Effect of Boron application on growth and yield of watermelon (*Citrullus lanatus*)

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By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of Boron application on growth and yield of Watermelon (*Citrullus lanatus*)"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (PLANT PHYSIOLOGY)** of the Odisha University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fide* and original research work carried out by **NUTAN KUMAR SOREN** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

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

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CERTIFICATE-II

This is to certify that the thesis entitled **"Effect of Boron application on growth and yield of Watermelon (*Citrullus lanatus*)"** submitted by **NUTAN KUMAR SOREN** to the Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (PLANT PHYSIOLOGY)** has been approved by the students' advisory committee and the external examiner.

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ABBREVIATIONS USED

% :	Percentage
C° :	Degree Celsius
SEM(±) :	Standard error mean
CD :	Critical difference
cm :	Centimeter
Kg :	Kilogram
gm :	Gram
mg:	Milligram
FYM :	Farm Yard Manure
i.e :	That is
et al. :	Et allia (and coworkers)
L:	Litre
ml :	Millilitre
DAS:	Days after sowing
RBD :	Randomized block design
e.g. :	For example
CV :	Coefficient of Variation
ha :	Hectare
Fig :	Figure
CGR :	Crop growth rate
RGR :	Relative growth rate
HI :	Harvest Index
@ :	At the rate of
EC :	Electrical conductivity
day^{-1} :	per day

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CERTIFICATE OF ANTI-PLAGIARISM

This is to certify that the M.Sc, (Ag) thesis of **NUTAN KUMAR SOREN**, Admission No. **191222307,** Department of Plant Physiology, College of Agriculture, OUAT, Bhubaneswar has been checked for anti-plagiarism by using Turnitin web portal and similarity index was found within 15% level(from Abstract to summary & conclusion) as prescribed by OUAT.

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ABSTRACT

The present research work entitled "Effect of Boron application on growth and yield of Watermelon (*Citrullus lanatus*)" was conducted in AICRP on micronutrient at central farm of OUAT, Bhubaneswar during Rabi 2020-2021 the experiment was carried out in open field condition with ten numbers of treatments with recommended dose of fertilizers fitted in randomized block design with 3 replication watermelon cultivar Augusta was grown in plots and treated with soil application of B @ 1.0 kg/ha and different frequencies of foliar application with 0.25%, 0.5%, 0.75% and 1.0% in the form of borax as once and twice at mid and late crop growth stages. The variations among the different morpho-physiological, biochemical parameters in watermelon were recorded after 45 DAS till harvesting and quality parameters after harvesting of fruit. The effect of boron on different forms and concentrations on morphological, growth parameters, biochemical changes, quality parameters and yield, yield attributing characters were statistically analyzed and the results are discussed and concluding in remarks. The results revealed that the maximum values of Morphatic characters such as plant height (172.97 cm), no of branches per plant (9.69), no of leaves per plant (55.48), leaf area (73.12 cm^2) were recorded in T_8 (FS@ 0.5% borax twice) than T_2 soil application (@1 kg B/ha) and other foliar spray. No. of days to 1st flowering and fruiting was earliest (45.48) and (65.61) respectively in T_8, FS@ 0.5% borax twice and more number of days is taking in control plot (52.00) and (72.96) respectively. Biochemical parameter like chlorophyll (1.360 mg/g FW) and quality parameters like lycopene (3.84 mg/100g) increased in its accumulation in FS@ 0.5% borax twice than rest of the treatments. The effect of growth parameters like CGR (1.11 g m^{-2} day^{-1}), RGR (0.67 g m^{-2} day^{-1}), total biomass (48.88 g) and yield, yield attributing characters like no of flower per plant (10.20), no of fruits per plant (7.14), fruit weight (2.85 kg) and HI (86,78%) showed highest significance in FS @0.5% borax twice than soil application and foliar application. The plant nutrient content N, P, K, Ca, Mg, S, B was influenced considerably by different forms and concentration of boron in treated plants. The above findings of present study suggest that foliage application of boron showed more effect to all the parameters of watermelon crop than soil application of B because application of boron on foliage is utilized directly at needed site of plants where B acts quite quickly, efficiently and require less time for assimilation.

INTRODUCTION

Watermelon (*Citrullus lanatus*) is a succulent fruit and vine like plant belonging to the Cucurbitaceae family that is native to equatorial Africa and grown all over the world. The fruit is normally eaten uncooked and includes vitamin A and some vitamin C. Pickling the rind is a popular method of preserving it. Watermelons have a long and illustrious history. Watermelon has a Sanskrit name, and fruits are shown in early Egyptian art, showing that agriculture has been around for about 4,000 years. Large, extremely sweet fruits with soft flesh and fewer seeds have evolved from domestication and selective breeding. There are almost no viable seeds in certain current "seedless" varieties.

Watermelon is a chayote-like trailing annual with 400 cm long stems. The roots are shallow (40-50 cm) and have a tap root as well as several lateral roots. The leaves are elliptical in shape, 8 to 20 cm long, scabrid (rough to the touch), and deeply pinnatified. On the same plant, watermelon bears separate male and female blooms (monoecious). Flowers are unisexual, solitary, axially pedicellate, and unisexual. The male flower's pedicel is slender and 12-30 cm long, whilst the female flower's pedicel is slightly thicker. Female flowers are the only ones that bear fruit. Pollen transmission requires the presence of bees. The fruit is made up of a strong outer rind, a thin layer of white inner rind flesh (0.5-1.4 cm thick), and a coloured edible pulp with seeds inside. The fruit is oblong to spherical in shape. The skin is smooth and varies in colour from yellow to orange to pale green to nearly black. White, cream yellow, pale crimson, scarlet, or dark red skin is possible. The endocarp (placenta) is the edible section of the fruit, and the watermelon fruit is known botanically as pepo. Fruit normally weighs between 1 and 4 kg. The seeds are small (4-6 cm), long, and flattened, and are embedded in the edible pulp. Seeds might be white, brown, black, red, green, speckled, or any other colour.

Watermelon is widely grown throughout the world, particularly in China, Turkey, India, Brazil, Algeria, and Iran. In terms of watermelon farming, India stands third behind China and Turkey. With a production of 619.65 thousand metric tons, Uttar Pradesh is in first place. Odisha is the fifth-largest producer, with 226.98 million metric tons (NHB Database , 2017-18).

Watermelon is a popular fruit that is enjoyed by both the rich and the poor. The ripe fruit's delicious, luscious pulp is consumed fresh across the tropical and subtropical regions. After adding a bit of salt and black pepper to the fruit juice, it is also drunk. The juice is tasty and nourishing, and it helps to chill you down during the hot summer months. 70 percent of the watermelon fruit is edible. Watermelon fruit provides 95.8 g of water, 0.61 g of protein, 0.3 g of minerals, 0.4 g of dietary fibre, 7.55 g of carbohydrates, and energy (30 Kcal). Per 100 g of edible portion, it also contains calcium 7 mg, phosphorus 12 mg, iron 7.9 mg, thiamine 0.02 mg, riboflavin 0.4 mg, niacin 0.1 mg, and vitamin-C 1.0 mg.

When the roots are unable to deliver adequate nutrients, foliar micronutrient spraying is very beneficial. Foliar feeding is an effective method of delivering nutrients during a period of intense plant growth, when it can improve the mineral status of the plants and increase crop yield. The proper nutrition of NPK and micronutrients is critical for watermelon growth. In watermelon, fruit size is the most important factor affecting yield (Karchi *et al.*, 1977). Aside from production in terms of fruit weight, the quality of the fruit is also crucial. Watermelon fruit productivity and quality could be improved by administering a balanced diet of macro and micronutrients.

Boron plays an important function in the vegetable production of cucurbitaceous plants. It is mostly required for protein synthesis, cell wall growth, glucose metabolism, sugar translocation, hormone modulation, pollen grain germination, and pollen tube development. Growth, fruit set, and seed formation are all important aspects of a plant's life cycle. Boron is a mobile element that can easily leached into the environment. Many cucurbitaceous vegetables require sandy soils and regular amendments, although only in small quantities. Boron has a negative impact on cellular functions and plays an important role in the structural integrity of the plant cell wall. Boron is necessary for pollen germination and pollen tube expansion, both of which contribute to fruit set. As a result, fertilizer may boost production, especially when plants are grown on sandy soil with limited boron availability, as demonstrated by (Wojeik *et al*., 2005). Because watermelon blooms are only viable for a short time, it is critical that the supply of boron is not limited during pollination.

Physiological studies have also suggested that an active boron transport exists in the roots (Dannel *et al.*, 2000; Stangoulis *et al.*, 2001; Dannel *et al.*, 2002). Toxic boron concentrations also influence the growth of vegetative plants. The reduced root cell division is one of the physiological impacts of boron toxicity (Liu *et al.*, 2000), inhibition of cell wall expansion and shoot and root growth, decreased lignin and suberin contents, and lowered chlorophyll concentration and photosynthetic rates (Nable *et al.*, 1997).

Boron shortage is the most common cause of yield decrease, second only to zinc deficiency in the cultivation of horticultural crops (Singh, 1999). The prevalence of B deficiency is extremely high in the West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, and Tamil Nadu. Boron deficiency is extremely important for agricultural productivity in highly calcareous, sandy soils, acidic and laterite soils that have been leached and limed. According to the All India Coordinated Research Project on Micronutrients (ICAR), B deficiency in Indian soils ranged from 0% to 68 percent, with a mean of 33% (Shrotriya and Phillips, 2002). Boron shortage in watermelon manifests itself as yellowing and withered young leaf margins, leaves curling to the exterior, falling umbrella form, old leaves remaining green, and new leaves smaller than normal. The tips that are the newest have necrotic tips. The stem and vine's tops turned brown and withered, and the stem and vine ceased to grow. Poor blooming and fruit set And the fruits have a deformed appearance due to a poor skin finish. It's more common to have a hollow heart.

In light of the above findings, a field experiment is being conducted to investigate the “Effect of boron application on growth and yield of watermelon (*Citrullus lanatus*)" with the following objectives:

OBJECTIVES:

1. To study the effect of Boron on different morpho-physiological parameters of watermelon.
2. To study the effect of Boron on yield and different yield attributing parameters.

REVIEW OF LITERATURES

Boron administration to watermelon causes a variety of physiological and metabolic changes in the plants. Micronutrients, as well as macronutrients, are critical in Indian soils. Boron is a critical mineral for vascular tissue formation and differentiation, as well as carbohydrate metabolism. The effects of boron application in the soil and on the leaves have been discussed in this chapter under the following areas.

2.1 Effects of boron on Morpho-physiological parameters

2.1.1 Morphological characters

Spraying of boron 1ppm significantly increased the no. of leaves per plant (68.9) and height of the plant (128.8cm) compared to control one in tomato reported by Verma *et al.*,(1973).

Singh and Verma (1991) from their study reported that application of boron as borax @ 2kg/ha showed increase in plant height and number of branches per plant.

Naresh Babu (2002) revealed that foliar application at 50, 100, 150, 200, 250 and 300 ppm of boron and he found out that the maximum number of branches at 250ppm boron application in tomato crop

Sharma (2002) noticed that in cauliflower maximum plant height, numbers of branches per plant and percentage of seed germination were obtained when @ 25 kg borax per hectare was applied.

