm), fruit yield per ha (q), storability (day) and total soluble solids (TSS). The results revealed that cultivars, NAA doses and their interaction effect were significant regarding yield and yield contributing characters and quality parameters.

2.2 Effect of plant growth regulators on yield attributes

Gupta *et al*. (2003) concluded that the application of 75 ppm NAA along with multiplex resulted in the largest fruit size at the maturity stage of tomato and gave maximum yield.

Tonder and Combrink (2003) studied the effects of plant growth regulators, *i.e.* synthetic cytokinin (CPPU) at 1 ml/litre, auxins (1- naphthalene acetic acid [NAA] at 1 ml/litre, 4-chlorophenoxyacetic acid (4-CPA) at 30 mg/litre), gibberellins (gibberellic acid) ProGibb 4% and SupaGibb 4SL at 1 ml/litre each, and a mixture of benzyladenine (6-BA) and GA_4+7 at 1 ml/litre, on the yield of tomato cv. Shirley. The synthetic auxins, 1-NAA and 4-CPA, resulted in an increase in the average fruit mass and number of fruits with a diameter larger than 37 mm but also increased the percentage of malformed fruits. Three applications of the mixture of BA and GA 4%resulted in the most promising by improving the yield of marketable fruits through increases in the incidence of fruit set, the number of fruit per truss, and the overall truss mass.

Ranjan *et al*. (2005) carried out a field trial on tomato to assess the effect of growth regulator NAA at 10 ppm and micronutrients mixture and found that NAA gave superior results in respect of modifying the character as leaf number, leaf area index, number of branches and total number of inflorescence/plant than micronutrients mixture. Higher fruit yield was obtained with NAA treated plants than ethrel and micronutrient mixture.

Meena (2008) conducted a field experiment, treatments comprised of GA_3 (25, 50, and 75 ppm) and NAA (25, 50, and 75 ppm). Two foliar sprays at 50 ppm produced significantly more plant height and plant spread at 45 DAT and at harvest, leaf area per plant at harvest, number of flowers per plant, fruit set percentage, number of fruits per plant, fruit weight, yield, TSS and ascorbic acid. GA3 at 75 ppm as foliar spray recorded significantly lower fruit drop percentage compared to the rest of the plant growth regulator treatments. Application of GA_3 at 50 ppm compared to 25 and 75 ppm GA_3 and NAA recorded significantly higher total soluble Solid, ascorbic acid content and TSS/acid ratio and lower acidity percentage.

Deb *et al*. (2009) studied the effect of various growth regulators namely NAA (0, 25, 50 and 75 ppm) and GA_3 (0, 15, 40 and 60 ppm) in factorial randomized block design on yield and fruit quality of tomato. The significant response of NAA (25 ppm) with respect to number of fruits/plant, fruit weight/plant, total soluble solid (TSS) and vitamin C and yield was obtained over the control. Similarly, application of 40 ppm GA_3 resulted in maximum yield and vitamin C. Combined application of NAA (25ppm) and GA_3 (40ppm) was more effective than their individual application in terms of yield, TSS and vitamin C content, respectively.

Saha *et al*. (2009) observed the effect growth regulators NAA (0, 25, 50 and 75 ppm) and GA_3 (0, 15, 40 and 60 ppm) on yield and fruit quality of tomato. The significant response of NAA (25 ppm) with respect to number of fruits/plant, fruit weight/plant, total soluble solid (TSS) and vitamin C and yield was obtained over the control. GA_3 at 40 ppm similarly gave maximum yield and vitamin C. Combined application of NAA (25 ppm) and GA_3 (40 ppm) was more effective than their individual application in terms of yield, TSS and vitamin C content, respectively.

Mourya *et al.* (2013) premeditated the effect of NAA *i.e*., (N_0: control, N_1: 20 ppm, N_2:40 ppm, N_3:60 ppm, N_4: 80 ppm) on tomato crop using three cultivars (V_1: Tomato Hybrid-2258, V_2: TM-1, V_3: TM-3). The fruit yield increased by about 30% with the application of NAA (40 ppm) under field condition. The application of 40 ppm NAA and cultivar TM-1 was found to be better. So he concluded that NAA has a beneficial role on yield and quality of tomato.

Prasad *et al.* (2013) observed the effect of GA_3 and NAA on tomato. The different concentration of GA_3 (20, 40, 60 and 80 ppm) and NAA (25, 50, 75 and 100 ppm) were sprayed on the crop to study the growth behaviour, yield and yield attributes of tomato. It was observed that there was a linear increase in growth parameters like plant height and number of branches per plant with an increasing level of GA_3 and NAA. The maximum plant height was obtained as 85.3 cm and 82.3 cm with the application of GA_3 @ 80 ppm and NAA @ 100ppm, respectively after 60 days of transplanting. The maximum yield of 483.6q/ha and 472.2 q/resulted with the use of GA_3 @ 80 ppm and NAA @100ppm, respectively

2.3 Effect of nutrients on morphomatric characters

Yadav *et al*. (2001) evaluated the impact of various concentrations of zinc and boron on the vegetative growth, flowering and fruiting of tomato. Application of 7.5 ppm zinc and 1.0 ppm boron gave the highest values for secondary branches, leaf area, total chlorophyll content, fresh weight, foliar length, fruit breadth and fruit number.

Babu (2002) conducted an experiment in Nagaland, India during 1998-2000 to determine the effects of foliar application of boron (50, 100, 150, 200, 250 and 300 ppm) on the growth, yield and quality of tomato. When the plant was drenched with 250 ppm aqueous solution of boron give the highest yield (327.18 and 334.58 q/ha).

Hamsaveni *et al*. (2003) convoyed involving foliar sprays of gypsum and boron on tomato at Dharwad, Karnataka revelled foliar spray of B at 0.5 per cent in increasing plant height fruit size, fruit weight, number of fruits per plant, fruit yield (31.82 tonnes/ha), number of seeds per fruit (142.83) and seed yield (241.00 kg/ha). At plant height and days to 50 per cent flowering the interaction effect of gypsum and B was significant, which were favoured by application of 150 kg gypsum/ha and 0.5 per cent boron.

Oyinlola (2004) conducted that the application of boron significantly increased the number of leaves and dry matter yield of the crop. A significant correlation existed between growth, yield parameters when plants supplied with 2 kg B/ha recorded the highest number of leaves and dry matter yield.

Bhatt and Srivastav (2006) accompanied a field experiment to study the effect of foliar application of micronutrients i.e iron, zinc, copper and boron at 100 ppm each on tomato and observed increased in the nutrient content of nitrogen, phosphorus and potassium in plants shoots which was 3.61,0.81and 1.54, respectively

Jyolsna and Usha (2008) observed that boron@1.0 kg/ha. with recommended doses of chemical fertilizers resulted that B significantly increased plant height and a number of primary branches. It also reduced the days to flowering and increased fruit set (12.5 to 20 per cent more at the highest level) both with and without FYM.

Meena (2010) observed that significantly more plant height and plant spread at 60 DAT and at harvest, leaf area per plant at harvest, number of flowers per plant, fruit set percentage, number of fruits per plant, average fruit weight and fruit yield and lower fruit drop percentage were obtained at application of boron as foliar spray at 2.0 kg ha^{-1}.

Sathya *et al*. (2010) studied the effect of foliar application of boron on growth, quality and fruit yield of PKM 1 tomato. The results revealed that out of twelve different treatments, the application of boric acid @ 0.25% resulted in maximum plant height and maximum number of branches.

Rab and Haq (2012) studied the effect of $cacl_2$ and borax on growth, yield and quality of tomato and found.$cacl_2$ (0.6%)+borax (0.2%) recorded in the maximum plant height(86.60 cm), branches per plant (7.21) , flowers per cluster (32.36), fruits per plant (96.37), fruits weight (96.33 g),yield (21.33 t ha -1), fruit firmness (3.46 kg cm -2) , and total soluble solids (6.10%) and the lowest blossom end rot incidence (6.25%), However , the difference among cacl2 (0.6%)+borax (0.2%), 0.3%$cacl_2$ +0.2% borax and 0.6%$cacl_2$ +0.4% borax was non-significant.

Naga *et al*. (2013) conducted a field experiment during *rabi*-2010.The experiment was laid out in RBD with three replications to find out the response of foliar application of micronutrients on vegetative and reproductive growth attributes, in two varieties of tomato viz- UtkalKumari and Utkal Raja. The treatments consist of boron, zinc, molybdenum, copper, iron, manganese, a mixture of all and control. All the Micronutrients except manganese at 50 ppm were applied at 100 ppm in three sprays at an interval of ten days starting from 30 days after transplanting. All the treatments resulted in improvement of plant growth characteristics viz. plant height, number of primary branches, compound leaves, tender and mature fruits per plant in both the varieties. In tomato cv. UtkalKumari, maximum growth rate (85.7 %) was obtained with the application of zinc, followed by application of micronutrients mixture (78.2 %) and boron (77.5 %). Tomato cv. Utkal Raja, maximum increase in branches per plant resulted in the application of manganese (148.7 %) followed by micronutrient combination (144.1 %). In UtkalKumari, the fruit yield per plant ranged from 1.336 kg to1.867 and in Utkal Raja, it ranged from 1.500 kg to 1.967 kg. In both the varieties, the combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

Haleema *et al*. (2018) investigated the effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato and found that Calcium application at 0.6% increased plant height (88.04 cm), a number of primaries (2.63) and secondary (7.15) branches, leaves plant-1 (182), leaf area (65.52 cm2), and fruit per plant (66.15). In case of B levels, more plant height (88.14 cm), number of primary (2.61) and secondary (7.44) branches, number of leaves plant-1 (177), number fruits plant-1 (67.78) resulted with foliar spray of B at 0.25%, while maximum leaf area was found at 0.5% B. Comparing the means for Zn concentrations, maximum plant height (86.53 cm), number of primaries (2.53) and secondary (6.42) branches, leaves plant-1 (167), leaf area (63.33 cm2), and fruit per plant(63.78) were higher with 0.5% foliar Zn application. The interaction between Ca, B and Zn also showed significant results for most of the attributes. Therefore, application of Ca (0.6%), B (0.25%), and Zn (0.5%) as foliar aerosol is used alone or in together to boost growth and fruit production of tomato.

Ashraf *et al*. (2018) found that treatment T_{12} (Boron (boric acid) =0.2%+calcium chloride=0.3%+nitrogen (urea) =3% solution) proved better results in all parameters (vegetative growth characters, flowering traits, and yield components) followed by T_{10} which shows nearly same effect then other treatments (Boron (boric acid)=0.2%+calcium chloride=0.3% solution) while T_0 (control) was found at the bottom of all treatments.

Reddy *et al.* (2018) observed that. In tomato cv. Arka sourabh, maximum growth rate (85.7 %) was obtained with the application of zinc, followed by micronutrients mixture (78.2 %) and boron (77.5 %). However in tomato cv. Arka vikas, maximum increase in branches per plant was observed with the application of manganese (148.7 %) followed by micronutrient combination (144.1 %). In Arka sourabh, the fruit yield per plant ranged from 1.336 kg to1.867 kg and in Arka vikas, it ranged from 1.500 kg to 1.967 kg. This study proves that foliar application of micronutrients produced good growth and maximum fruit yield in tomato.

2.4 Effect of nutrients on yield attributes

Singaram and Prabha (2000) resulted that the application of borax at 20-20kg /ha or as foliar application 0.2-0.3 % increases the dry weight of tomato shoots at both the flowering and harvest stages and highest fruits yield found in tomato hybrid cv. Naveen.

Srilatha and Shery (2000) observed that weekly foliar calcium application to tomato *(Lycopersicon esculentum* cv. OH 8245 and TR 12) after fruit set resulted in a decreased percentage of tomatoes that peeled completely during processing. With the addition of calcium, the average fruit weight decreased. There was no effect of calcium application on fruit pH or soluble solids, but calcium decreased the titratable acidity).

Bayers *et al*. (*2001*) observed that tomato is grown on with two concentrations of calcium (150 and 300 mg/litre) in combination with four concentrations of magnesium (20, 50, 80 and 110 mg/litre) in autumn 1999. High Ca (300 mg/litre) concentration increased fruit yield, fruit firmness, dry matter, soluble solids and reduced the incidence of blossom end rot.

Cardozo *et al*. (*2001*) conducted an experiment at Espirito Santo do Pinhal, Sao Paulo, Brazil from April to July 2000. The effects of Ca and B fertilizers on the productivity of tomato cv. Debora Max was investigated in Aminobor at 300 ml/100 litres gave the highest value for fruit weight, while Ca at 60 g/100 litres and B at 150 g/100 litres recorded the highest number of fruits.

Saure (2001) concluded that blossom end rot (BER) in tomato is a deficiency of Ca^{++} in the fruit or parts of the fruit in connection with the uptake of nutrients by the roots, transport of Ca^{++} within the fruit or a varying demand for Ca^{++}depending on the growth rate of fruits.

Naresh (2002) established that the application of boron @ 250ppm give the highest fruit yield of 327.18 quintals/ha and 334.58 quintals/ha during two seasons i.e

1998-99 and 1999-2000, respectively. Application of boron also resulted in an increase in total soluble solid (TTS), reducing sugar and ascorbic acid content.

Chandra and Verma (2003) revealed that the effect of boron and calcium on the growth and yield (fruits and seeds) of tomato at Jabalpur, Madhya Pradesh. The results recommended that 2 kg boron/ha + 2 kg calcium/ha when applied recorded the highest fruit (295 q/ha) and seed yield (1.45 q/ha).

Hao and Papadopoulos (2003) studied the effects of Ca and Mg on plant growth, leaf photosynthesis, fruit yield and quality (fruit firmness, dry matter, soluble solids and russeting) and obtained that increased fruit yield and reduce the incidence of blossom end rot (BER) and fruit russeting at higher concentration of calcium (300 mg L^{-1}). High concentration did not affect fruit firmness, fruit size and leaf photosynthesis.

Singh *et al*. (2003) studied that in tomato, foliar application of Boron @0.5% at 40, 50 and 60 DAT gave higher yield.

Poithankar *et al*. (2004) resulted the treatment 0.3% borax and 2% DAP recorded least percentage of cracked tomato fruits (6.54%) and was followed by treatments 0.3% borax + 1% DAP and 0.3% borax alone in tomato cv. Pusa Ruby. Concluded that the foliar application of boron at higher concentration either alone or in combination with DAP reduced the percentage of cracked tomato fruits.

Taylor *et al*. (2004) Concluded that BER was a symptom of Ca deficiency and this deficiency was aggravated by high rainfall, low evapotranspiration and the reduced irrigation and reduced Ca uptake.

Shoba *et al*. (2005) examined the effects of calcium (Ca) and boron (B) fertilizer and ethrel applications in 45x45 cm and 65x45 cm spacing against fruit cracking in the tomato in Tamil Nadu, India. Among the 2 spacing, less fruit: cracking obtained in closer spacing and among the different nutrient treatments, the spraying of B with Ca was effective in controlling fruit cracking.

Murlee *et al*. (2006) reported that application of 0.20 per cent boron gave the highest number of fruits per plant (44.0), number of fruits per plot (704.0), yield per plant (0.79 kg), yield per plot (12.78 kg) and yield/ha (319.50 quintal) whereas the greatest fruit weight (27.27 g) was recorded for 0.10 per cent boron.

Patil *et al*. (2008) observed that. The application of boric acid @ 100ppm resulted in a maximum number of primary branches (18.30), yield (2.07kg) and fruit yield (30.50 t/ha)/plant. Followed by best treatment was the mixture of micronutrients (Bo, Zn, Mn and Fe@ 100ppm and Mo@ 50ppm) recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatment.

Waghdhare *et al*. (2008) documented that the foliar application of boron through solubor and borax @ 140 mg kg^{-1} recorded a significant increase in yield over control. Suggesting that foliar application of solubor or borax @ 280 mg $kg\text{-}^{1}$ is beneficial for increasing yield as well as enhancing the quality of tomato grown on alkaline calcareous soils.

Punith *et al.* (2012) studied the effect of different levels of nitrogen and potassium solution on the yield and quality of tomato, a two factor completely randomized experimental design (CRD) with three replications was conducted with \`Maha\` cultivar in an unheated plastic tunnel. Nitrogen and potassium solution from the source calcium nitrate and potassium phosphate were used with an amount of 4, 6 and 8 and 2, 4 and 6 mmol-1 respectively. Results of the presented experiment revealed different effects of calcium nitrate and potassium phosphate as foliar nutrition and the interaction of these fertilizers on the yield and quality of tomato. The results of this experiment revealed tomato crops fertilized with 6 mmol-1 calcium nitrate and 4 mmolL-1 potassium phosphate contained greater quality.

Salam *et al.* (2011) found that. The combination of-of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cow dung gave the highest pulp weight (90.24%), dry matter content (5.82%), ascorbic acid (11.2 mg/100g). lycopene content (147 μg/100g), chlorophyll-a (42.0 μg/l00g), chlorophyll-b (61.0 μg/100g), boron content (36 μg/g), zinc content (51 μg /g), marketable fruits at t30 days after storage (74%) and shelf life (17 days) .

Naz *et al*. (2012) observed that foliar application of boron at 2kh/ha resulted in maximum number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solid.Maximum number of flower clusters per plant, fruit set percentage and total yield were recorded with Rio Grand cultivar of tomato. Generally, it can be concluded that 2 kg B ha-1 significantly affected flowering and fruiting of Rio Grand cultivar.

Saravaiya *et al*. (2014) steered an experiment to study the effect of foliar application of micronutrients in tomato (Lycopersicon esculentum Mill.) cv. Gujarat Tomato-2. The result clearly displayed that the yield obtained with treatment T_7 (NPK+mixture of all nutrients) had significantly maximum fresh weight of plants (25.65 t ha-1), number of fruits plant-1 (34.26), fruit length (5.52 cm), fruit diameter (4.64 cm), fruit volume (67.53 cm3), single fruit weight (49.20 g), fruit weight per plant (1.68 kg fruit yield ha-1 (46.78 t) and marketable fruit yield ha-1 (45.62 t). This treatment had maximum net return (1, 66,757 Rs./ha) and B:C Ratio 2.72: 1 out all other treatments than over control.

Ali *et al.* (2015) observed that foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3 resulted in maximum plant height (106.9 cm), number of leaves (68.9/plant), leaf area (48.2 cm^2), number of branches (11.9/plant), number of clusters (21.6/plant), number of fruits (1.8/clusters and 33.6/plant), fruit length (5.3 cm), fruit diameter (5.1 cm), single fruit weight (60.4 g) and yield (1.9 kg/plant, 25.7 kg/plot and 58.3 t/ha) while minimum from control. Early flowering (49.3 days) and minimum diseased infested plant (9.4%) were also recorded from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3. Combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth and yield for summer season tomato (BARI hybrid tomato 4).

2.5 Combined effect of plant growth regulators and nutrients.

Kishan *et al*. (2001) studied a maximum number of primary branches (4.73) in the treatment NAA 25 ppm. While the lowest number of primary branches resulted in the treatment boron 50 ppm. Number of primary branches was not influenced by the growth of regulatory substances.

Rai *et al.* (2002) reported that higher temperature interferes with the fruit set and results in flower drop. Reduction in the flower drop, increase the fruit set and improve in yield of tomatoes recorded by foliar application of growth regulating substances and micronutrients.

Bhalekar *et al*. (2006) observed the effects of GA_3, NAA, 4-CPA and boron at 25 or 50 ppm on the growth and yield of tomato (cv. Dhanshree). Plant height was highest with GA3 at 25 and 50 ppm (74.21 and 75.33 cm, respectively), and 4-CPA at 50 ppm (72.22 cm). The number of primary branches per plant did not significantly vary among the treatments. GA_3 at 50 ppm recorded in the lowest number of primary branches per plant (69.55). Boron 50 ppm resulted in the number of fruits per plant (38.86). Boron at 25 and 50 ppm recorded the highest yields (254.2 and 264.4 quintal/ha).

Bokade (2006) informed the effect of NAA and boron at 25 and 50 ppm on the growth and yield of tomato cv.Dhanshree during summer season .Plant height was maximum with NAA at 25 and 50 ppm .The number of primary branches also pointedly increased with the application of NAA.

Desai *et al*. (2012) conducted an experiment to find out the effect of different plant growth regulators and micronutrient on fruit characters and yield of tomato cv. GT-3. Found that application of gibberellic acid @ 75 ppm resulted in maximum fruit length (7.57 cm), girth (6.47 cm) and pulp-seed ratio (12.93) whereas fruit weight (57 g), yield/plant (2.47 kg) and yield/hectare (913.258 q/ha) were found in treatment naphthalene acetic acid @ 75 ppm and the minimum for all the parameters were found in control treatment.

Abbasi *et al*. (2013) studied the effect of Naphthalene acetic acid (0.02%) and calcium chloride (0.5%, 1%) individually as well as in combination applied as foliar in tomato and its effect on growth, nutrient uptake, incidence of blossom end rot, fruit yield, and enhancement of shelf life. The results showed better absorption of calcium in tomato plants and fruits that were treated with NAA togather with $CaCl_2$. A higher level of $CACl_2$ (1%) with NAA (0.02%) increased plant growth and yield by improving mineral uptake of tomato plants. The improved calcium absorption also resulted in lowering the occurrence of blossom end rot in tomato fruits. In addition, it was also observed that during storage at ambient conditions (20-25 °C) for sixteen days, tomato fruits maintained the best quality for longer period of time when treated with calcium chloride (1%) along with naphthalene acetic acid (0.02%) as compared to other treatments. Although, fruit quality was lowered with passage of storage time tomato fruits from treated plants but maintained their quality for longer duration as compared to control.