Amarchandran and Verma (2003) conducted an experiment to evaluate the effects of boron and calcium on growth and yield of tomato cv. Jawahar Application of Boron @ 2kg/ha + 2kg/ha of calcium recorded the highest number of branches per plant, maximum plant height, fruit yield and seed yield.

Hamsaveni *et al.,* (2003) inferred that the plant height (112.92 cm) increased considerably with the foliar spray of boron @ 0.5% at 50% flowering in tomato crop.

Prasad and Yadav (2003) suggested that foliar application of borax @ 0.3% for better growth in plant height, number of leaves per plant, stem length, stem diameter, root length and plant weight in cauliflower.

Singh *et al.,* (2003) found that the increase in growth parameters as a result of boron application might be due to better growth of growing parts(meristematic tissues), resulting in increased vegetative growth of the crop as B involved in several ongoing physiological process in plants.

Jyolsna and Usa (2008) studies the effects of boron at the rate of 0, 0.5, 1.0, and 1.5 kg per hector with recommended dose of fertilizers at southern Kerala and resulted that application of boron significantly increased plant height and number of primary branches per plant.

Sathya *et al*., (2010) studied the effect of foliar application of boron on growth, quality and fruit yield of PKM 1 Tomato. The result revealed that out of twelve different treatments, the application of boric acid @ 0 25% resulted in maximum plant height and maximum number of branches per plant.

Al-Amery *et al.,* (2011) found that boron has a positive correlation with in leaf area of plant Increased leaf area provides a better leaf exposure for light and maximum light penetration in to the leaf canopy of the plant, thereby creating favourable conditions for maximum photosynthesis in leaf.

Naz *et al.,* (2012) conducted a study to observe the effect of boron on the growth and yield of two cultivars of tomato Rio grand and Rio figure. He showed that Boron has significant effect on the growth and yield of tomato. However, 2kg B/ha resulted in maximum number of flower cluster per plant, fruit set percentage, fruit weight loss, total yield and total soluble solid.

Rab and Haq (2012) reported that foliar application of borax alone significantly enhanced the maximum plant height and the number of branches per plant in tomato crop.

Rab and Haq (2012) reported that combined application of $CaCl_2$ @ 0.6% and borax @ 0.2% resulted in maximum plant height (86.60cm) and number of branches per plant (7.21) and also noticed that application of boron alone significantly increased the number of flowers per cluster, fruits per cluster, fruits per plant, fruit weight.

Ali *et al.,* (2013) reported that the maximum plant height, number of leaves per plant, leaf length, number of flower clusters per plant and minimum number of days to flowering were observed when combination of Nitrogen 5.5g/100 ml, boron 5g/100ml and zinc 5 g/ml applied as compared to other treatments in tomato crop.

Growth and yield of groundnut was positively affected by both soil and foliar application of Boron reported by Ansari *et al.* (2013).

Manna *et al.,* (2014) stated that the application of boron @ 0.5% significantly increased the growth (plant height and number of leaves per plant), yield and quality (T.S.S. and Pyruvic acid) of onion.

Shnain *et al.,* (2014) reported that the maximum plant height (2.93m) and number of leaves per plant (39.33) in tomato crop was obtained when a combined applications of boron 1.25g/l and zinc 1.25g/l in agro-climatic conditions of Allahabad (India).

2.1.2 Physiological characters

Kalyani *et al.,* (1993) reported that when boron applied as boric acid in case of pigeon pea that increased the plant height and growth parameters like leaf area index (LAI), relative growth rate (RGR), and net assimilation rate (NAR).

Sanker *et al.,* (1998) found that crop growth rate (CGR) was also increased with increase in leaf area index (LAI) and the highest crop growth rate was recorded in between 50-75 DAS similarly, the highest leaf area index was recorded at 75 DAS. A quick response was observed at 0.75 kg boron per ha which was higher than the increased rate of boron application i.e. 1.5 kg/ha. The decrease in crop growth rate towards maturity might be due to natural senescence of older leaves in plants.

Salam *et. al.,* (2004) reported that boron increased plant growth, leaf area index, and root girth and root nodules of bean.

Pandey and Gupta (2012) investigated that foliar spray of borax@ 0.2% at 35 DAS (pre- flowering) along with recommended dose of chemical fertilizers at the rate of 20:60:20 NPK recorded maximum plant height (53.60 cm), number of leaves per plant (21.16), number of branches per plant(6.76), no. of nodules per plant (8.80), crop growth rate (0.53g m^{-2} day^{-1}), relative growth rate (0.04g g^{-1} day^{-1}), dry weight (24.82g) and harvest index (36.15%) in green gram.

Sivaiah *et al.,* (2013) recorded the higher growth rate (77.5%) with the application of boron in tomato.

2.1.3 Total biomass

Singaram and Prabha (2000) reported that the application of borax at 20-30 kg ha^{-1} or as foliar application at 0.2-0.3% increases the dry weight of tomato shoots at both the flowering and harvesting stages and also highest fruit yield found in hybrid tomato cv. Naveen.

Farzaneh *et al.,* (2011) conducted a factorial experiment to study the effect of nitrogen and boron on yield, shoot and root dry weights and leaf concentration of nutrient elements in hydroponically grown tomato. The finding results indicated that the simple and interaction effect of nitrogen and boron on yield, shoot and root dry weights were effectively significant and application of N @ 200 and B @ 1.0 (kg ha^{-1}) of treatment showed the highest yield and root dry weights in tomato.

Lewis *et al.,* (2012) conducted a study to evaluate the effect of boron on two cultivars of tomato (ev. Kosaco and cv. Josefina) under the treatments of 0.5 and 2mM boron. The results showed a loss of biomass and foliar area in tomato plants and at the same time, in the leaves of both cultivars, the B concentration increased rapidly from the first day of the experiment.

Shaimaa *et al.,* (2014) conducted experiment on effect of boron on growth and some physiological activities of tomato plants and observed that application of different concentration of boron significantly increases in case of both fresh and dry weights of the plants at low concentrations of boron i.e100 and 200ppm as compared to the control one.

2.2 Effect of boron on biochemical studies

Alice Kurien and Perer (1995) reported the lycopene ranging from 2.31 to 6.36 mg $100g^{-1}$ of fruits in 64 tomato germaplasm lines.

Sharma *et al.,* (1996) reported the maximum (7.75mg) and minimum (0.44mg) of lycopene content in 100 g of fruit in 53 genotypes of tomato.

Boron is required for many enzymatic processes, which contributed to the improved quality parameters of black pepper as reported by Villarias *et al.* (2000).

Yadav *et al.,* (2001) reported that foliar application of boron at 1.0ppm and 7.5ppm zine gives the highest number of secondary branches per plant, total chlorophyll content, leaf area, fresh weight and fruit length in tomato.

Rastogi and Abidi (2006) reported that reducing sugar content in hybrid strain NDM -21 of watermelon was 4.52 % when 75 kg K_2O ha^{-1} through soil and 0.5% Zn+0.1% B was applied through foliar spray showed maximum reducing sugar as compare to other treatment combination.

Hosseini *et al.* (2007) reported that soil application of boron increased K concentration in leaves due to the synergetic interaction between B and K.

Kumar *et al.,* (2011) stated that chlorophyll synthesis in plants is directly related to the availability of physiologically active boron in plants available form.

Salam *et al.,* (2011) investigated that the combination of boron and zine @ 2.5 kg B ha^{-1} and 6 kg Zn ha^{-1} , resulted the maximum chlorophyll content, ascorbic acid, lycopene content, highest pulp weight and dry matter content in tomato.

Gurmani *et al.,* (2012) reported that boron application at 1.0 and1.5 mg kg^{-1} significantly increased sugar, protein and chlorophyll content, in both cultivars of tomato.

Vasanthkumar *et al*. (2012) studied on different type of genotype in watermelon and reported that genotype NS -295 showed 9.69° Brix TSS when applied with foliar spray of boron alongwith application of potassium and foliar spray of zinc.

2.3 Foliar nutrition of boron

Bowszys (2001) noted that foliar application of B with 0.2% solution was superior to soil application in improving the growth and yield of Amaranthus.

Savithiri et. al., (2001) concluded that foliar spray of 0.2% boric acid thrice significantly increase the yields of groundnut and maize as compared to control one.

2.4 Effects of boron on yield and yield attributing parameters

Dongre *et al.*, (2000) recorded the maximum fruit yield per plant (395.33 g) and per hectare (109.8 q) when boron was sprayed in the form of H_3BO_3 @ 0.25% as against control (324.33 g/plant and 90.08 q/ha) in chili.

Savithiri *et al.*, (2001) concluded that foliar application of 0.2% boric acid thrice significantly increased the yields of groundnut and maize as compared to control treatment.

Paithankar *et al.*, (2004) reported in tomato highest number of fruits (25.13) by spraying mixture of 0.1% boron and 3% DAP followed by less number of fruits (19.67%) in 0.2% borax and 3% DAP sprayed plants, compared to the control (17.40). He also reported more number of healthy fruits (18.13) in 0.1% borax and 3% DAP sprayed plants, compared to the control sprayed with water only (8.53).

Sathya (2006) conducted an experiment to evaluate the various levels of boron on yield of PKM1 tomato. The result revealed that the highest fruit yield (33 t/ha) was recorded in the treatment of borax @ 20 kg/ha and was found to be significantly superior to rest of the treatments (0, 5, 10, 15 and 25 kg/ha). The yield increase was about 33.6% over control one.

Yadav *et al.*, (2006) studied the effects of boron at (0, 0 10, 0.15, 0 20, 0 25, 0.30 and 0.35%) on yield of tomato the result revealed that the highest number of fruits per plant (44.0), yield per plant (0.79 kg), number of fruits per plot (704.0), yield per plot (12.78 kg) and yield/ha (9319.50 q) were obtained with 0.20 % boron, whereas the maximum fruit weight (27 27g) was recorded at 0.10% of boron.

Application of B in sunflower @ 1.5 kg ha^{-1} gave the highest seed yield (2.01 t ha^{-1}) given by Shekhawat and Shivay (2008).

Waghdhare *et al.,* (2008) however observed that foliar application of boron through soluble and borax @ 140mg/kg recorded significantly increase in yield over control treatment.

Ceyhan *et al.,* (2008) observed that the improvement in grain and biological yield of maize is mainly attributed to complementary role of boron in the reproduction and vegetative stage of plant.

Narayanamma *et al*. (2009) reported that the application of nutrients increased the girth of watermelon and other cucurbits.

Khamwaree and Khurnpoon (2010) reported that spraying of calcium and boron had significantly increased the plant growth, yield and quality of muskmelon.

Kumar and Malabasan (2011) observed that foliar application of borax at 0.5% resulted in significantly highest number of fruits (8.3) and fruit yield per plant (377.8g) in bell pepper.

Boron foliar application @ 0.2% at flowering stage found to be optimum for realizing optimum economic yield of summer mungbean in West Bengal was obtained by Mondal *et al.,* (2012).

Vasanthkumar *et al.* (2012) reported that treatment combinations of 75 kg K_2O ha^{-1} and 0.5% Zn + 0.1% B genotype i n NS-200 and NS-295 showed maximum fruit weight 6.53 kg and 6.27 kg, respectively in watermelon.

Vasanthkumar *et. al*.(2012) obtained that that the use of higher level of potash fertilizer with foliar spray of micronutrient Zn and B in genotype NS-246 and NS-295 recorded 38.60 and 36.01 t ha^{-1} fruits yield in watermelon, respectively.

Suganiya *et al.,* (2015) reported that the foliar application of boron in form of boric acid (H_3BO_3) at 150 ppm increased the number of flower clusters per plant (48%), number of flower buds per plant (70%), number of flowers per cluster (141%), total number of flowers per plant (122%), number of fruits per plant (216%) per cent fruit set (46%) and fresh weight of fruits per plant (88%) than that of control treatment in Brinjal.

An increase in the diameter and length of watermelon fruits was observed with the use of boron in the dosage of 2 kg ha^{-1} , which can be attributed to the broad structural function of the cell wall and membrane and enzyme activator in plant metabolism; thus, affecting a better development of the cells of the fruit membrane, resulting in fruits of greater diameter and length (Bhosale *et al*., 2017).

Boron fertilization significantly increased tuber number and yield of potato was reported by Sarkar *et al.* (2018).

MATERIALS AND METHODS

A field investigation entitled, "Effect of Boron application on growth and yield of Watermelon (*Citrullus lanatus*)" conducted in the AICRP on Micronutrient at R.R.T.T.S. Central farm, OUAT, Bhubaneswar, Odisha during Rabi 2021. The information on detailed account of the materials used experimental procedures and methods adopted during the course of field and laboratory investigation are described in this chapter.

3.1 Experimental site

An experiment on watermelon was carried out at instructional cum research farm at Regional Research and Technology Transfer Centre in Coastal Zone Central farm, OUAT, Bhubaneswar, Odisha during Rabi 2021 which is situated at 20° 15"N latitude and 85°52"E longitude, elevation of 25.9 m above MSL (mean sea level) and comes under east and south eastern Coastal plain agro- climatic zones of Odisha and falls under the east Costal plains and hills zone of the humid tropics of India.

3.2 Soil Characterization

After land preparation, initial soil sample was collected from different locations in field Soil processing had done and different soil properties were analysed in the laboratory of AICRP on micronutrients and results were furnished in Table-1. The soil is slightly acidic with pH 5.73, organic carbon, available nitrogen, phosphorus; potassium and boron are found to be low. Accordingly in all treatments recommended dose of fertilizers of N P K 125:100:100 kg /ha were applied including control.

3.3 Methodology

The detail methodology adopted during the course of investigation is given below.

3.4 Weather circumstances

The climate during the crop growth and development was relatively cool and warm in nature during weekly intervals. The weather data recorded and cited in Table 1.

Table – 1: Metrological data during the period of study

Period	Month	Temperature (C°)		Relative Humidity (%)		Wind velocity (km/hr)	BSH (hrs.)	Rainfall (mm)	Evapo-ration (mm)
		Max.	Min.	7hr	14hr				
1-7	Jan.	29.4	13.4	92	36	2.1	6.2	0.0	3.7
8-14		32.8	17.9	90	40	1.8	5.4	0.0	3.6
15-21		29.8	16.9	93	45	3.3	2.7	0.0	3.6
22-28		30.6	16.8	94	35	3.4	3.4	0.0	3.6
29-4	Feb.	29.0	13.6	94	36	2.7	5.0	0.0	3.6
5-11		31.0	13.2	92	29	2.2	8.1	0.0	3.8
12-18		33.6	11.5	92	29	3.7	6.4	0.0	3.9
19-25		33.4	16.9	89	25	2.8	5.8	0.0	4.0
26-4		38.1	20.2	95	25	3.7	7.8	0.0	4.5
5-11	Mar.	37.1	22.3	95	36	5,7	6.5	0.0	4.7
12-18		36.3	22.7	92	33	4.7	7.1	0.0	5.6
19-25		38.5	23.5	92	30	3.7	3.7	0.0	6.2
26-1		39.7	24.6	93	35	5.9	6.3	7.5	7.3
2-8	Apr.	37.6	25.5	92	46	6.9	6.8	3.5	7.6
9-15		37.0	24.8	89	50	6.6	4.6	3.7	7.8
16-22		38.8	26	90	42	6.2	8.0	0.0	8.6
23-29		39.9	26.6	89	37	7.1	7.3	0.0	9.0
30-6		37.3	25	87	47	7.5	7.6	5.6	7.9
MEAN		34.9	20.0	91.6	36.4				

Table – 2: Initial soil properties of experimental plot

a) Physical properties

PARTICULARS	**COMPOSITION**	**Methods adopted**	**Scientist**
Sand %	81.40	Mechanical analysis by Bouyoucos hydrometer method	Piper (1966)
Slit %	7.30		
Clay %	11.30		
Texture class	Sandy loam	International triangle method	

b) Chemical properties

Particulars	**Composition**	**Method adopted**	**Scientist**
Soil pH (1:2.5::soil water)	5.73	Systronics pH meter	Jackson (1973)
Electrical Conductivity(dS/m)	0.066	Electrical conductivity meter	Piper (1950)
Organic carbon (g/kg)	2.62	Rapid titration method	Walkey and Black (1934)
Available Nitrogen (kg/ha)	131	Alkaline potassium Permanganate method	Subbiah and Asija (1956)
Available Phosphorus (kg/ha)	8.6	Bray's-P extractant method	Page et al. (1982)
Available potassium (kg/ha)	29.3	Ammonium acetate flame photometry method	Jackson (1973)
Available Boron (mg/kg)	0.35	Hot water soluble followed by colorimetric estimation	Berger and Troug(1939)

Table -3: Experimental details

Season	Rabi 2021
Crop	Watermelon
Source of seed	AICRP on Micronutrient, OUAT, BBSR
Variety	Augusta (Sugar baby variety)
Experiment	Field Experiment
Location	E Block, Central Farm, RRTTS, CZ, OUAT, Bhubaneswar
Design	Randomized block design (RBD)
No. of Replications	3
No. of Treatments	10
Plot size	4m X 4m
Spacing of Pits	1.5m X 1.5m
Recommended dose of fertilizer (RDF)	125:100:100 NPK kg/ha

3.5 Details of treatments

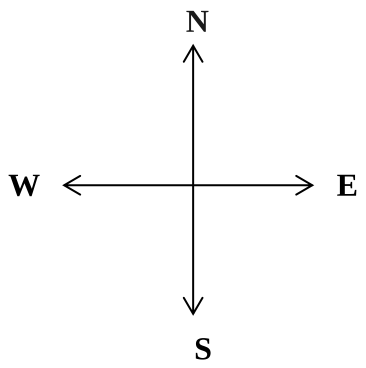
Table -4: Treatment details

TREATMENTS	PARTICULARS
T1	RDF
T2	RDF + B @1.0 kg soil application
T3	RDF + FS @0.25% Borax once
T4	RDF + FS @0.5% Borax once
T5	RDF + FS @0.75% Borax once
T6	RDF + FS @1.0% Borax once
T7	RDF + FS @0.25% Borax twice
T8	RDF + FS @0.5% Borax twice
T9	RDF + FS @0.75% Borax twice
T10	RDF + FS @1.0% Borax twice

Calender of Field operation

Table -5: Calender of works during experiment

OPERATIONS	DATE
Date of 1st ploughing field	30/12/2020
Date of 2nd ploughing field	12/1/2021
Field weed cleaning	16/1/2021
Ring Preparation, layout and bund preparation	18/1/2021
Date of sowing	18/1/2021
Application of FYM and RDF	18/1/2021
Monocrotophos spraying	8/2/2021
Date of 1st spraying (borax)	18/2/2021
Date of 2nd spraying (borax)	18/3/2021
Date of harvesting	30/4/2021



R1			R2			R3	
T7	T5		T9	T2		T10	T1
T4	T3		T10	T1		T9	T2
T6	T9		T7	T4		T8	T3
T8	T10		T6	T5		T7	T4
T2	T1		T8	T3		T6	T5

Fig – 1 Layout of experimental field

Fig –2 Experimental plot preparation

Fig -3 Sowing of seeds

3.6 Fertilizer application

A dose of N, P_2O5, K_2O at the rate of 125-100-100 kg ha in the form of urea, DAP (Diammonium phosphate) and MOP (Muriate of potash) respectively was used for the experiment The entire dose of P and K and 1/3 dose of nitrogen were applied basally while balance nitrogen was given at 30, 45, and 60days after sowing in equal doses.

Boron treatment as soil application @ 1.0kg borax/ha and foliar spray at @ 0.25%, 0.5%, 0.75% and 1.0% borax in once and twice manner in respective plots.

3.7 Biometric observation

3.7.1 Vine length (cm)

Vine length was measured from the base of the plant to the base of the fully opened top leaf Height of the randomly selected five plants was recorded at 15 days interval from previous observation, averaged and expressed in centimetre.

3.7.2 Number of leaves

The total number of leaves per plant was counted at 15 days interval from previous observation was taken and the average number of outer leaves per plant was worked out.

3.7.3 Leaf area per plant (cm^2)

The leaf area per plant was taken at 15 days interval from 45 days after transplanting and leaf area of all the leaves were measures directly over a graph paper and calculated by actual area of leaf from graph (cm) to calculated area Leaf length x Leaf breadth).

3.7.4 No. of branches

On a regular interval the number of branches per plant was counted and averaged at harvest time of final harvest.

3.7.5 No. of flowers

Under the three replications, the number of flowers on each treatment was counted at regular intervals.

3.7.6 Days to first flowering and fruiting

Days to first flowering was recorded as number of days from sowing to the when first plant of the treatment comes in flowering and treated which plants produce small watermelon.

3.8 Biochemical parameter

3.8.1 Estimation of chlorophyll content by acetone extraction method (Arnon 1949)

Total chlorophyll content in the leaves were determined by using the method stated by Amon (1949). The fresh leaf samples collected were immediately kept in moist polythene bags to keep them fresh.100 miligrams of fresh leaf was taken from the middle portion of the leaf and were cut into small pieces. The leaf discs were then put in 80% v/v acetone solution and kept in dark for 24 hours. Then they were filtered by Whatman No. 1 filter paper and the filtrate was used to record the absorbance (OD) at 645 nm and 663 nm. The respective chlorophyll content was calculated using the following formula and expressed as mg/g FW leaf.