Chovatia *et al*. (2014) observed that the maximum acidity per cent (1.41%) and ascorbic acid (109.33 mg/100 g pulp) were found in T_4=(naphthalene acetic acid) @ 75 ppm, maximum reducing sugars (1.68%), non-reducing sugars (1.98%), total sugars (3.67%) and TSS (4.33 degrees Brix) were found at (GA_3 75 ppm), whereas maximum boron content (31.00 ppm), Fe content (31.00 ppm) and Zn content (22.33 ppm) were found at (Boric acid 75 ppm), ($FeSO_4$ 150 ppm) and ($ZnSO_4$-1%), respectively The minimum for all the parameters were found in control treatment.

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MATERIALS AND METHODS

The present research work entitled, "Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L**.)** hybrid Arka Rakshak" was carried out to study the sole as well as combined effect of plant growth regulators (NAA, triancontanol) and nutrients (Calcium, Boron) on growth performance and yield attributing characters of tomato hybrid c.v Arka Rakshak.

The experiment was carried out during *rabi*, 2018-19 at Research field of Department of Vegetable Science, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India. The details of materials used and methods implemented for conducting the experiment are characterized in this chapter with appropriate information supported by tables, figures, photographs etc. as and when required.

3.1. Experimental site

The experiment was carried out during the *rabi* season of 2018-19 at research field of Department of Vegetable Science, Odisha University of Agriculture and Technology, Bhubaneswar. The farm is situated about 7 km away from the university and nearer to Bus-stand.

3.2. Topography and climate conditions

Geographically, it is located at latitude of $20^{0}15'$ N and longitude of $85^{0}52'$E. It is about 60 km away from Bay of Bengal having an altitude of 25.5 m above mean sea level. The experimental site falls under the eighteenth agro-climatic region of the country *i.e*. eastern coastal plain and experience a sub-humid climate characterized by warm moist weather. During 2018-19, the minimum and maximum temperature of the experimental site varies between 13 ^{O}C to 38 ^{O}C and receives mean annual rainfall of about 2129 mm. The details of weather parameter for experimental year 2018-19 are presented in the Table 3.1 and figures 3.1, 3.2 and 3.3. A perusal of table revealed the prevailing climate condition during the time of field experimentation.

Table 3.1 Weather data for the period from Nov-2018 to April-2019

Month	Temperature(^{0} C)		Rainfall(mm)		Relative Humidity (%)		Wind Velocity (km/hr)	Bright sunshine hour (hrs)
	Max.	Min.	Rainfall in mm	Total rainy days in month	Max.	Min.		
Nov-18	31.5	18.7	0.0	0	93	48	0.3	7.7
Dec-18	27.2	14.1	11.1	2	89	45	0.5	5.8
Jan-19	28.5	13.0	0.0	0	95	38	0.3	6.5
Feb-19	32.9	17.0	24.6	3	94	35	0.5	7.9
Mar-19	35.2	23.2	7.1	3	92	46	0.8	7.2
April-19	38.0	25.3	29.6	4	90	45	1.8	8.2

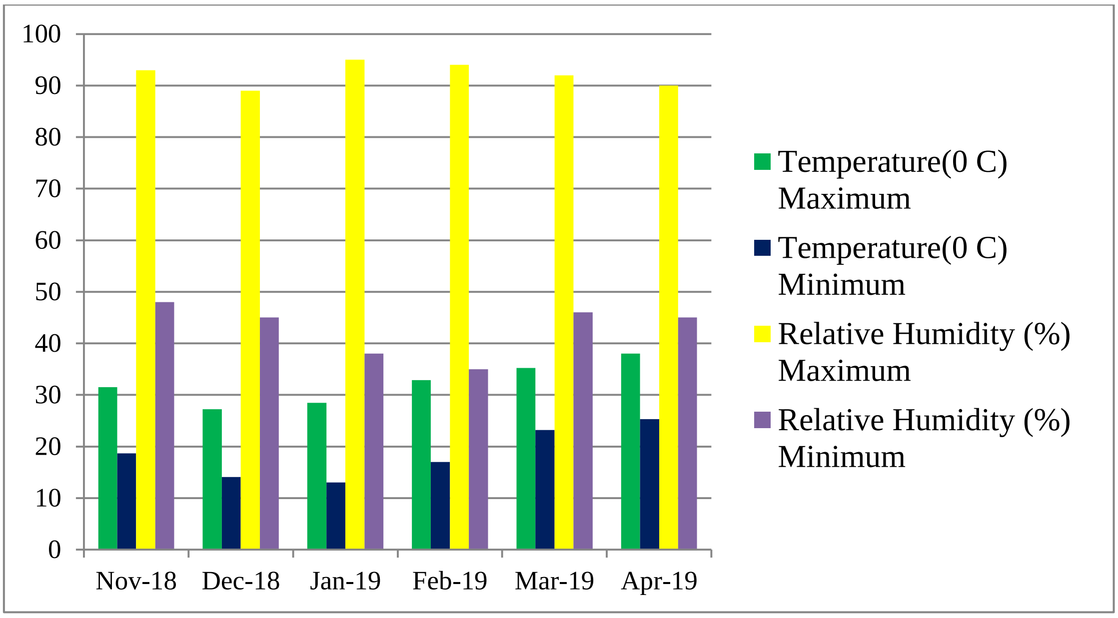

Fig. 3.1 Temperature and relative humidity for the period from Nov 2018 to April 2019

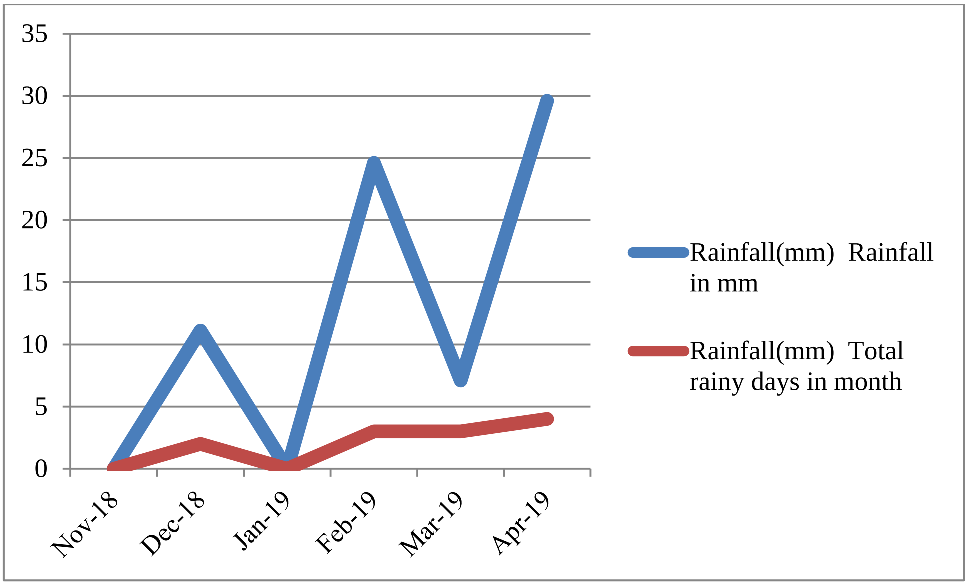

Fig. 3.2 Rainfall for the period Nov-2018 to April-2019

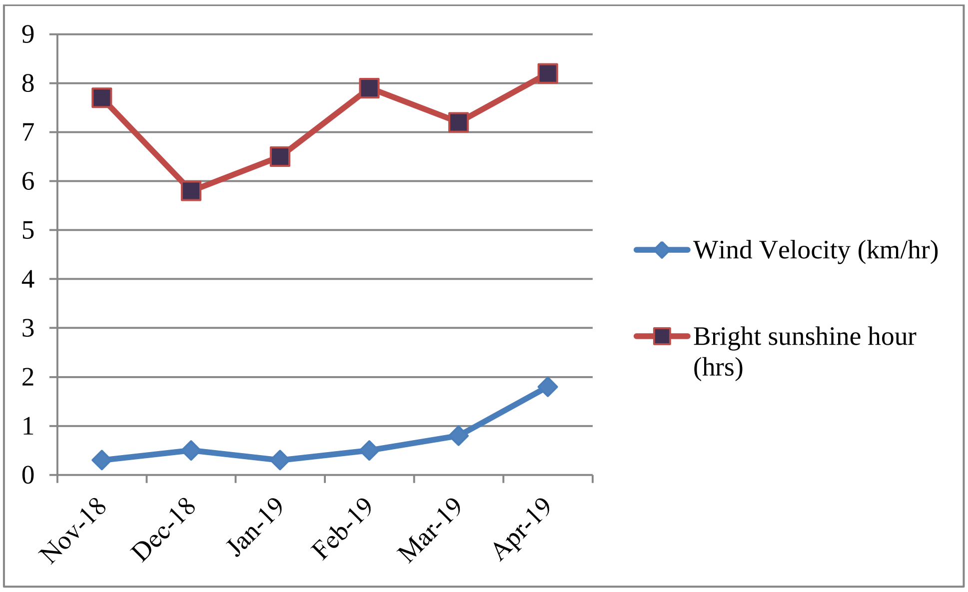

Fig. 3.3 Bright sunshine hours and wind velocity for the period from Nov-2018 to April-2019

3.3. Experimental details

The experiment was laid out in Randomized Block Design (RBD) with two replications. There were thirteen treatments and each treatment was allocated randomly in each replication of the trial. The details of field layout of the experiment are presented in table **3.2, fig.3.4** and standard operating procedure was followed to raise healthy diseased free seedlings. All the recommended package of practices was adapted uniformly to all the treatments in order to raise a good tomato crop. During the period of field experimentation all the observations were recorded from randomly selected plants (5 plants) which are properly tagged.

Table 3.2 Details of layout

Sl. No.	**Crop**	**Tomato**
01	Variety	Arka Rakshak
02	Design	Randomized Block Design (RBD)
03	Number of Replications	2
04	Plot size	2.7m×2.5m
05	Spacing	60cm×60cm
06	Total number of plots	28
07	Number of rows per plot	4
08	Number of plants per row	4
09	Date of sowing	16.11.2018

3.4. Experimental material

Thirteen treatments of Tomato cv. Arka Rakshak were grown in a randomized block design with two replications. The transplanting of experimental material was done on 16 th November 2018. The plants are transplanted in the field at the distance of 60 cm for row to row and 60 cm plant to plant and the plot size was 2.7 × 2.5 m^2. Five competitive plants were selected randomly from each plot to record observation on various characters. The average value of each character was calculated on the basis of five plants for each treatment in every replication.

3.5. Details of treatments

Experiment was laid out in randomized block design with two replications of each treatment. Details of treatments are given in Table 3.3.