Calculation

$$\text{Chlorophyll a} = (12.7 \times OD663 - 2.69 \times OD645)\ V/1000 \times W$$

$$\text{Chlorophyll b} = (22.4 \times OD645 - 4.68 \times OD663)\ V/1000 \times W$$

$$\text{Total chlorophyll} = (20.2 \times OD645 + 8.02 \times OD663)\ V/1000 \times W$$

Where,

OD645 = OD Value at 645 nm

OD663 = OD Value at 663 nm

V = total volume of extract (ml)

W = fresh weight of leaf (g)

3.8.2 Lycopene (mg / 100g of fruit)

In a flask with a stopper, one ml of filtered juice was placed. It was then diluted with 20 ml acetone and shaken for 30 minutes at 100rpm in a mechanical shaker. Then 40ml of petroleum ether was added to each flask and forcefully stirred to transfer the pigments to the petroleum phase, which was used to measure the colour intensity using a spectrophotometer with a 503 nm wave length.5 ml of 5% sodium sulphate was added for distinguishing ether layer and acetone layer.by using the formula of Ranganna (1977) Lycopene (mg/100g) content in juice was calculated.

$$\text{Lycopene (mg/100g of fruit)} = \frac{(3.1206 \times OD \times volume)}{\text{weight of sample}} \times 100$$

3.9 Physiological parameters

3.9.1 Crop growth rate (CGR)

The method was suggested by Watson, (1952). The CGR explains the dry matter accumulated per unit land area per unit time (g m^{-2} day^{-1}).

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

Where,

W_1 and W_2 are whole plant dry weight at time t_1 - t_2 respectively.

P is the ground area on which W_1 and W_2 are recorded.

CGR of a species are usually closed related to interception of solar radiation

3.9.2 Relative growth rate (RGR)

The daily rate of gain in dry weight per unit dry weight is called relative growth rate. The data obtained from the observations were used to determined RGR according to the following formula . (Radford, 1967) . Expressed as unit dry weight /unit dry weight /unit time (g g^{-1} day^{-1})

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

Where , W_1 = dry weight of whole plant at the start of the test period

W_2 = dry weight of whole plant at the end of the test period

$(t_2 - t_1)$ = the period in days between initial and final sampling

3.9.3 Harvest index (HI)

It is expressed as the ratio yield (yield of main product) and tot biological yield and is expressed in percentage. HI was calculated by using the following formula The term suggested by Donald, (1962).

$$HI = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

3.9.4 Total biomass (g)

The dry weight of the total plant were recorded from each treatment after harvesting and expressed as gram weight per plant.

3.10 Yield parameters

3.10.1 No. of fruits per plant

Total numbers of fruits in selected plants were counted at each harvest the number of fruits of every picking were averaged and expressed in per plant.

3.10.2 Fruit weight per plant (kg)

Weight of fruits from was recorded in kilograms from each treatments at every harvest by using digital electronic balance.

3.10.3 Yield per plant (t ha^{-1})

Yield per plant was calculated by adding weight of the fruit recorded from each plot at each harvest and expressed in tonnes per hectare.

3.10.4 No. of cracked fruits per plant

Total numbers of cracked fruits are counted and were averaged and expressed in per plant.

3.10.4 No. of marketable fruits per plant

Total numbers of cracked fruits are counted and were averaged and expressed in per plant.

3.10.5 Average fruit weight per plant (kg)

Weight of fruits from was recorded in kilograms from each treatments at every harvest by using digital electronic balance and mean weight was expressed in kilograms.

3.10.6 Fruit length (cm)

Length of fruits from was recorded in centimeter from each treatments at every harvest and mean length was expressed in centimeters.

3.10.7 Single fruit weight (kg)

Weight of each fruit is measured by the help of electronic weighing balance.

3.11 Plant tissue nutrient analysis

3.11.1 Collection and preparation of plant samples

Plant samples were collected treatment wise, replication wise cleaned with double distilled water and then dried in oven at 70°C to constant weight was attained and ground to fine powder in Willey mill with stainless steel blades. Powdered plant samples were used for nutrient analysis.

3.11.2 Digestion of plant sample

A known quantity of powdered plant sample was pre-digested with concentrated nitric acid overnight. Further, digestion was carried out with 5 ml of diacid mixture (HNO_3 :$HClO_4$) . Then the white residue left out was dissolved in 6N HC1 and volume was made up to 50 ml. Blank was prepared by following same procedure without plant material.

3.11.2.1 Nitrogen estimation

Nitrogen in the processed sample was determined by Kjeldahl digestion method as described in AOAC (1960). Exactly 200 mg of powered plant samples were taken in 100 ml digestion tubes separately, about 200mg of digestion mixture (K_2SO_4 + $CuSO_4$ = 5:1) and 4 ml of concentrated H_2SO_4 were added. These tubes were kept as such for about 1 hr and then heated slowly till frothing occurred. to checks the frothing, two crystals of sodium thiosulphate were added to each of the digestion tubes. Then the digestion was continued until the contents of the tubes become completely clear blue syrup liquid without any bubbling. The tube was cooled and content was diluted to 50 ml with distilled water. Then 10 ml of diluted sample extract was transferred in to a micro - Kjeldahal distillation unit. The digestion flask was washed twice with little amount of distilled water and all the washing were transferred in to the distillation unit. There after 10 ml of 40% NaOH was added and distillation was continued for 10 minutes. During distillation, liberated ammonia was absorbed by 10 ml of 4% boric acid in a 150 ml conical flask containing 2 drops of mixed indicator. After completion of distillation, the distillate was titrated against 0.05N HCI till pink colour appeared.

Calculation :

$$\% \text{ N in sample} = \frac{(\text{sample titer - blank titer}) \times \text{N of HCL} \times 14 \times 100 \times 2.5}{\text{Sample weight (gm.)} \times 100}$$

3.11.2.2 Phosphorus

Phosphorus content in the digested plant samples was determined by vanadomolybdophosphoric acid yellow colour method using spectrophotometer at 430 nm wave length (Jackson, 1973).

3.11.2.3 Potassium

Potassium content in the digested plant samples was determined by flame photometer after making suitable dilutions (Jackson, 1973).

3.11.2.4 Estimation of boron in plant tissue (Jackson, 1973)

One gram of dry powdered plant samples were taken in silica crucibles and placed in muffle furnace for 1-3 hr at 450-600°C. It is cooled to room temperature The sample colour was grey. The samples were wetted with 8 to 10 drops of deionised water Subsequently 0.1 N 20 ml HCI was pipette into the crucible. Samples were kept at room temperature for 50-60 minutes. The samples were stirred with plastic or boron free glass rod to break up ash exciting and filtered through Whatman No.1 filter paper. The filtrate was used for boron estimation.

3.11.2.4.1 Colour development

2 ml of filtrate was pipette into test tube and 2 ml of buffer masking reagent (EDTA) and 1 ml of azomethine-H reagent were added and mixed thoroughly. The samples were kept as such for colour development. The O.D. value was recorded in spectrophotometer at 420 nm. The absorbance readings were plot against the standard to find the concentration of boron in ppm.

3.11.2.5 Boron uptake (g/ha)

Based on concentration in parts per million nutrient content in plant on dry weight basis and dry matter ha^{-1}, the uptake of micronutrients was worked out and expressed in g ha^{-1}.

$$\text{Micronutrient uptake (g/ha)} = \frac{\text{Nutrient content (ppm)} \times \text{dry matter yield (kg ha}^{-1})}{1000}$$

3.12 Chemical analysis of soil samples

Before the commencement of experiment, a composite representative soil sample (0-15 cm depth) from the experimental site was collected. The soil samples were dried in shade, processed, passed through 2 mm sieve and used for further analysis of EC and pH, available macronutrients viz. nitrogen, phosphorus, potassium and micronutrients boron.

3.12.1 pH and electrical conductivity

Soil pH was measured in 1:2.5 soil water suspension by using pH meter. Clear supernatant solution of the soil water suspension was taken and EC was measured using conductivity meter (Jackson, 1973).

3.12.2 Organic carbon (g kg^{-1})

One gram of processed soil sample was taken in a dry glass 500 ml conical flask and 10 ml of IN $K_2Cr_2O_7$ was added and swirled a little. The flask was kept on asbestos sheet 20 ml of concentrated H_2SO_4 was added and swirled again two or three times. The flask was allowed to stand for 30 minutes preferably in darkness. 200 ml of distilled water, 10 ml of ferroin indicator were added to the contents along with fresh (0.5N) ferrous ammonium sulphate solution till the colour changed to wine red. Simultaneously, a blank was run without soil.

3.12.3 Available nitrogen (kg ha^{-1})

Available soil nitrogen was estimated by alkaline permanganate oxidation method as outlined by Subbiah and Asija (1956).

3.12.4 Available phosphorus (kg ha^{-1})

Available soil phosphorus was estimated by Olsen's method as outlined by Jackson (1973) using spectrophotometer (660 nm wave length).

3.12.5 Available potassium (kg ha^{-1})

Available soil potassium was extracted using neutral normal ammonium acetate and the content of K in the solution was estimated by flame photometer (Sparks, 1996).

3.12.6 Estimation of available boron in soil

Available boron was determined by taking 10 g of air dried soil in a boron free conical flask. 20 ml of distilled water was added and was placed on a hot plate The content of the conical flask was allowed to boil for 10 minutes. Then it was filtered through Whatman No. 42 filter paper into a Boron free container 2 ml of extract (or standard) was pipette out into a suitable plastic or Boron free glass test tube 2 ml of buffer reagent was added to it followed by addition of 2 ml of Azomethine-H reagent. It was mixed well and allowed to develop colour for 1 hr Then the colour intensity was measured at 420 nm wave length in Systronics Spectrophotometer model 166 (John et al., 1975).

3.12.7 Estimation of Calcium and Magnesium in plant sample

3.12.7.1 Principle

Calcium and magnesium forms complexes with EDTA, in the order of Ca first and Mg afterwards. In this experiment Ca is estimated first by using an indicator murexide at pH12 in the presence of sodium hydroxide. The calcium magnesium is estimated by using an indicator Eriochrome black T at pH 10 in the presence of ammonium chloride and ammonium hydroxide buffer solution.

3.12.7.2 Materials Required

1.0.02N EDTA

2. 10% sodium hydroxide

3. Ammonium Chloride ammonium hydroxide buffer solution

4. Murexide indicator

5. Eriochrome black-T indicator

3.12.7.3 Procedure

3.12.7.4 Calcium analysis

Pipette out 25 ml of triple acid extract into a porcelain basin. Add 10% sodium hydroxide drop by drop to neutralise the acidity (red litmus turn blue) and add another 5ml excess to maintain the pH at 10. Add a pinch of murexide indicator and titrate against 0.02 N EDTA till red colour changes from pinkish red to purple or violet.

3.12.7.5 Calcium & Magnesium analysis

Pipette out 25 ml of triple acid extract into a porcelain basin. Add ammonium hydroxide buffer solution drop by drop to neutralise the acidity and 5 ml excess to maintain the pH at 10. Add 2-3 drops of Eriochrome black T indicator and titrate against 0.02N EDTA till the colour changes from purplish red to sky blue.

3.12.7.6 Observations and Calculations

Weight of plant sample taken = w g

Volume of triple acid extract prepared = V ml

Volume of triple acid extract pipette out for titration = 25ml

Volume of 0.02 N EDTA used for Ca+ Mg = A ml

Volume of 0.02 N EDTA used for Ca alone = B ml

Volume of 0.02 N EDTA used for Mg = 'A-B' ml

1 ml of 0.02N EDTA = 0.0004g of calcium

Percentage of calcium in the given sample on moisture free basis

$= 0.004 \times B \times 250/5 \times 100/3 - 3$

1 ml of 0.02N EDTA = 0.0024g of Mg.