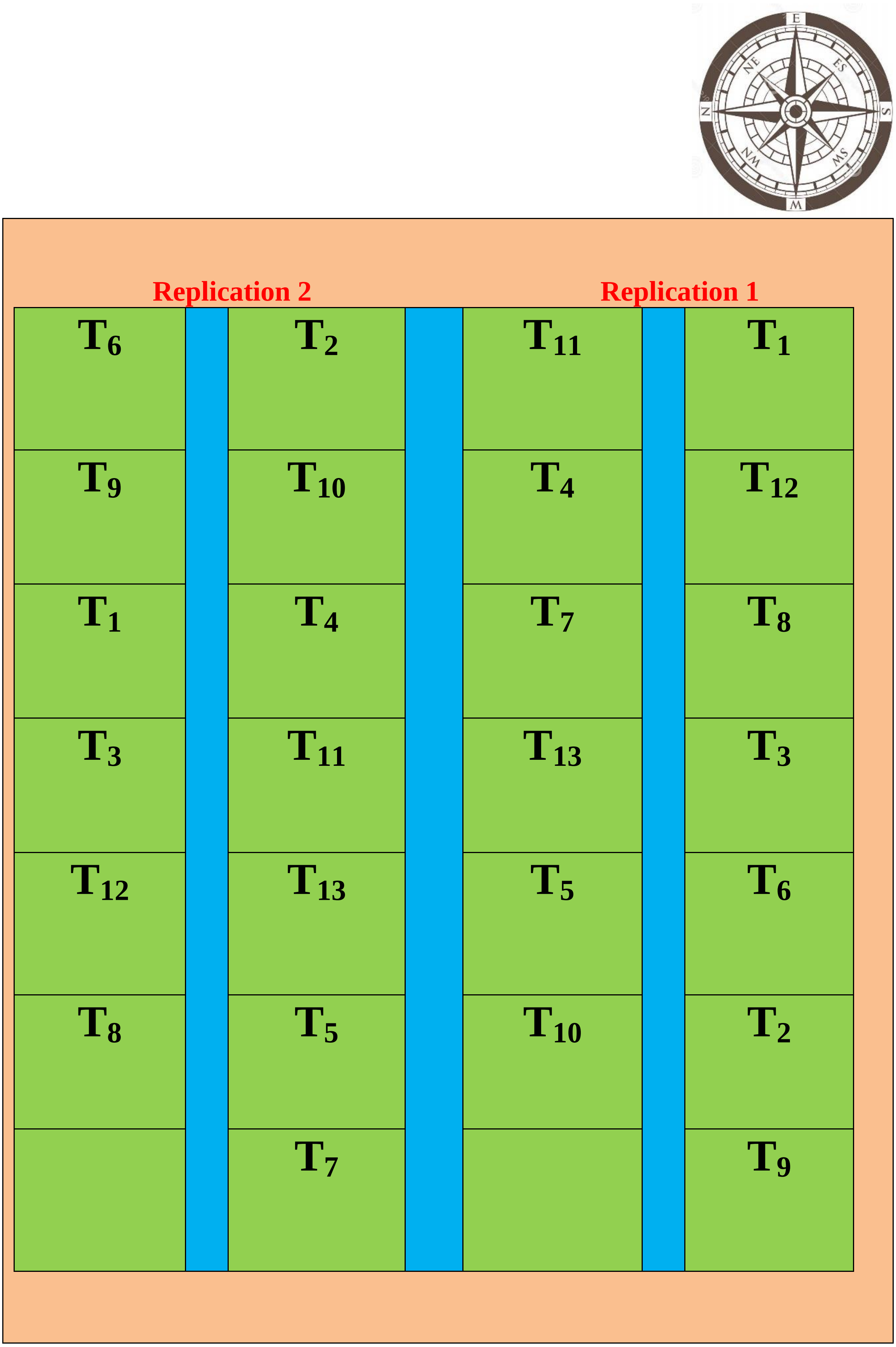

Fig.3.4 lay out plan of experimental plot

Table 3.3 Details of the treatments

TREATMENTS	TREATMENT DETAILS
T_1	Control
T_2	NAA (25 ppm)
T_3	NAA (25 ppm)1st spray, Triancontanol 0(.05%EC) 2nd spray
T_4	Boron (0.2%) 1st spray, NAA (25 ppm) 2nd spray
T_5	Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray
T_6	Boron (0.2%) 1st spray, Calcium(0.5%) 2 nd spray, NAA (25 ppm) 3rd spray
T_7	Triancontanol (0.05%EC)
T_8	Boron (0.2%)1st spray, Triancontanol (0.05%EC) 2nd spray
T_9	Calcium (0.5%)1st spray, Triancontanol (0.05%EC) 2nd spray
T_{10}	Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triancontanol (0.05%EC) 3rd spray
T_{11}	Boron (0.2%)
T_{12}	Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray
T_{13}	Calcium (0.5%)

3.6. Raising of crop nursery

The seeds of Tomato cv. Arka Rakshak sown in nursery were obtained from Indian Institute of Horticulture Research, Bangalore. The seeds of tomato were sown in nursery bed by line sowing followed by covering with paddy straw as mulching material and light irrigation is done by rose can. After germination the mulch was removed and proper care was taken to ensure the proper growth of seedlings in the nursery. Seedlings became ready for transplanting in 30 days.

3.7 Field operation

The field was ploughed twice with incorporation of FYM during final land preparation and levelled properly. Then the individual plots of 2.7m×2.5m were laid out as per the plan of layout with required irrigation channel.

Fig. 3.5 Levelling of field

Fig. 3.6 Prepared nursery bed

Fig. 3.7 Transplanted seedlings

Fig. 3.8 Taking field observations

Fig. 3.9 Field overview

Fig. 3.10 Field overview at peak flowering

Fig. 3.11 Field Overview at peak fruiting stage

3.8 Fertilizer application

` The recommended fertilizer dose of 125 kg N, 75 kg P_2O_5 and 60 kg K_2O per ha was applied. Before applying chemical fertilizers, 2 baskets full of well decomposed FYM was applied to each plot before last ploughing. The first top dressing was done at 20 days after transplanting. The second top dressing was done 40 days after planting at. Two sprays of each nutrients and plant growth regulators were applied sequentially at 15 days interval starting from 30 days after transplanting.

3.9 Irrigation

A light irrigation was given immediately after transplanting of seedlings in the main field. Subsequently, irrigation was provided in the irrigation channel at an interval of 6-8 days during the cropping season.

3.10 Inter-cultural operation

Hoeing, weeding and earthing up were done at periodic intervals. Manual hoeing followed by weeding and earthing up was done followed by earthling up,top dressing and irrigation at 20 and 40 days after transplanting.

3.11 Harvesting

Green fruits were harvested when they reached maturity and attained marketable size i.e. edible maturity stage. Picking of fruits was done till the last marketable produce was obtained.

3.12 Observations recorded

3.12.1 Sampling technique

Observations on various characters were recorded by selecting randomly five competitive plants of each treatment in a replication which were tagged properly. The border plants were excluded while selecting the sample plants. The observations of these tagged plants were taken time to time starting from initiation of 1st flowering to final harvesting of fruits as per the standard research operating procedure,

3.12.2 Plant height (cm)

The plant height of five randomly selected plants was recorded with the help of a meter scale from the base of the plant up to the tip at the time of final harvest and the average height (cm) was calculated.

3.12.3 Number of branches per plant

The total number of primary branches of five randomly selected plants were counted and averaged at the time of final harvesting.

3.12.4 Number of leaves per plant

The total number of leaves of five randomly selected plants were counted and averaged and their mean value was taken.

3.12.5 Leaf area (cm^2)

Leaf area calculated by using graph paper and then the average leaf area of the tagged plants were measured from five randomly selected leaves and these average data was taken to find out mean leaf area of the treatment and expressed in cm^2

3.12.6 Canopy spread

Canopy spread was calculated for both directions by measuring scale taking in two opposite directions.

3.12.7 Flowers per cluster

Number of flower per cluster was recorded as average of full bloom clusters on five randomly tagged plants at flowering stage and the average was calculated.

3.12.8 Fruits per cluster

The average number of fruits cluster was calculated in the same manner as for flowers.

3.12.9 Fruit diameter (cm)

Fruit diameter was recorded by randomly selecting five fruits from five randomly selected plants of each treatment in each replication and average to express in cm.

3.12.10 Fruit weight (g)

Weight of five fruits was recorded in gram from five randomly selected plants of each genotype in each replication and then averaged.

3.12.11 Number of fruits per plant

During each harvesting the number of fruits harvested from the five numbers of randomly tagged plants in each plot was recorded and summed up after final harvest.

3.12.12 Total fruit yield per plant (kg)

The weight of marketable fruits and unmarketable fruits from five numbers of tagged plants from each plot was added up and averaged to get the final value for total fruit yield per plant (kg).

3.12.13 Total fruit yield (qha-1)

The total fruit yield per plot thus obtained was converted to total fruit yield in q per ha for each of the replications for each genotype under study.

3.12.14 Plant weight at harvest (g)

The weight of five randomly selected plants were taken at the time of harvest and expressed in grams.

3.12.15 Root weight at harvest (g)

The root weight of five randomly selected plants were taken at the time of harvest and expressed in grams.

3.12.16 Root shoot ratio

After estimation of root weight and shoot weight of five randomly selected plants root and shoot ratio were calculated.

3.12.17 Disease and pest infestation (%)

During experiment no significance diseased occurred but the incidence of pest leaf minor *Liriomyza trifolii* was observed. Infestation in leaf as well as fruit made by leaf minor was recorded from randomly selected plants. Mean damage by the pests infesting individual plant was then calculated.

3.13 Statistical analysis

The data collected for all the characters involved in the study were subjected to statistical scrutiny for proper interpretation. The standard method of analysis of variance technique appropriate to Randomized Block Design (RBD) as described by Gomez and Gomez (1984) was used. Treatment differences were tested by employing “F” test at five percent level of significance on the basis of null hypothesis. The appropriate standard errors (S.Em. ±) were calculated and the critical difference (C.D.) at five per cent level of probability was worked out to compare the two treatment means, where the treatment effects were found significant under “F” test. The co -efficient of variation percentage (C.V. %) was also worked out given in Table 3.4.

Table 3.4 Skeleton of ANOVA

S.N	Source of Variation	Degree of Freedom	Sum of Squares	Mean sum of squares	F value Calculated	F value Table
01	Replication	(r-1)	SSR	MSR	MSR/MSE	Table value
02	Treatment	(t-1)	SST	MST	MST/MSE	**Significant at 1% *Significant at 5%
03	Error	(r-1) (t-1)	SSE	MSE		
04	Total	(rt-1)				

Where,

r = Number of replications

t = Number of treatments

RSS = Sum of squares due to replication

TrSS = Sum of squares due to treatment (genotypes)

ErSS = Sum of squares due to error

TMS = Mean sum of squares due to treatment

EMS = Mean sum of squares due to error

Critical difference

CD = SEd x t Value at 5% at error degree of freedom

SEd= $\sqrt{2EMS/r}$

Where, S Ed = Standard error of difference between two treatment means

EMS = Error Mean of square

r = Number of replication

Standard error of mean

SE (m) ± = $\sqrt{EMS/r}$

Coefficient of variation (CV) (%)

Coefficient of variation is standard deviation expressed as percentage of Mean.

CV % =SD/X $\times 100$

Where, SD = Standard deviation

X = Mean of character

RESULTS

The results obtained during the course of present experiment "Effect of growth regulators and nutrients on the performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak" has been presented under suitable titles. Observations recorded during the growth phase and yield attributing characters per plant at a suitable interval have been presented by graph and diagrams. The data of the final observation of the various characters were subjected to statistical analysis and have been given under suitable headings. During the course of investigations, the detail findings of the experiments are presented in this chapter. The data are presented in tabular form with a mean and critical difference (CD) at 5 % level of significance.

4.1Morphometric characters

4.1.1Plant Height (cm)

The data obtained on plant height of tomato at the final stage of crop growth as subjective by foliar spray of micronutrients are presented in Table 4.1. The findings showed that plant height was significantly affected by different treatments at the final stage of crop growth.

Plant height varied from 81.14 to 105.51 cm. The maximum plant height was noted in T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray,Triacontanol (0.05%EC) 3rd spray (105.51 cm), which was significantly superior over other treatments but at par to treatment T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (98.95 cm), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (96.56cm) T_9 Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray(95.44cm) and T_3- NAA (25 ppm)1st spray,Triacontanol (0.05%EC) 2nd spray (95.12cm), whereas minimum plant height was documented in T_1-control (81.14 cm).

4.1.2 Number of branches per plant

The data pertaining to number of branches per plant have been obtained in Table 4.1. Number of branch per plant ranged from 7.81 to 9.75 and among the treatments, the significantly maximum number of branches per plant was recorded in

T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray,Triacontanol (0.05%EC) (9.75) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (9.12), T_{12}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (8.98). While minimum number of branches per plant noted in T_1-control (7.81). However the treatments T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (98.95 cm), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (96.56cm) , T_9 Calcium (0.5%)1st spray,Triacontanol (0.05%EC) 2nd spray(95.44cm) and T_3- NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray (95.12cm) are statistically at par with treatments T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (9.75).

4.1.3 Number of leaves per plant

The witnessed data documented in Table 4.1 was analyzed statistically and found to be significant with respect to the number of leaves per plant. Among the treatments a highest plant height was recorded in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (255.20) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (244.57), T_{12}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (231.28), whereas minimum number of branch per plant recorded in T_1-control (180.28). While the treatment T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (98.95 cm), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (244.57) is statistically at par with treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (255.20).

4.1.4 Leaf area (cm^2)

The perceived data recorded in Table 4.1 was investigated statistically and found to be non-significant with respect to the Leaf area. Among the treatments highest leaf area was viewed in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (67.52) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (65.25), whereas minimum number of branch per plant recorded in T_1-control (54.01)

4.1.5 Canopy spread

The observed data documented in Table 4.1 was analyzed statistically and found to be significant with respect to the canopy spread. Among the treatments a highest canopy spread both in south-north and east-west direction was witnessed in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (123.40) (104.28) respectively followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (109.01)(91.90) respectively, T_{12}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray (105.04) (89.07) respectively, whereas minimum for this parameter recorded in T_1-control (88.04)(81.50) respectively.

Table 4.1 Mean performance of the morphometric character

Treatment	Plant height (cm)	No. of branches /plant	No. of leaves /plant	leaf area(cm^2)	canopy spread(cm)	
					N-S	E-W
T_1	81.14	7.81	180.28	54.01	88.04	81.50
T_2	82.19	7.82	189.22	54.29	89.01	82.76
T_3	95.12	8.89	228.80	64.28	104.03	89.01
T_4	86.53	8.39	190.31	57.44	92.01	85.02
T_5	90.11	8.02	212.23	64.01	96.32	87.92
T_6	98.95	9.12	244.57	65.25	109.01	91.90
T_7	89.06	8.87	206.96	55.01	89.40	83.54
T_8	82.11	8.18	208.09	58.85	93.78	85.62
T_9	95.44	8.81	218.48	64.08	104.89	89.04
T_{10}	105.51	9.75	255.20	67.52	123.40	104.28
T_{11}	83.03	7.91	198.25	55.12	90.00	82.90
T_{12}	96.56	8.98	231.29	54.01	105.04	89.07
T_{13}	85.53	7.82	207.46	54.29	90.02	84.10
MEAN	90.15	8.49	213.16	59.09	98.07	87.44
SE(m±)	4.12	0.38	6.73	3.73	2.68	1.47
CD	12.84	1.18	20.9	N/A	8.35	4.59
C.V.	6.47	6.32	4.46	8.94	3.86	2.38

T_1 – Control, T_2-NAA (25 ppm), T_3-NAA (25 ppm)1st spray, Triacontanol (.05%EC) 2nd spray, T_4-Boron (0.2%) 1st spray, NAA (25 ppm) 2nd spray,T_5-Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray, T_6-Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray, T_7-Triacontanol (0.05%EC),T_8-Boron (0.2%)1st spray, Triacontanol (0.05%EC) 2nd spray, T_9-Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray ,T_{10}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray ,T_{11}-Boron (0.2%),T_{12}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, T_{13}-Calcium (0.5%).

4.2 Yield and yield attributing characters

4.2.1 Number of flowers per cluster

The observed data acknowledged in Table 4.2 was analyzed statistically and found to be significant with respect to the number of flowers per cluster. The perusal of data for number of flowers per cluster ranged from 9.1 to 5.9. The maximum number of flowers per cluster was noted in T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (9.1) which was significantly superior over other treatments but at par to treatment T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (8.9) and T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray(8.6), whereas minimum number of flowers per cluster recorded in T_1-control (8.9).

4.2.2 Number of fruits per cluster

The observed data revealed in Table 4.2 was analyzed statistically and found to be significant with respect to the number of fruits per cluster. The perusal of data for number of fruit per cluster ranged from 8.0 to 3.9. The maximum number of fruits per cluster was recorded in treatment T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, NAA (25 ppm) 3rd spray (8.0) which was significantly superior over other treatments but at par to T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (7.8) and T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray(7.6), whereas minimum number of flowers per cluster recorded in T_1-control (3.9).

4.2.3 Number of fruits per plant

The noticed data documented in Table 4.2 was analyzed statistically and found to be significant with respect to the number of fruits per plant. The perusal of data for number of fruit per plant ranged from 60.01 to 50.00. Among the treatments the significantly highest number of fruits per plant was perceived in the T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (60.01) followed by T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (59.07) and T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray (58.51), whereas minimum number of fruits per plant recorded in T_1-control (50.00).

4.2.4 Fruit diameter (cm)

The observed data recorded in Table 4.2 analyzed statistically and found to be significant with respect to the fruit diameter. The perusal of data for fruit diameter ranged from 4.65 to 2.58. Among the treatments a significantly highest fruit diameter was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (4.65) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (4.14) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(3.95) , However, the treatments T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (4.14), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(3.95) and T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray (3.91) are statistically at par with the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (4.65). whereas minimum fruit diameter recorded in T_1-control (2.58)

4.2.5 Fruit weight (g)

The experimental data are shown in Table 4.2 analyzed statistically and found to be significant with respect to the fruit weight. The assessment of data revealed that fruit weight (g) ranged from 72.06 to 52.77. significantly highest fruit weight was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (72.06) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (68.04) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(65.03) , whereas minimum fruit weight recorded in T_1-control (52.77). However, the treatments T6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (68.04), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(65.03) and T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray (64.96) are statistically at par with the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (72.96).

4.2.6 Yield per plant (kg)

The observed data recorded in Table 4.2 and Fig. 4.1 analyzed statistically and found to be significant with respect to the yield per plant. The assessment of data revealed that yield per plant (kg) ranged from 4.26 to 2.28. significantly highest yield per plant was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (4.26) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (4.08) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(3.55). However, the treatments T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (4.08), T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(3.55) ,T_3 NAA (25 ppm)1st spray, Triacontanol (0.05%EC) 2nd spray (3.40),T_9 Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray (3.25) and T_5 Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray (3.24)are statistically at par with the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (4.26) , whereas minimum yield per plant recorded in T_1-control (2.28).

4.2.7 Yield per hectare (t)

The perceived data recorded in Table 4.2 and Fig. 4.1 analyzed statistically and found to be significant with respect to the yield per hectare. The assessment of data revealed that yield per hectare (t) ranged from 60.39 to 44.58ton /ha. Significantly highest yield was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (60.39) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (55.61) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(54.66) , whereas minimum yield per plant recorded in T_1-control (44.55). However, the treatment T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (55.61) is statistically at par with the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (60.39).

4.3 Other attributes

4.3.1 Plant weight at harvest (g)

The observed data recorded in Table 4.3 analyzed statistically and significant variations were observed with respect to the plant weight at harvest. The perusal of data for plant weight at harvest ranged from 540.55 g to 312.26g. Among the treatments a highest plant weight at harvest was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (540.55) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (512.78) and T_{12} Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray(430.15). However, the treatment T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (512.78) is statistically at par with the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (540.55) , whereas minimum plant weight at harvest recorded in T_1-control (312.26).

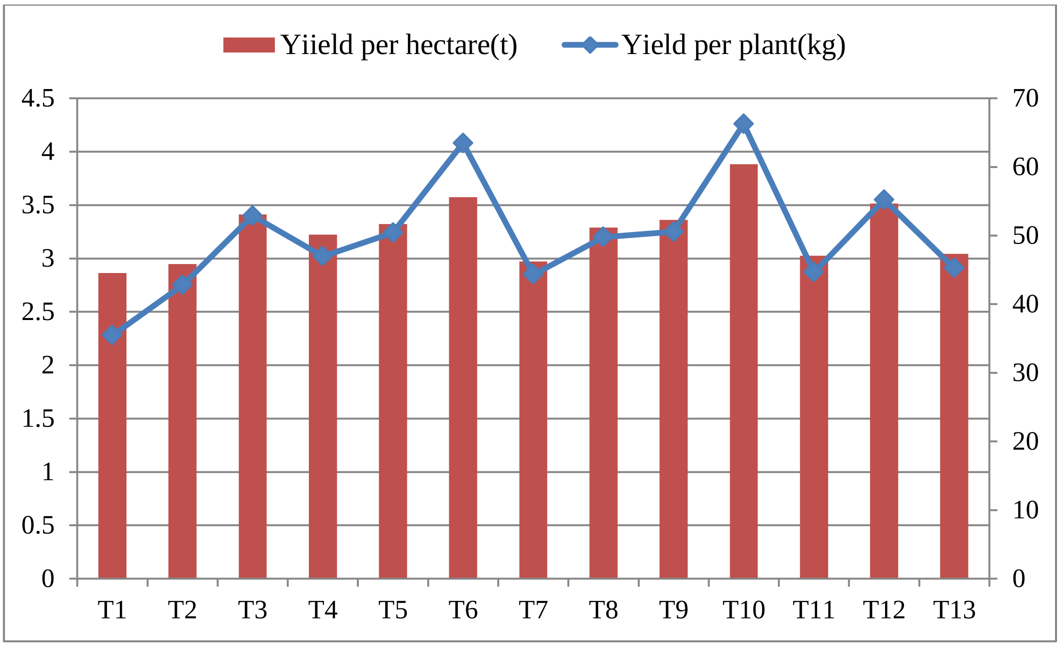

Fig. 4.1 Effect of foliar application of nutrients and plant growth regulators on yield per plant (kg) and yield per hectare (t)

4.3.2 Root weight at harvest (g)

The observed data recorded in Table 4.3 was analyzed statistically and significant variation was observed with respect to the root weight at harvest. The perusal of data for root weight at harvest ranged from 155.80 to 68.23. Among the treatments significant highest root weight at harvest was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray (155.80) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (135.52) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(102.28) , whereas minimum root weight at harvest recorded in T_1-control (68.23).