Percentage of magnesium in the given sample on moisture free basis

$= 0.004 (A-B \times 250/5 \times 100/3 \times 100/100-m)$

Where M = moisture percentage in the given sample

3.12.8 Calcium and Magnesium analysis of soil

By EDTA titration method the calcium and magnesium content of soil wass analysed.

3.12.9 Sulphur analysis of soil

By turbidimetric method the aulphur content of soil was analysed.

3.13 Statistical analysis and interpretation of data

The data collected from the experiment at different growth stages and from laboratory analysis were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used in ‘F’ test was 0.05 Critical difference values were calculated wherever the 'F' test was significant.

RESULTS

The present field experiment was carried out in Rabi 2021 in the central farm of OUAT to find out the impact of soil and foliar application of boron on physiological aspects of watermelon (*Citrullus lanatus*) to different concentrations in the form of borax at the rate of 0.25%, 0.5%, 0.75%, 1.0% as chemical formulation and applied as foliar application once at 45 DAS and another at 75 DAS respectively. A single soil application of boron at the rate of 1.0 kg per ha was used as basal dose at the time of sowing. The treatments was replicated thrice with completely randomized block design. Boron translocation and accumulation in watermelon along with its effect to different growth parameters, alteration of metabolites and yield attributes were recorded. The data generated was statistically analysed and results obtained were presented with tables and figures wherever necessary in this chapter.

4.1 Morpho-Physiological parameters

Different concentrations of boron in three formulations i.e. soil application, foliar spraying once and twice to watermelon crop had shown a visible impact on morphological and physiological parameters.

4.1.1 Vine Length

Vine length was measured at intervals of 15 days up to harvest and were presented in table - 6, which revealed that application of boron both in form of foliar and soil in watermelon was significantly enhanced among the treatments at different growth stages up to harvest with a range of 144.13 cm to 172.97 cm. Increased in vine length was highest in foliar spray of borax @ 0.5% when applied at two different crop growth stages over control (144.13 cm). In soil application @ 1kg B/ha it was 166.8 cm at the time of harvesting. Increased in vine length among the treatments was found statistically significant at all intervals except 45 days after sowing.

Table -6 Impact of soil and different conc. of foliar application of boron on vine length (cm) of watermelon

TREATMENTS	45 DAS	60 DAS	75 DAS	90 DAS
T1 – Control (No Boron)	77.96	107.05	131.35	144.13
T2 – Soil application (@ 1kg B/ha)	88.63	124.61	151.91	166.8
T3 – FS @ 0.25% once	79.72	116.55	145.35	162.97
T4 – FS @ 0.5% once	87.69	122.61	150.85	165.97
T5 – FS @ 0.75% once	82.32	120.11	149.35	165.00
T6 – FS @ 1.0% once	82.77	121.15	149.52	165.13
T7 – FS @ 0.25% twice	84.56	121.65	150.19	165.80
T8 – FS @ 0.5% twice	86.40	134.78	163.35	172.97
T9 – FS @ 0.75% twice	81.89	121.08	148.02	164.3
T10 – FS @ 1.0% twice	80.85	119.95	147.85	163.63
C. V. (%)	13.58	10.37	11.40	7.54
S.E.m (±)	3.47	3.20	4.07	2.82
C.D. (0.05)	NS	9.56	12.14	8.44

4.1.2 No. of branches

The no of branches was counted at 45 DAS up to harvest and was depicted in table -7. Increase in no. of branches was highest in foliar spray @ 0.5% twice borax (9.69) followed by soil application @ 1kg/ha (9.46) to least in control (6.58) whereas FS 0.5% borax once and FS 0.25% borax twice showed almost on par with each other. The results revealed that the mean no. of branches was found statistically significant at all intervals except 45DAS.

Table -7 Impact of soil and different conc. of foliar application of boron on No. of branches of watermelon

TREATMENTS	45 DAS	60 DAS	75 DAS	90 DAS
T1 – Control (No Boron)	2.54	5.51	6.31	6.58
T2 – Soil application (@ 1kg B/ha)	4.48	7.28	8.45	9.46
T3 – FS @ 0.25% once	2.61	5.75	6.85	7.64
T4 – FS @ 0.5% once	4.31	6.98	8.35	9.09
T5 – FS @ 0.75% once	3.38	6.28	8.05	8.40
T6 – FS @ 1.0% once	3.78	6.45	8.05	8.71
T7 – FS @ 0.25% twice	4.08	6.77	8.31	9.08
T8 – FS @ 0.5% twice	4.78	7.48	8.55	9.69
T9 – FS @ 0.75% twice	3.31	6.06	7.82	8.01
T10 – FS @ 1.0% twice	2.98	5.97	7.21	7.64
C. V. (%)	4.65	7.76	6.20	13.41
S.E.m (±)	0.10	0.27	0.26	0.62
C.D. (0.05)	0.28	0.84	0.81	1.90

4.1.3 No. of compound leaves

The no. of leaves were counted at 45 DAS up to harvest and were presented in table no-8, which revealed that foliar spray @0.5% twice found higher no. of compound leaves (55.4) followed by soil application @ 1kg B/ha (53.6) and least in control (38.3). Whereas FS @1.0% once and FS @ 0.25% twice found almost at par with each other. The compound leaf number was found statistically significant except at 45 days after sowing.

Table -8 Impact of soil and different conc. of foliar application of boron on No. of compound leaves of watermelon

TREATMENTS	45 DAS	60 DAS	75 DAS	90 DAS
T1 – Control (No Boron)	12.64	26.31	38.31	34.23
T2 – Soil application (@ 1kg B/ha)	22.48	42.48	53.64	48.97
T3 – FS @ 0.25% once	16.48	35.31	44.17	40.01
T4 – FS @ 0.5% once	22.14	41.81	50.78	46.76
T5 – FS @ 0.75% once	20.14	36.81	46.64	41.46
T6 – FS @ 1.0% once	20.98	39.48	49.48	46.55
T7 – FS @ 0.25% twice	21.14	40.81	49.81	45.21
T8 – FS @ 0.5% twice	24.14	43.64	55.48	51.72
T9 – FS @ 0.75% twice	18.98	36.64	45.48	42.10
T10 – FS @ 1.0% twice	18.48	36.14	45.31	41.02
C. V. (%)	11.38	14.15	10.47	11.85
S.E.m (±)	1.28	3.08	2.88	1.52
C.D. (0.05)	3.85	9.21	8.61	4.62

4.1.4 Leaf area (cm^2)

The leaf area calculated in cm^2 per plant was depicted in table no- 9 which revealed that photosynthesizing leaf area was increased within the treatments up to peak growth stage and later towards harvesting stage it decreases. The plant treated with foliar application of borax @ 0.5% twice showed highest leaf area of 73.12 cm^2 at 75 DAS (peak crop growth stage) than other treatments followed by soil application @ 1kg B/ha showed leaf area of 70.00 cm^2. The leaf area was found statistically significant among the treatments.

Table -9 Impact of soil and different conc. of foliar application of boron on leaf area of watermelon

TREATMENTS	45 DAS	60 DAS	75 DAS	90 DAS
T1 – Control (No Boron)	17.45	29.97	40.08	39.35
T2 – Soil application (@ 1kg B/ha)	27.79	43.05	70.00	69.34
T3 – FS @ 0.25% once	20.82	36.89	50.51	48.89
T4 – FS @ 0.5% once	27.00	42.56	68.56	65.60
T5 – FS @ 0.75% once	24.84	38.60	59.85	58.78
T6 – FS @ 1.0% once	24.72	40.64	60.75	59.40
T7 – FS @ 0.25% twice	25.00	41.94	67.68	63.31
T8 – FS @ 0.5% twice	29.60	43.45	73.12	72.80
T9 – FS @ 0.75% twice	23.75	38.51	62.23	61.42
T10 – FS @ 1.0% twice	22.65	37.62	56.94	55.94
C. V. (%)	2.71	4.72	10.24	8.04
S.E.m (±)	0.28	1.05	3.30	1.26
C.D. (0.05)	0.89	3.18	9.78	3.80

4.1.5 No. of days to first flowering and fruiting after sowing

Watermelon subjected to soil application and foliar application (once and twice) showed different days to 1st flowering and 1st fruiting presented in table -10 revealed that after 6-7 weeks there was first flowering which was statistically significant among all treatments. Foliar spray 0.5% twice showed early flowering in 45.48 DAS and late flowering of 52 DAS was in control.

First fruiting take place at 20-22 days interval of time after flowering which shows statistically significant in all treatments. FS@ 0.5% twice showed early fruiting in 65.61 days followed by FS@ 0.5% once at (67.22 days) and soil application @ 1kg B/ha at (67.92 days) and there was late fruiting in case of control.

Table -10 Impact of soil and different conc. of foliar application of boron on No. of days to 1st flowering and 1st fruiting in watermelon

TREATMENTS	Days to 1st flowering	Days to 1st fruiting
T1 – Control (No Boron)	52.00	72.96
T2 – Soil application (@ 1kg B/ha)	46.64	67.92
T3 – FS @ 0.25% once	51.67	71.90
T4 – FS @ 0.5% once	46.98	67.22
T5 – FS @ 0.75% once	48.31	70.64
T6 – FS @ 1.0% once	47.83	69.93
T7 – FS @ 0.25% twice	47.49	68.67
T8 – FS @ 0.5% twice	45.48	65.61
T9 – FS @ 0.75% twice	48.65	69.29
T10 – FS @ 1.0% twice	49.16	70.60
C. V. (%)	4.12	2.89
S.E.m (±)	0.52	0.47
C.D. (0.05)	1.58	1.44

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

The gain in weight of the plants per unit plant per time called CGR was recorded after spraying of borax to harvest and presented in table - 11. The data showed that the CGR was highest within 45-75 DAS than other observation period. The presented data showed that highest CGR value was in T_8 (1.11 g m^{-2} day^{-1}) followed by T_2 (0.98 g m^{-2} day^{-1}) and then T_4 (0.95 g m^{-2} day^{-1}) respectively. Similarly growth pattern was also found in other observation dates and was statistically significant among the treatments.

Table -11 Impact of soil and different conc. of foliar application of boron on crop growth rate (g m^{-2} day^{-1}) in watermelon

TREATMENTS	45-75 DAS	75-90DAS
T1 – Control (No Boron)	0.68	0.42
T2 – Soil application (@ 1kg B/ha)	0.98	0.62
T3 – FS @ 0.25% once	0.79	0.47
T4 – FS @ 0.5% once	0.95	0.57
T5 – FS @ 0.75% once	0.87	0.58
T6 – FS @ 1.0% once	0.89	0.55
T7 – FS @ 0.25% twice	0.91	0.56
T8 – FS @ 0.5% twice	1.11	0.67
T9 – FS @ 0.75% twice	0.92	0.48
T10 – FS @ 1.0% twice	0.85	0.55
C. V. (%)	7.89	10.11
S.E.m (±)	0.039	0.031
C.D. (0.05)	0.121	0.097

4.1.7 Total dry matter (g)

The total biomass (on dry weight basis) estimated in this experimental treatments which was depicted in table -12 the result showed that the maximum biomass obtained in foliar application of @ 0.5% borax twice (48.88 g) followed by soil application @ 1Kg B/ha (44.32 g) and foliar application of @ 0.5% once (43.33 g) than the control at harvesting stage. The total biomass was found statistically significant among the treatments.