4.3.3 Root shoot ratio

Minimum (balanced shoot and root growth) resulted in Fig. 4.2 analyzed statistically and found significant variation with respect to the root-shoot ratio. The scrutiny of data for the root-shoot ratio ranged from 4.08 to 2.43. Among the treatments a minimum root-shoot ratio was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray (2.43) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (2.78) and T_{12} Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray(3.20) , whereas maximum root-shoot ratio recorded in T_7-Triacontanol (0.05%EC), (4.08).

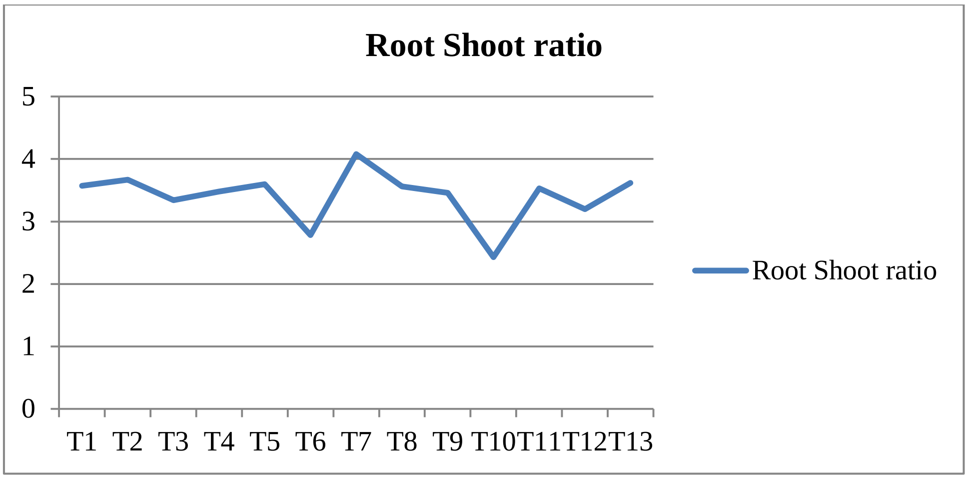

Fig. 4.2 Effect of foliar application of nutrients and plant growth regulators on root shoot ratio.

4.3.4 Disease and pest infestation (%)

Both percentage of leaf and fruit damage by serpentine leafminer was recorded on different treatments. The maximum pest damage both leaf (7.15) and fruit (2.15) was observed in T_7-Triacontanol (0.05%EC) followed by T_8-Boron (0.2%) 1st spray, Triacontanol (0.05%EC) 2nd spray (6.0). (2.05) respectively.

4.4 Economics

Studies on the economics of the treatments in Table 4.4, application are very important as they are of farmer's primarily concerned with monetary returns and profitability. By crop recommendation and adaptation of any package of practices by the farmer depends upon economics viability of the treatments. Hence, it becomes necessary to work out the economics of different treatments for determining the best cost-effective treatment of the experiment.

4.4.1 Total cost of cultivation

Total outlay of each treatment was separated into two parts viz., common expenditure and treatments wise additional cost. Common expenditure includes cost of field preparation, seed, sowing expenses, weeding and use of insecticide spraying, watching, irrigation, harvesting and general expenses. The cost of cultivation of Rs 78940.00 was common for all the treatments (Table 4.4), but the cost of different treatments varied from treatment to treatment. The highest total cost of cultivation (Rs 89082.44) was earned under application of nutrients and bioregulators (calcium chloride, borax, and triacontanol) (T_{10}) against the total cost of Rs 78940.00/ha involved in control (T_1).

4.4.2 Gross income

Data personified in Table 4.4 show that the maximum gross income of Rs 301950/ha was gained with the treatment of (calcium chloride, borax, and triacontanol) treatment (T10) followed by in direction resulting are T_6 (Rs 278050) and T_{12} (Rs 273300).

4.4.3 Net income:

The supreme net return of Rs 212867.56/ha was found with T_{10} followed by T_6 (Rs 188819.50) and T_3 (Rs 185945.06).

4.4.4 Benefit: Cost ratio

Highest benefit: cost ratio obtained with T_{10} (2.40) followed by T_3 (2.36). Whereas, minimum with T_{11} (1.81).

Fig. 4.3 Tomato flower per cluster

Fig. 4.4 Tomato fruit per cluster

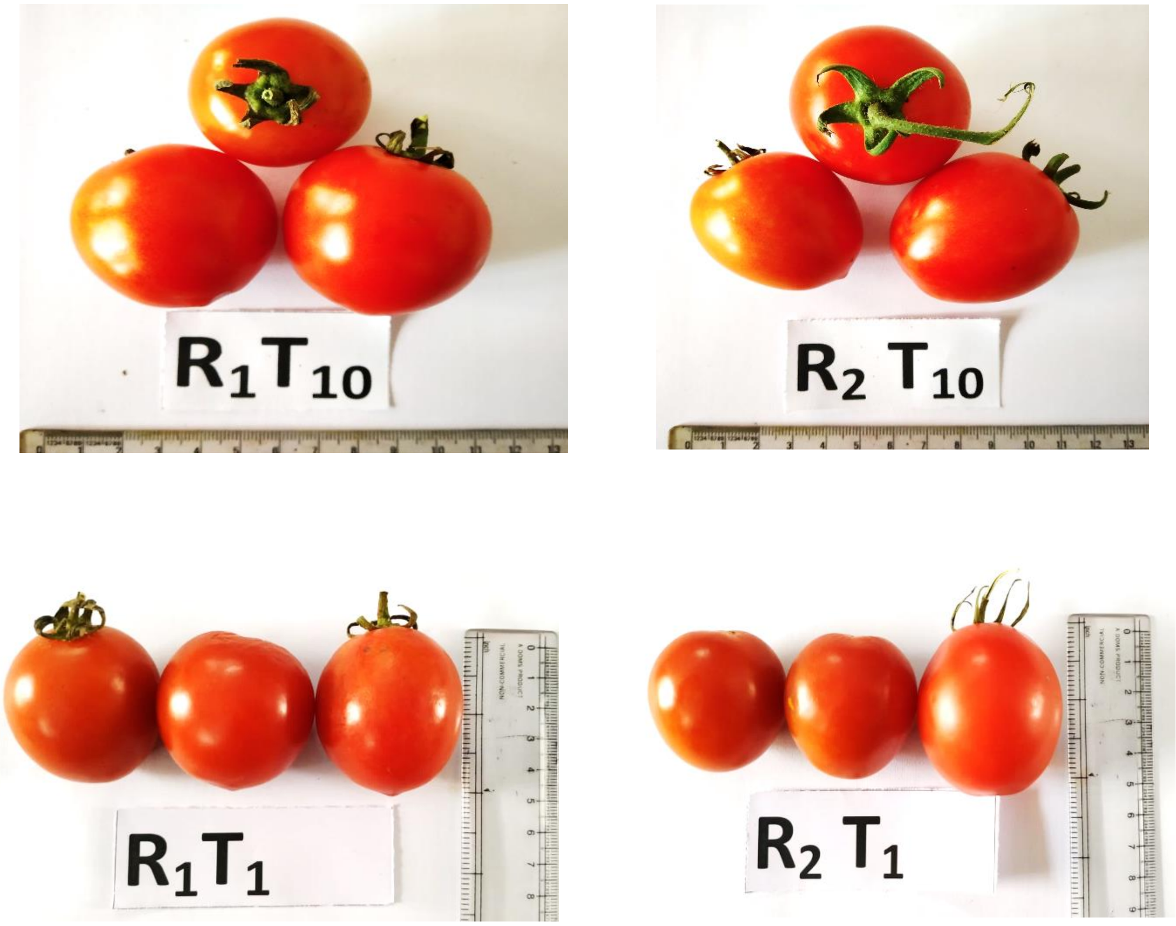

Fig. 4.5 Maximum and minimum size of tomato fruit

Table 4.2 Mean performance of yield and yield attributing traits

Treatment	Flowers per cluster	Fruits per cluster	Number of fruits per plant	Fruit diameter (cm)	Fruit weight (g)	Yield per plant (kg)	Yield per hectare
T_1	5.9	3.9	50.00	2.58	52.77	2.28	44.55
T_2	7.5	6.4	50.05	2.88	54.15	2.75	45.83
T_3	8.6	7.6	58.51	3.91	64.96	3.40	53.06
T_4	6.8	5.8	54.28	3.03	56.19	3.02	50.12
T_5	7.0	6.1	55.89	3.30	59.53	3.24	51.66
T_6	9.1	8.0	60.01	4.14	68.04	4.08	55.61
T_7	6.1	4.8	50.10	2.98	55.20	2.85	46.21
T_8	6.4	4.6	55.42	3.11	57.50	3.20	51.19
T_9	7.2	5.3	56.20	3.33	60.73	3.25	52.30
T_{10}	8.9	7.8	59.07	4.65	72.06	4.26	60.39
T_{11}	6.2	4.7	50.20	3.00	55.62	2.87	47.05
T_{12}	7.4	5.9	58.01	3.95	65.03	3.55	54.66
T_{13}	6.4	4.8	51.00	3.00	55.95	2.91	47.32
MEAN	7.19	5.82	54.52	3.37	59.83	3.20	50.77
SE(m)	0.42	0.38	2.26	0.39	2.60	0.38	1.62
CD	1.33	1.21	7.04	1.21	8.10	1.16	5.07
C.V.	8.43	9.40	5.85	16.50	6.15	16.57	4.52

N.B- Treatment details

T_1 – Control, T_2-NAA (25 ppm), T_3-NAA (25 ppm)1st spray, Triacontanol (.05%EC) 2nd spray, T_4-Boron (0.2%) 1st spray, NAA (25 ppm) 2nd spray,T_5-Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray, T_6-Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray, T_7-Triacontanol (0.05%EC),T_8-Boron (0.2%)1st spray, Triacontanol (0.05%EC) 2nd spray, T_9-Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray ,T_{10}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray ,T_{11}-Boron (0.2%),T_{12}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, T_{13}-Calcium (0.5%).

Table 4.3 Mean performance of other attributes

Treatment	plant wt. at harvest (g)	root wt. at harvest (g)	disease infestation	
			% leaf damage	% fruit damage
T_1	312.26	68.23	1.70 (7.48)	1.15 (6.12)
T_2	322.06	68.92	0.00 (0.00)	0.00 (0.00)
T_3	426.25	98.20	1.80 (7.70)	0.00 (0.00)
T_4	334.32	74.28	0.00 (0.00)	0.00 (0.00)
T_5	346.51	75.33	0.00 (0.00)	0.00 (0.00)
T_6	512.78	135.52	1.45 (6.91)	0.00 (0.00)
T_7	358.83	70.54	7.15 (15.50)	2.15 (8.42)
T_8	342.65	74.88	6.00 (14.12)	2.05 (8.21)
T_9	395.30	88.08	2.65 (9.26)	1.95 (8.01)
T_{10}	540.55	155.80	1.60 (7.24)	0.00 (0.00)
T_{11}	330.25	72.79	0.00 (0.00)	0.00 (0.00)
T_{12}	430.15	102.28	1.15 (6.14)	1.00 (5.73)
T_{13}	334.45	72.92	0.00 (0.00)	0.00 (0.00)
MEAN	383.57	89.06	5.72	2.81
SE(m)	9.22	4.25	0.35	0.13
CD	28.72	13.25	1.11	0.43
C.V.	3.39	6.72	8.81	7.00

N.B.-Parenthesis is angular transferred

T_1 – Control, T_2-NAA (25 ppm), T_3-NAA (25 ppm)1st spray, Triacontanol (.05%EC) 2nd spray, T_4-Boron (0.2%) 1st spray, NAA (25 ppm) 2nd spray,T_5-Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray, T_6-Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray, T_7-Triacontanol (0.05%EC),T_8-Boron (0.2%)1st spray, Triacontanol (0.05%EC) 2nd spray, T_9-Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray ,T_{10}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray ,T_{11}-Boron (0.2%),T_{12}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, T_{13}-Calcium (0.5%).

Table 4.4 Calculation of benefit cost ratio

Treatment	fruit yield (T/ha)	Treatment cost (Rs)	Common cost (Rs)	Total cost of cultivation (Rs)	Gross return (Rs)	Net return (Rs)	B:C ratio
T_1	44.55	0	78940.00	78940.00	222750	143810.00	1.83
T_2	45.83	272.5	78940.00	79212.50	229150	149937.50	1.91
T_3	53.06	414.94	78940.00	79354.94	265300	185945.06	2.36
T_4	50.12	5452.5	78940.00	84392.50	250600	166207.50	1.98
T_5	51.66	5110.5	78940.00	84050.50	258300	174249.50	2.09
T_6	55.61	10290.5	78940.00	89230.50	278050	188819.50	2.13
T_7	46.21	142.44	78940.00	79082.44	231050	151967.56	1.93
T_8	51.19	5322.44	78940.00	84262.44	255950	171687.56	2.05
T_9	52.30	4980.44	78940.00	83920.44	261500	177579.56	2.13
T_{10}	60.39	10142.44	78940.00	89082.44	301950	212867.56	2.40
T_{11}	47.05	5180	78940.00	84120.00	235250	151130.00	1.81
T_{12}	54.66	10018	78940.00	88958.00	273300	184342.00	2.08
T_{13}	47.32	4838	78940.00	83778.00	236600	152822.00	1.84

DISCUSSION

Based upon the verdicts of the field experiment entitled, "Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid Arka Rakshak" as accessible in the preceding chapter an effort has been made to analyse it judgmentally and discuss the result on the light of reasoning as well as cause-effect relationship. The result of previous researchers on this experiment is also taken into the record while discussing the result of the study of different morphometric as well as yield attributing character of tomato.

5.1 Plant height

The plant height of the crop was recorded at harvest taking it to account the base up to tip which was statistically analysed. The results so obtained indicated that the maximum plant height was attained in the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray (105.51 cm) followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (98.95 cm). All the treated plants perform significantlly better than the control which has minimal plant height (81.14 cm). Analogous results were informed by Ashraf *et al*. (2018), Weerasinghe *et al.* (2014) and Khan *et al*. (2009)

It signposted that foliar spray of boron, calcium, and triacontanol are responsible for the accelerated growth of the plant. Deficiency of calcium and boron declines plant height by declining mitotic activity in the terminal meristem (Nelson and Niedziela, 1998). Thus, the application of calcium chloride and borax increases plant height (Dole and Wilkins, 2005). Increase in plant height by application of calcium and boron may be due to their involvement in chlorophyll formation, which might have helped to favor cell division, meristematic activity in apical tissue, expansion of cell and formation of the new cell wall (singh *et al*., 2009). Whereas triacontanol enhances the physiological efficiency of the cell and thus exploits the genetic potential of the plant to a large extent (Chen *et al*., 2002).

5.2 Number of branches per plant

So far the number of branches per plant are concern again the plants treated with exploited highest number of branches per plant T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray (9.75), followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray (9.12) .This may be due to accelerated cell division mediated by the application of calcium, boron, and triacontanol. It also may be due to having a significant function in the formation of plant meristem so resulted in a higher number of branches (Shnain *et al*., 2014). Since boron enhances calcium metabolism, especially in the cell wall (Blevins and Lukaszewski, 1998), the calcium and boron combinations were more effective than sole application in increasing the number of branches per plant (Asad *et al*., 2003). These exhibiting the findings of Rab and Haq (2012), Das and Sahoo (1975) and Das (1974).

5.3 Number of leaves per plant and leaf area

Although the number of leaves and leaf area together constitute the vegetative growth of a plant. But a total number of leaves are a genetically pre-determined factor still the environment condition has a tremendous effect on the expression of the potentiality of particular genetic combination. Under a stressed condition, the leaf area gets reduced but on normal condition when the responsible gene gets ample scope for its phenotypic expression all the leaves become more or less equal in a plant. Short lived vegetable plant like tomato, the size of the leaf remains constant irrespective of nutrients and bioregulators application. Our results revealed more number of leaves (255.20) obtained by the application of T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray sequentially which superheats the control but the leaf area do not significantly differ in nutrient and bioregulators treated plant than the non-treated plant . It indicates that the vegetative growth is dependent on the nutrient and bioregulator application which proliferated by the stimulus received from the plant growth regulators in the form of signals. Also, a nutrient linked with the development of plant cell wall and differentiation of cells and results in improved shoot growth and thus increased leaves per plant (Ilyas *et al.*, 2014; Oyinlola, 2004). Similar findings also reported by Haleema *et al*. (2018), Ashraf *et al*. (2018), Khan *et al*. (2009) and Medhi and Kakati (1994).

5.4 Canopy spread

A perusal of detailed data obtained in the preceding chapter with respect to the canopy spread both in south-north and east-west direction demonstrate significantly maximum of (123.40 cm) (104.28 cm) respectively in the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray sequentially . All the treated plants perform better than control. Control has minimal canopy spread (88.04 cm) (81.50 cm) respectively.Which may be due to Ca & B which encouraged the uppermost lateral growth of the tomato plant. In the observed plant canopy spread was probably enhanced by improved plant nutrients in the soil that stimulated photosynthesis (Hashemimajd *et al*., 2004). Comparable results were conversant by Saravaiya *et al*. (2014) and Sathya *et al*. (2010).

5.5 Number of flowers per cluster

When a plant switches over from vegetative to reproductive phase a transition phase in between is sandwiched to give scope for necessary physical manifestation. This period is the active period for cell differentiation. The activity of plant regulators natural or exogenous application is continual at this stage. The yield attributes like number of flowers per cluster in a tomato plant are previously decided. Basing on its habit of determinant and indeterminate. In vegetable like tomato which is a short live plant in which the transitional phase is very short duration. The partitioning of photosynthate from leaf to the flower buds happens very quickly.

The number of flowers per cluster was observed significantly highest in the T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, NAA (25 ppm) 3rd spray (9.1) and lowest in the control (8.9). Foliar application of borax alone and calcium chloride resulted in a significant increase in the number of flowers. Thus, it is likely that the higher number of flowers per cluster could be due to sufficient levels of carbohydrates available for flower formation (Smit and Combrink, 2004). However, it is also attributed due to NAA which showed a positive effect on the number of flower clusters due to higher calcium contents in the tomato plant. Similar findings also reported by Tuna *et al*. (2007) and Hao & Papadopoulus (2003).

5.6 Number of fruits per cluster and number of fruits per plant

So far as the present experiment is concerned the maximum number of fruits per cluster is found in T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, NAA (25 ppm) 3rd spray (8.0) indicating the definite role of nutrients amplified by the growth regulators. The treatment receiving a foliar spray T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, NAA (25 ppm) 3rd spray of chronologically yield the highest number of fruits per cluster followed by T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (7.9). The controlled treatment that exhibited the lowest number of fruit per cluster and fruit per plant (3.9, 50.00) respectively. So far as the number of fruits per plant is a concern again the treatment in T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, and NAA (25 ppm) 3rd spray exhibited significantly the highest number of fruit per plant (60.01).

The number of fruits per plant depends upon the number of flowers and the ability of the plant to provide the nutrients required for growth and development. Since the application of boron increased the fruits per cluster (Desouky *et al*., 2009), it is likely that a higher number of fruits per plant will be observed with the borax application.

Similarly, the application of boron alone resulted in a lower number of fruits per plant as compared to the $CaCl_2$ and borax combination. This indicates that both calcium and boron are required for decreasing the abscission of flowers and increase carbohydrate supply for the formation of flowers and fruit set in tomato thereby increases the fruits per cluster and per plant (Smit and Combrink, 2005). NAA reduces pre-harvest fruit drop by reducing the effect of ethylene and resulted in the appearance of higher fruit set percentage (Alam & Khan, 2002; Yuan & Carbaugh, 2007). These findings corroborate that of Haleema *et al*. (2018), Abbasi *et al*. (2013) and Rab and Haq (2012).

5.7 Fruit diameter and fruit weight

A perusal of detailed data presented in the preceding chapter with respect to the fruit characters like fruit diameter and fruit weight revealed that the treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) resulted in the significant highest fruit diameter (4.65cm). The treatment not receiving the spray of nutrient and bioregulators yields lesser fruit diameter (2.58 cm). Considering the fruit weight, it was also evident that highest fruit weight of (72.06 g) was obtained from treatment combination T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) which is superior over control (72.96 g).

The increase in fruit weight might be due to better mineral utilization of plants accompanied by the enhancement of photosynthesis, other metabolic activity and greater diversion of food material to fruits. Increase in fruit size and weight by the application of micronutrients have been reported by Bajpai *et al*. (2001)

It is attributing to the partitioning of carbohydrate, photosynthates so accumulated by an enhanced rate of photosynthates as affected by combined application of boron and calcium (Passam *et al*., 2007).which is influenced by triacontanol (Kumaravelu *et al*., 2000). Similar findings also obtained by Naeem *et al*. (2011) and Rab and Haq (2011).