Table -12 Impact of soil and different conc. of foliar application of boron on total dry matter (g) in watermelon

TREATMENTS	Shoot dry weight	Root dry weight	Total dry weight
T1 – Control (No Boron)	26.88	2.62	29.49
T2 – Soil application (@ 1kg B/ha)	38.64	5.69	44.32
T3 – FS @ 0.25% once	28.41	4.33	32.86
T4 – FS @ 0.5% once	38.14	5.01	43.33
T5 – FS @ 0.75% once	32.38	4.33	36.80
T6 – FS @ 1.0% once	35.18	3.44	38.68
T7 – FS @ 0.25% twice	35.81	4.58	40.40
T8 – FS @ 0.5% twice	41.91	6.30	48.88
T9 – FS @ 0.75% twice	30.05	3.68	33.85
T10 – FS @ 1.0% twice	29.08	2.76	31.99
C. V. (%)	4.71	4.61	4.68
S.E.m (±)	0.91	0.11	0.65
C.D. (0.05)	2.64	0.33	1.03

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

The increase in dry weight per original dry weight of the plant per unit time called (RGR) was calculated at peak growth stages of crop cited in table -13. The experimental data revealed that there is a significant higher value at 45-75 DAS and then decreased in 75-90 DAS. At 45-75 DAS RGR showed a variable range of (0.046 -0.067) g g^{-1} day $^{-1}$ and was found highest in FS 0.5% twice borax. Whereas T_2, T_4, T_7 was at par with each other. Similarly T_9 and T_{10} was at par with each other. The relative growth rate among the treatments was found statistically significant.

Table -13 Impact of soil and different conc. of foliar application of boron on relative growth rate (g m^{-2} day^{-1}) in watermelon

TREATMENTS	45-75 DAS	75-90DAS
T1 – Control (No Boron)	0.046	0.039
T2 – Soil application (@ 1kg B/ha)	0.063	0.062
T3 – FS @ 0.25% once	0.051	0.046
T4 – FS @ 0.5% once	0.063	0.060
T5 – FS @ 0.75% once	0.057	0.053
T6 – FS @ 1.0% once	0.058	0.056
T7 – FS @ 0.25% twice	0.063	0.057
T8 – FS @ 0.5% twice	0.067	0.063
T9 – FS @ 0.75% twice	0.056	0.050
T10 – FS @ 1.0% twice	0.056	0.053
C. V. (%)	10.42	12.76
S.E.m (±)	0.003	0..003
C.D. (0.05)	0.010	0.011

4.1.9 Total chlorophyll (mg/g FW of leaf sample)

The total chlorophyll in leaves analysed during the experiment was presented in table-14. The result revealed that the amount of total chlorophyll synthesized during experimental period in leaves was maximum up to 75 DAS thereafter decreased gradually. The data showed the higher amount of chlorophyll in 75 DAS. Foliar spray of @ 0.5% borax twice showed higher chlorophyll content (1.360 mg/g FW) followed by soil application @ 1kg B/ha (1.356 mg/g FW) respectively. The least amount is in control (1.126 mg/g FW). All the chlorophyll content was found statistically significant in the treatments**.**

Table -14 Impact of soil and different conc. of foliar application of boron on chlorophyll content (mg/g FW of leaf sample) of watermelon

TREATMENTS	45 DAS	60 DAS	75 DAS	90 DAS
T1 – Control (No Boron)	0.681	0.879	1.126	0.648
T2 – Soil application (@ 1kg B/ha)	0.973	1.271	1.356	1.032
T3 – FS @ 0.25% once	0.748	0.949	1.162	0.730
T4 – FS @ 0.5% once	0.931	1.233	1.345	0.977
T5 – FS @ 0.75% once	0.820	0.982	1.269	0.789
T6 – FS @ 1.0% once	0.791	0.947	1.203	0.747
T7 – FS @ 0.25% twice	0.864	1.092	1.277	0.874
T8 – FS @ 0.5% twice	1.094	1.295	1.360	1.142
T9 – FS @ 0.75% twice	0.757	0.964	1.168	0.745
T10 – FS @ 1.0% twice	0.691	0.943	1.147	0.671
C. V. (%)	4.71	4.73	4.83	4.67
S.E.m (±)	0.020	0.033	0.035	0.023
C.D. (0.05)	0.071	0.089	0.106	0.073

4.2 Mineral nutrition

N P K content

The plant sample of NPK estimation is done at harvest stage which reveals from Table-15 was application of boron as soil and foliage recorded a significant variation in nitrogen. The highest NPK % is recorded in T_8 when applied twice @0.5% borax (1.726%, 0.195%, 1.242%) followed by T_2 soil application @ 1kg B/ha (1.720% , 0.193% , 1.173%).The lowest percentage is recorded in control T_1 (1.371% , 0.139% , 0.931%).

Table -15 Impact of soil and different conc. of foliar application of boron on N P K content at harvest in watermelon

TREATMENTS	Nitrogen % in plant sample	Phosphorus % in plant sample	Potassium % in plant sample
T1 – Control (No Boron)	1.371	0.139	0.931
T2 – Soil application (@ 1kg B/ha)	1.720	0.193	1.173
T3 – FS @ 0.25% once	1.543	0.162	1.015
T4 – FS @ 0.5% once	1.664	0.192	1.129
T5 – FS @ 0.75% once	1.625	0.177	1.101
T6 – FS @ 1.0% once	1.590	0.176	1.052
T7 – FS @ 0.25% twice	1.639	0.191	1.116
T8 – FS @ 0.5% twice	1.726	0.195	1.242
T9 – FS @ 0.75% twice	1.475	0.171	1.041
T10 – FS @ 1.0% twice	1.437	0.159	0.987
C. V. (%)	4.81	4.77	4.80
S.E.m (±)	0.044	0.012	0.032
C.D. (0.05)	0.138	0.037	0.093

4.3 Lycopene content (mg/100g)

Lycopene content of the experimental fruits after harvesting was analysed and represented in Table no. 16. The plots are treated with FS and control. Higher lycopene content (3.84 mg/100g) was observed in FS@ 0.5% borax twice and least lycopene content (2.75 mg/100g) was found in control.

Table -16 Impact of soil and different conc. of foliar application of boron on lycopene content (mg/100g) in watermelon

TREATMENTS	Lycopene (mg/100g)
T1 – Control (No Boron)	2.75
T2 – Soil application (@ 1kg B/ha)	3.08
T3 – FS @ 0.25% once	2.83
T4 – FS @ 0.5% once	3.49
T5 – FS @ 0.75% once	3.21
T6 – FS @ 1.0% once	3.28
T7 – FS @ 0.25% twice	3.31
T8 – FS @ 0.5% twice	3.84
T9 – FS @ 0.75% twice	3.08
T10 – FS @ 1.0% twice	2.93
C. V. (%)	3.76
S.E.m (±)	0.071
C.D. (0.05)	0.208

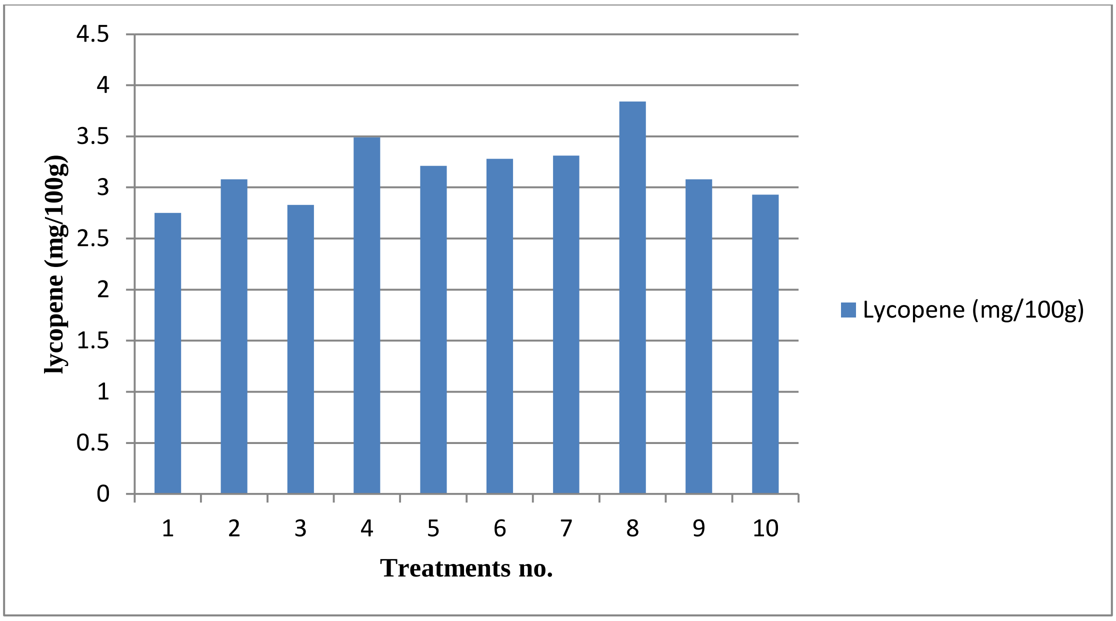


Fig - 4 Effect of foliar and soil application of boron on lycopene content of watermelon

Fig -5 Borax spraying in watermelon

4.4 Boron content (mg/100g) and boron uptake (mg/plot)

Boron content and uptake by watermelon was influenced by different form and concentration of boron presented in table-17. The result showed that FS @ 1.0% twice was found to be superior than rest of the treatments in boron content (fruit and leaf samples) which is followed by FS borax 0.75% twice. At harvest FS @1.0% borax twice showed boron content of calculated 3.94 mg /100g in fruit and 3.26 mg/100g in leafs of boron and 3.12 mg/plot mid 3.01 mg/plot boron uptake in fruit and leaf respectively. The effect of boron on boron content and uptake among the treatment was statistically significant.

Table -17 Impact of soil and different conc. of foliar application of boron on boron content and uptake (fruit and leaf sample) of watermelon

TREATMENTS	B content (fruit)	B content (leaf)	B uptake (fruit)	B uptake (leaf)
T1 – Control (No Boron)	2.70	2.14	1.77	1.46
T2 – Soil application (@ 1kg B/ha)	2.99	2.37	2.38	2.64
T3 – FS @ 0.25% once	2.79	2.32	1.97	1.65
T4 – FS @ 0.5% once	2.93	2.41	2.90	1.66
T5 – FS @ 0.75% once	2.87	2.46	2.70	1.97
T6 – FS @ 1.0% once	3.22	2.85	2.43	2.65
T7 – FS @ 0.25% twice	3.13	2.66	2.55	1.91
T8 – FS @ 0.5% twice	3.50	3.17	3.44	3.01
T9 – FS @ 0.75% twice	3.80	3.04	2.11	2.59
T10 – FS @ 1.0% twice	3.94	3.26	3.12	3.01
C. V. (%)	9.32	8.57	8.09	12.81
SEm (±)	0.17	0.14	0.13	0.19
CD (0.05)	0.50	0.41	0.37	0.55

4.5 Ca^{2+} and Mg^{2+} content (%) of plant sample

Calcium and magnesium content of the plant sample after harvesting was analysed and represented in Table no. 18. Results indicated that the plots treated with FS @ 0.5% borax twice showed higher calcium and magnesium than rest of treatments. Higher Ca^{2+} and Mg^{2+} content 0.848% and 1.189% respectively was found in FS@ 0.5% borax twice and least Ca^{2+} and Mg^{2+} content 0.709% and 1.189% respectively in control.