5.8 Yield per plant and yield per hectare

Yield is a function of the effect of both vegetative and floral attributes. Every grower has poses a coveted desire for a better yield rather than quality. The observed data on yield per plant was significant highest in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (4.26 kg/plant) and yield per hectare T10- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (60.39 t/ha). The plants fed with balanced dose of nutrients and bioregulators enviably increased yield due to micronutrient application might be attributed to enhanced photosynthetic activity, resulting into the increased production and accumulation of carbohydrates and favorable effect on vegetative growth and maximum retention of flowers and fruits, which might have increased the number and weight of fruits (Basavarajeswari *et al.*, 2008). TRIA application has been reported to increase dry weight, CO_2 fixation, reducing sugars, soluble proteins, and free amino acids in various crops (Ries and Houtz, 1983), indicating its role towards yield and quality improvement of the crop. So far the yield per hectare is concern it is a computed value with respect to yield per plant, yield per plot. So obviously the per hectare yield of best treatment T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) is highest followed by T_6- Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray . These findings corroborate that of Singh and Tiwari (2013), Basavarajeswari *et al*. (2008), Borowski *et al*. (2000), Kapitismadi and Viroyl (1995) and Eriksen *et al*. (1981).

5.9 Plant weight, root weight at harvest and Root shoot ratio

A perusal of the detailed data presented in the previous chapter with respect to the plant weight and root weight at harvest revealed that, the treatment T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray chronologically resulted in the highest plant weight and root weight (540.55g), (155.80 g) respectively . The treatments not receiving any nutrient and bioregulators (control) showed the minimal plant and root weight (312.26 g), (68.23 g) respectively. It is further revealed that the treatment with Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) chronologically gave root-shoot ratio of (2.43), which may be due to the both nutrients and growth regulator maintain the balance between shoot and root growth by regulating partitioning of photosynthates or metabolites from source to sink properly and thereby maintain source-sink relationship

Owing to the fact that, calcium is a vital component of the plant cell wall and shows a substantial function in cell division and enlargement (Rashid, 2000; Ilyas *et al*., 2014), the foliar application of Ca responds positively and increases vegetative or shoot growth. Ca application also linked with higher uptake of phosphorous which is the key factor for root growth and elongation. Likewise, the boron is also linked with the development of plant cell wall and the differentiation of cells and results in improved shoot growth (Basavarajeshwari *et al*., 2008). The application of triacontanol increased the fresh and dry weights of plants were ascribed to the enhanced photosynthesis and enhanced accumulation of photosynthates (Eriksen *et al*., 1981). Application of triacontanol also elicited the appearance of L (+) adenosine in the roots. The study suggested that L (±) adenosine triggered a rapidly transmitted signal within the whole plant that resulted in a transient increase in apoplastic ion concentration within stem tissue (Ries *et al*., 1993). It goes with the findings of Ayyub *et al*. (2012) and Ries (1991).

5.10 Economics

Foliar application of T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) exhibited noticeable influence in the economics of tomato cultivation comprising the cost of cultivation, gross return, the net return, and B:C ratio during the research. Maximum contribution of cost (₹89082.44) was marked when Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray applied chronologically. The lowest cost of cultivation was earned in control where no nutrients and bioregulators were applied in the period of investigation.

Application of Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray applied chronologically per ha noted the highest gross return of (₹301950/-) whereas, the lowest gross return (₹ 222750/-) was obtained in control where no nutrients and bioregulators were applied. The highest net return of (₹212867.56/-) was also observed in the treatment where Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC)3rd spray applied chronologically as compared to other treatments tried in the experiments. The highest gross return and net return was mainly due to the effective utilization of the nutrients and resulted in improved fruit yield. However, the lowest net return was calculated to be (₹143810.00/-).

Highest B:C ratio 2.40 was witnessed in the treatment where 1.5 kg Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05% EC)3rd spray was applied chronologically, whereas the lowest B:C ratio of 1.81 was documented. Shukla (2017) observed the foliar application of Mixture of micronutrients gave the highest benefit-cost ratio of (3.08). Application of boron and zinc gave the highest benefit-cost ratio of 4.05 (Shnain *et al*., 2014). The similar finding also observed by (Borah, 2012) that the combined application of inorganic K at 60 kg K_2O ha-1 and foliar applications of triacontanol gave the maximum benefit-cost ratio of 4.89.

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SUMMARY AND CONCLUSION

The brilliant red plant tomato (*Solanum lycopersicum* L.**)** is a popular dish item in every cuisine of the countryside. Marching along from tropical parts of America, it reached in the Indian subcontinent, acclimatised here and conquered the kitchen from South to North, in such a manner that it is hard to be believed for an exotic vegetable.

Annually 91.03 thousand ha area is cultivated it produces. The potential yield standard is 1311.72 thousand MT and by which we lag behind the national standard yield (19697 thousand MT). Owing to the congenial climatic condition, the Odisha farmers are in need of a high yielding variety which is stout enough to fight back the deadly diseases like bacterial wilt, early blight, leafcurl, fruit rot. Which are the primary reasons for retracting from a bumper harvest.

Efforts are 'on' in developing a good hybrid at the behest of changing climatric scenario. F1 Hybrid Arka Rakshak released by IIHR, Banglore is considered as a boon for farmer. It is popular among the growers because of its triple disease resistant to Tomato leaf curl virus, Bacterial wilt and Early blight. Besides that, it has better fruit quality attributes like uniform fruit weight (80-90gm.), shape, colour and shelf life (18 -20 days). Also fruits square round, deep red, firm, suitable for fresh market and yield 40-50 ton /ha.

The present research work entitled, "Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.**)** hybrid Arka Rakshak" was carried out during *rabi*, 2018-19 in the field of Department of Vegetable Science, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India. With the objective to study the effect of plant growth regulator (NAA, triacontanol) and micronutrients (Calcium, Boron) on the performance and combined effect on yield, yield attributing character of tomato hybrid c.v Arka Rakshak. With thirteen treatments and two replications, the experiment was laid out in a randomized block design. The treatments were such as T_1– Control, T_2-NAA (25 ppm), T_3-NAA (25 ppm)1st spray, Triacontanol 0(.05%EC) 2nd spray, T_4-Boron (0.2%) 1st spray, NAA

(25 ppm) 2nd spray, T_5-Calcium (0.5%) 1stspray, NAA (45 ppm) 2nd spray, T_6-Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray, T_7-Triacontanol (0.05%EC),T_8-Boron (0.2%)1st spray, Triacontanol (0.05%EC) 2nd spray, T_9-Calcium (0.5%)1st spray, Triacontanol (0.05%EC) 2nd spray ,T_{10}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) 3rd spray ,T_{11}-Boron (0.2%),T_{12}-Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, T_{13}-Calcium (0.5%).These treatments were observed for 16 parameters including, vegetative growth, flowering, fruit yield and yield attributing parameters. The striking findings of the research work have been concised below.

- The morphometrix characters like plant height, number of branch per plant, number of leaves per plant, canopy spread both in south-north and east-west direction is significant among all the treatment except leaf area (cm^2). Foliar application of T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, triacontanol (0.05%EC) 3rd spray were documented ominously extreme plant height (cm) (105.51 cm), maximum number of branch per plant (9.75), highest number of leaves per plant (255.20), highest canopy spread both in south-north and east-west direction (123.40) (104.28) .While the minimum plant height, minimal number of branch per plant, and lesser number of leaves per plant noted in T1-control (81.14cm),(7.81),(180.28),(88.04),(81.50) respectively.
- The phenological characters like number of flowers and fruits per cluster and fruits per plant differ significantly among the treatment. The maximum of all these parameters was noted by application of T_6- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, NAA (25 ppm) 3rd spray noted number of flower per cluster (9.1), number of fruit per cluster (8.0), and number of fruits per plant (59.07), whereas minimum value of number of flowers per cluster (5.9), number of fruits per cluster (3.9), fruits per plant (50.00) were obtained in control.
- Yield attributing characters like fruit diameter, fruit weight and fruit yield per plant varied ominously over all the treatments. Foliar application of T_{10}-Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, triacontanol (0.05%EC) 3rd spray chronologically resulted in highest fruit diameter (4.65), maximum fruit weight (72.06) and fruit yield per plant(4.26 kg/plant).

- ❖ Maximum yield per hectare was resulted in of T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, triacontanol (0.05%EC) 3rd spray (60.39 t/ha). Whereas, the minimum yield per hectare (44.55 t) was observed in T_1-control.
- ❖ The observed data were analyzed statistically and found to be significant with respect to the plant weight and root weight at harvest. Among the treatments a highest plant and root weight at harvest was perceived in the T_{10}- Boron (0.2%)1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05%EC) (540.55 g) (155.80 g) respectively. Whereas the minimum value of plant weight at harvest (312.26 g) and root weight at harvest (68.23) were obtained in T_1-control.
- ❖ Minimum (balanced) and maximum root shoot ratio documented in T_{10}- Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, Triacontanol (0.05% EC) 3rd spray (2.43) and T_7-Triacontanol (0.05%EC) respectively.
- ❖ The highest percentage of leaf (7.15 %) and fruit damage (2.15 %) by leaf minor were recorded in T_7-Triacontanol (0.05%EC).

CONCLUSIONS

The current study was conducted out for one season. Hence, no definite conclusion could be drawn. However, on the basis of the results achieved, it can be concluded that foliar application of nutrient (Ca, B) and plant growth regulators (NAA, triacontanol) were the finest option for crop growth and yield. The findings revealed that two foliar application of Boron (0.2%) 1st spray, Calcium (0.5%) 2nd spray, and Triacontanol (0.05% EC) 3rd spray at 15 days interval starting from 30 days after transplanting documented the maximum plant height (cm), highest number of branch per plant, highest number of leaves per plant, maximum canopy spread both in south-north and east-west direction, highest leaf area (cm^2) fruit diameter (cm), fruit weight (g), yield per plant (kg), yield per hectare (t) , highest plant weight and root weight (g) at harvest, minimum root-shoot ratio and highest cost-benefit ratio while number of flower and fruit per cluster, number of fruit plant was recorded highest by foliar application of Boron (0.2%) 1st spray, Calcium(0.5%) 2nd spray, NAA (25 ppm) 3rd spray.

SUGGESTIONS FOR FUTURE RESEARCH WORK

- The equivalent experiment can be recurrent for one or more years to get some tangible results. It can also be confirmed under different combinations.
- Studies should be directed for residual effect of spray in tomato.
- This study may be extrapolated in other agro climatic zones of Odisha to get a concrete result.
- The best combination of nutrients and bioregulators having desirable performance identified in the present study could be comprised in further improvement programme of tomato.

The following recommendation are emerged out from the experiments for better benefits of farming community

- Arka rakshak is a promising variety which can be cultivated in coastal Odisha during rabi season.
- It possesses horizontal resistance to bacterial wilt, early blight and leaf curl which has observed during field experiments.
- The nutrients Ca (0.5%) and B (0.2%) should apply to the crop as foliar spray at 30-45 days after transplanting.
- The bioregulators like triacontanol (0.05%EC) and NAA (25ppm) should applied as foliar application after application of nutrient to boost up the yield.

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