Table -18 Impact of soil and different conc. of foliar application of boron on Ca^{2+} and Mg^{2+} content (%) of plant sample in watermelon

TREATMENTS	Ca^{2+} content (%)	Mg^{2+} content (%)
T1 – Control (No Boron)	0.709	0.913
T2 – Soil application (@ 1kg B/ha)	0.843	1.154
T3 – FS @ 0.25% once	0.767	0.931
T4 – FS @ 0.5% once	0.842	1.124
T5 – FS @ 0.75% once	0.793	1.055
T6 – FS @ 1.0% once	0.788	1,050
T7 – FS @ 0.25% twice	0.799	1.060
T8 – FS @ 0.5% twice	0.848	1.189
T9 – FS @ 0.75% twice	0.776	0.946
T10 – FS @ 1.0% twice	0.757	0.923
C. V. (%)	10.73	8.37
S.E.m (±)	0.104	0.080
C.D. (0.05)	0.287	0.243

4.7 Yield attributes

4.7.1 No. of fruits per plant

No. of fruits per plant was calculated in experimental plants and final harvesting was presented per plant in table -20. The plants treated with FS @ 0.5% borax twice showed higher no. of fruits per plant (7.14) followed by soil application @ 1kg B/ha (6.79) and FS @ 0.5% borax once (6.00). The least no of fruits per plant showed in control (3.76). The no. of fruits per plant was found statistically significant among all the treatments.

4.7.2 No. of cracked fruits per plant

No. of cracked fruits per plant was calculated in experimental plants at final harvesting, averaged them and presented per plant in table -20. The plants treated with FS @ 0.25% borax once, FS @ 1.00% borax once, FS @ 0.75% borax twice, FS @ 1.00% borax twice and control showed fruits cracking 1.06, 1.04, 1.02, 1.01, 1.08 respectively. Also no fruit cracking seen in rest of the treatments.

4.7.3 No. of marketable fruits per plant

No. of marketable fruits per plant was calculated in experimental plants at final harvesting. averaged them and presented per plant in table -20. The plants treated with FS @ 0.5% borax twice showed higher no. of marketable fruits per plant (7.14) followed by soil application @ 1kg B/ha(6.79) and FS @ 0.5% borax once (6.00) respectively. Also the least no: of marketable fruits per plant was in control (2.16).

Table -20 Impact of soil and different conc. of foliar application of boron on no. of fruits per plant, no. of cracked fruits per plant and no. of marketable fruits per plant of watermelon

TREATMENTS	No. of fruits	No. of cracked fruits	No. of marketable fruits
T1 – Control (No Boron)	3.76	1.08	2.16
T2 – Soil application (@ 1kg B/ha)	6.79	0	6.79
T3 – FS @ 0.25% once	3.84	1.06	2.85
T4 – FS @ 0.5% once	6.00	0	6.00
T5 – FS @ 0.75% once	5.82	0	5.82
T6 – FS @ 1.0% once	4.95	1.04	3.12
T7 – FS @ 0.25% twice	5.94	0	5.94
T8 – FS @ 0.5% twice	7.14	0	7.14
T9 – FS @ 0.75% twice	4.80	1.02	3.06
T10 – FS @ 1.0% twice	3.80	1.01	2.82
C. V. (%)	12.13	8.07	4.62
S.E.m (±)	0.32	0.02	0.12
C.D. (0.05)	0.92	0.07	0.35

4.7.4 Average fruit weight (g)

The experimental data showed in table -21 analysed statistically and found significant with respect to average fruit weight (kg). The assessment of data revealed that average fruit weight ranges from 1.70 to 2.85 kg. Highest average fruit weight was in the treatment T_8 (FS @ (0.5% borax twice) with 2.85 kg followed by T_2 (soil application) @ 1kg B/ha andT_4 (FS @0.5% borax once) as 2.70 kg and 2.40 kg respectively. Lowest average fruit weight found in control i.e. T_1 (1.70 kg).

4.7.5 Fruit length (cm)

The experimental data showed in table -21 analysed statistically and found significant with respect to fruit length (cm). The assessment of data revealed that fruit length ranges from 21.3 – 29.4 cm. Highest fruit length found in the treatment T_8 (FS @ (0.5% borax twice) was 29.4 cm followed by T_2 (soil application) @ 1kg B/ha andT_4 (FS @0.5% borax once) as 28.9 cm and 25.6 cm respectively. Lowest fruit length found in control i.e. T_1 (21.3 cm).

Table -21 Impact of soil and different conc. of foliar application of boron on average fruit weight (kg) and fruit length (cm) of watermelon

TREATMENTS	Avg. fruit weight (kg)	Fruit length (cm)
T1 – Control (No Boron)	1.70	21.3
T2 – Soil application (@ 1kg B/ha)	2.70	28.9
T3 – FS @ 0.25% once	1.84	22.4
T4 – FS @ 0.5% once	2.40	25.6
T5 – FS @ 0.75% once	2.10	23.8
T6 – FS @ 1.0% once	1.95	22.8
T7 – FS @ 0.25% twice	2.27	24.5
T8 – FS @ 0.5% twice	2.85	29.4
T9 – FS @ 0.75% twice	1.85	22.6
T10 – FS @ 1.0% twice	1.74	22.1
C. V. (%)	4.68	4.77
S.E.m (±)	0.06	0.67
C.D. (0.05)	0.17	1.94

4.7.6 No. of flowers per plant

No. of flowers was counted and cited in table -22. The results revealed that there was significant effect of boron on no. of flowers per plant. Foliar application of boron @ 0.5% borax twice provides higher no of flowers in peak flowering stages. The no. of flowers per plant was highest in FS @ 0.5% borax twice, as the watermelon plant continues fruiting till final harvesting. The no. of flowers per plant was found statistically significant in all treatments.

4.7.7 Single fruit weight (kg)

The experimental data showed in table -22 analysed statistically and found significant with respect to single fruit weight (kg) . The assessment of data revealed that single fruit weight ranges from (1.80 – 2.94) kg . Highest single fruit weight was perceived in the treatment T_8 (FS @ (0.5% borax twice) was 2.94 kg followed by T_2 (soil application) andT_4 (FS @0.5% borax once) as 2.74 kg and 2.52kg respectively. Lowest single fruit weight found in control T_1 (1.80 kg).

Table -22 Impact of soil and different conc. of foliar application of boron on no. of flowers per plant and single fruit weight (kg) of watermelon

TREATMENTS	No. of flowers	Single fruit weight (kg)
T1 – Control (No Boron)	7.60	1.80
T2 – Soil application (@ 1kg B/ha)	9.70	2.74
T3 – FS @ 0.25% once	7.92	1.93
T4 – FS @ 0.5% once	9.50	2.52
T5 – FS @ 0.75% once	8.82	2.26
T6 – FS @ 1.0% once	8.73	2.03
T7 – FS @ 0.25% twice	8.91	2.36
T8 – FS @ 0.5% twice	10.20	2.94
T9 – FS @ 0.75% twice	8.40	1.95
T10 – FS @ 1.0% twice	7.68	1.86
C. V. (%)	4.79	4.69
S.E.m (±)	0.24	0.06
C.D. (0.05)	0.70	0.18

4.8 Yield (t ha^{-1})

Application of boron in different concentrations to watermelon recorded a significant increment over control as presented in Table-23. The treatment T_8 (38.15 t ha^{-1}) was recorded maximum followed by T_2 (36.21 t ha^{-1}). The lowest yield was observed in case of treatment T_1 (24.35 t ha^{-1}). Yield is statistically significant among the treatments.

4.9 Harvest index (%)

The data revealed from Table-23 was shown a similar response when compared with yield i.e., soil and foliar application of boron has direct impact on harvest index of watermelon. The treatment T_8 (85.78%) was recorded highest followed by T_2 (84.67%). However, the lowest harvest index was observed in case of T_1 (75.34 %). Harvest index among the treatments is statistically significant.

Table -23 Impact of soil and different conc. of foliar application of boron on yield (t/ha) and harvest index (%) in watermelon

TREATMENTS	Yield (t/ha)	HI (%)
T1 – Control (No Boron)	24.35	75.34
T2 – Soil application (@ 1kg B/ha)	36.21	84.67
T3 – FS @ 0.25% once	28.73	77.04
T4 – FS @ 0.5% once	35.43	83.32
T5 – FS @ 0.75% once	32.19	81.50
T6 – FS @ 1.0% once	29.25	79.63
T7 – FS @ 0.25% twice	32.62	82.35
T8 – FS @ 0.5% twice	38.15	85.78
T9 – FS @ 0.75% twice	29.00	78.27
T10 – FS @ 1.0% twice	27.60	76.42
C. V. (%)	8.21	4.89
S.E.m (±)	1.45	2.35
C.D. (0.05)	4.52	6.78

4.10 Post harvest soil analysis

Post harvest soil analysis was done at laboratory and cited in Table-24 indicates that a variation in soil pH from initial 5.73 when imposed different concentrations of boron. The soil pH at FS @ 0.5% borax twice application had increased from 5.73 to 6.14 and there was no change in control treatment. Soil boron is recorded maximum at treatment T_2 (0.299) which at par with FS @ 0.5% borax twice application T_8 (0.289).

Table -24 Impact of soil and different conc. of foliar application of boron on post harvest soil analysis on watermelon

TREATMENTS	pH	EC (dS/m)	Soil boron (mg/kg)
T1 – Control (No Boron)	5.73	0.104	0.198
T2 – Soil application (@ 1kg B/ha)	5.84	0.084	0.299
T3 – FS @ 0.25% once	5.75	0.085	0.255
T4 – FS @ 0.5% once	5.72	0.077	0.276
T5 – FS @ 0.75% once	5.56	0.094	0.232
T6 – FS @ 1.0% once	5.48	0.091	0.277
T7 – FS @ 0.25% twice	5.66	0.094	0.271
T8 – FS @ 0.5% twice	6.14	0.095	0.289
T9 – FS @ 0.75% twice	5.69	0.087	0.261
T10 – FS @ 1.0% twice	5.88	0.092	0.286
C. V. (%)	3.92	5.37	4.08
S.E.m (±)	0.14	0.02	0.01
C.D. (0.05)	NS	NS	NS

DISCUSSION

Boron (B) is an essential micronutrient for growth and development of watermelon. It plays important role in physiological and biochemical processes and increases total yield of watermelon when applied to soil as well as foliar spray at critical stages of crop growth. Boron regulates the metabolism of carbohydrates in plants and enhance the translocation from the site of synthesis to reproductive tissue in fruit. It is also essential for process by which meristematic cells differentiate to form specific tissue and promotes the absorption of nitrogen from soil and increases the plant dry weight (Jing *et al.*, 1994). In case boron deficiency plant cell may continue to divide but structural components are not differentiated. Retrieval of the facts, the present experiment aimed at assessing the impact of soil and frequencies of foliar application of boron on physiological aspects of watermelon. Data recorded for various morpho-physiological, biochemical and yield as well as quality parameters reveals several point of interest which can be discussed in conjugation with findings of other workers. Therefore, the assessment of experimental treatments by such supplementary data has been reasonably justified.

5.1 Morpho-Physiological characters

5.1.1 Vine length, Leaf number, and leaf area responses

Our findings indicate that application of boron to watermelon have a marked effect on increase in vine length, no of branches, number of leaves, and leaf area(cm^2) in all the treatments over untreated control plants. The highest plant height was observed in T_8 (FS @ 0.5% borax twice) and T_2 (soil application) showed averaged results. Also the no. of branches per plant was higher in T_8 (FS @ 0.05% borax twice) , T_2 (soil application) and least in control one. The findings are supported by finding of Yoganand (2001) recorded the lowest plant height and no of branches per plant with borax at 0.2% sprayed at pre flowering stage against control one.

The vine length, leaf number is an important growth character directly linked with potential of watermelon plant and yield. This might be due to direct absorption of boron by growing parts of the plant which resulted in more tissue differentiation, cell division, and cell elongation. An increase in the above parameters might be due to availability of boron at later growth stages of watermelon and are absorbed right at the site where they are used as quite fast acting, as the foliar application of boron can protect stomata from drying and helped to remain closed (Mahud *et al.*, 2007). On the other hand, soil applied fertilizer in form of borax might be less advantageous because of lower solubility and immobile in plants though the soil pH is 5.73. The above results are in mutual agreement with the findings of Gupta, 1993 and Ain *et al.* (1991).

Number of leaves per plant and average leaf area was higher in 9 treatments including soil application than control one. The maximum leaf no and leaf area was recorded in T_8 followed by T_2 and T_4 respectively. Boron has positive correlation with leaf area of plant (Al Amery *et al.* 2011) Verma *et al.*, 1973 found that spraying of boron significantly increase no. of leaves per plant compared to control in tomato.

The effect of foliar spray of boron at treatment T_8 (FS @0.05% borax twice) was found to be significant to 1st flowering and fruiting than control. Early and better flowering might be due to cell wall development ,cell division and pollen growth takes place due to influence of boron. Similar result was also reported by Singh and Verma (1991), Makhan *et al,*. (2003) and Patil *et al.* (2010).

5.2 Growth responses

Crop growth rate (CGR) is a function of dry matter accumulated by the crop plant. Application of RDF+ FS 0.05% borax twice significantly improved (1.11gm^{-2} day^{-1}) CGR signifiers proper translocation of photosynthates to sink which corroborates with the findings of Pandey and Gupta 2012 as reported in green gram. Sanker *et al.,* 1998 found that CGR was also increased with increase in LAI and highest crop growth rate was recorded in between 50-75 DAS. The decrease in crop growth rate (CGR) towards maturity might be due to natural senescence of older leaves.

Similarly Relative growth rate (RGR) value was found highest in T_8 (RDF+FS 0.5% borax twice) followed by T_2 (RDF+ soil application @ 1 kg B/ha) and T_4 (RDF +FS @0.5% borax once) respectively. Kalyani *et al.,* (1993) observed that boron applied as boric acid increased RGR and LAI in pigeon pea.

5.3 Biochemical responses of boron

Total chlorophyll content was highest in plants treated with FS@ 0.5% borax twice followed by soil application of B@ 1 kg ha^{-1} and FS@ 0.5% borax once respectively. In the present study, it was found that B affected chlorophyll concentration. More specifically, a higher application of B may have the effect of decreasing the level of chlorophylls in watermelon. The chlorophyll content decreased at FS@ 0.75% and 1.0% borax once/twice. The toxic effect was observed in the treatments might be due to marginal necrosis and degradation of chlorophyll because B toxicity generate reactive oxygen species in plant cells (Maoka *et al*., 2001). Similarly, the deficiency symptom was also observed in control plants as the effects of insufficient B supply on many processes or structure relevant for the regulation of plant water status have been described by Miwa K *et al*. (2010) and Kunal seth *et al.* (2014).

Total dry matter content in watermelon showed signifier differences among the treatments. Higher dry matter was observed from T_8 (FS @ 0.5% borax twice) and lowest in control one (No boron). The findings were supported by findings of Singaram and Prabha (2000)), they reported that application of borax as soil application or foliar application increases the dry weight of tomato shoots at both the flowering and harvesting stages in tomato hybrid cv. Naveen. Also Shaiman *et al.,* 2014 conducted experiment on effects of boron on growth and some physiological activities of tomato plant. Application of different concentration of boron significantly increases fresh weight and dry weights compared with control. This might be due to boron enhances the uptake of other nutrients notably N, P, K which has important role in different physiological process of plant.

5.4 Quality parameters

Remarkable increase in lycopene content of watermelon fruit was observed in all treatments over control. Among treatments T_8 (FS @ 0.5% borax twice) excelled over other and produce the higher lycopene content in fruit (3.84 mg/100g). The above findings supported by findings reported by Alice Kurien and Perer (1995) in fruits of 64 tomato genotype germplasm. Sharam et al., 1995 reported lycopene in 100g of fruits of 53 genotype of tomato.

5.5 Mineral nutrition

5.5.1 Nitrogen, Phosphorus, Potassium and Boron

Significant difference in fruit weight and fruit length was obtained with application of NPK along with B at different concentrations. In case of B application as FS@ 0.5% borax twice, watermelon fruit weight obtained was 2.85 kg followed by T_2 soil application 2.70 kg and T_4 FS@ 0.5% borax once 2.40 kg respectively. This crop response to the application of NPK and B for development of vegetative parts, roots and to maintain plant protein level. Thus NPK and B have important effects on watermelon productivity and quality. B needed in plants in low quantities due to its interaction with and thus reduce the physiological disturbances because the deficiency may be induced by the plant rapid growth promoted by N as evident from the present findings that the plant height increased in control. Similar findings was also reported by Campagnol *et al.*, 2009.

The boron uptake by plant parts was significantly higher, where ever borax was applied to soil or through foliar application compared to RDF. In present study a significant difference was observed in the plants treated with RDF + B over control. A combined nutrient of NPK and boron was found always higher impact on different characteristics of a plant. However the B uptake was found more effective when the plants were treated with FS @ 0.5% borax twice, might be due to easy absorption of B through leaves and fruit compared with soil @ 1kg/ha as lower solubility materials and became less availability to plants. The N, P and K uptake and translocation in leaf and fruit was found in T_8.

Borax appeared to have positive effect on nitrogen content leaves. This may be related with the nutrient interactions in soil. Boron increases the uptake of nitrogen (Chundawat, 1997). On the other hand, FYM increases the nitrogen use efficiency and reduces the leaching losses of nitrogen. The boron content in leaves was increased linearly with increasing the dose of borax. Due to indeterminate type of plant growth in watermelon, growth and developmental processes occur in a plant simultaneously. Therefore, the plant requires constant supply of essential nutrient elements to continue growth at a faster rate and at the same time fulfill the need of developing fruit.

The calcium and magnesium content in the leaves showed significant variation among different boron concentration. Among treatments, T_8 (FS @ 0.5% borax twice) excelled over others and showed the maximum calcium and magnesium content.

5.6 Soil analysis

Analysis of residual boron availability in the soil after harvest revealed that soil boron is increased from the initial boron concentrations in all treatments. Soil application of B@ 1 kg ha^{-1} is shown maximum soil boron concentration be due to increase in availability and absorption of boron to soil which was deficient in these nutrients. However, foliar application @ 0.5% twice had shown superior over soil application because of direct facilitation of micronutrient B through foliage made easy and quick consumption of boron by penetrating the stomata or leaf cuticle and enters the cells at critical stages of watermelon crop. Boron retention is lowest in acid soils, but increases rapidly in the neutral pH range, indicating that boron availability is dependent on soil pH. In these results are recorded with a findings of Cutclliffe and Gupta (1980), Kotur (1992), Singh *et al.* (1994), Singh and Dixit (1994) and Zhao Yong-hou (2006).

5.7 Yield and yield attributing character

Numbers of flowers per plant is significantly increases in treatment T_8 (FS @ 0.5% borax twice) than T_1 (control). These findings are accordance with findings supported by Dey (2000) who reported that the higher no of flower per plant might be due to optimum supply of boron. Balley (1999) reported that optimum supply of B stimulated the uptake of phosphorus by plant roots and might have promoted more flower formation as P directly involved in promotion of flowering. Also Naz et al., 2012 found that application of boron significantly increase the no. of flower per plant.

The increasing no. of fruits, fruit weight, fruit length, single fruit weight , avg. fruit weight was found highest in RDF+ FS @ 0.5% borax twice. No. of fruits (7.14), fruit weight (2.85 kg), fruit length (29.4) , single fruit weight (2.94), avg. fruit weight (2.85) respectively was obtained in T_8 . The plants treated with FS @ 0.5% borax twice showed higher no. of marketable fruits per plant (7.14). No cracked fruits seen in FS @ 0.5% borax twice. The no. of fruits per plant depends upon the no. of flowers and flower per plant and ability of the plants to provide the nutrients required for growth and development. Since application of boron increase the fruits per plant (Desouky et al, 2009) it is likely that a higher no. of fruits per plant will be observed in borax application. The findings are accordance with the findings of Govindan (1950) in pot culture, Das and Das (1978) and Sharma (1995), Paithankar et al., (2004).

Yield is a function of effective of both vegetative and floral attributes. Highest yield was obtained in T_8 FS @ 0.5% Borax twice (38.15 t ha^{-1}). The increasing yield with B application might be due to accumulation of carbohydrates in fruits, synthesized in leaves, transported to the fruit in the form of sugar borate complex (Gauch and Dugger, 1952) similar result was obtained by Suganiyal et al. (2015). Similarly foliar spray of borax 0.5% significantly increases the no. of fruits and fruit yield per plant in bell pepper (Kumar and Malabasari, 2011) and Yadav et al., (2006), Dongre at al., (2000) in chili.

Harvest index was directly proportional to the fruit yield and inversely proportional to the vegetative growth of the plant HI was found highest in RDF +FS @ 0.5% borax twice (85.78 %). It might be due to the reason that the foliar application of B induced the early growth of reproductive tissue relative to shoot biomass, which leads to higher fruit yield and higher Hl. The reported findings were supported by findings of Pandey and Gupta (2012) in green gram and Ceyhan et al., (2008) observed in maize plant.

SUMMARY AND CONCLUSION

Watermelon (*Citrullus lanatus*) is a warm, long-season crop and is now grown in all tropical and subtropical areas of the globe. This fruit mostly cultivated for its fresh juice and sweet flesh. . The fruit is normally eaten uncooked and includes vitamin A and some vitamin C. Pickling the rind is a popular method of preserving it. The ripe fruit's delicious, luscious pulp is consumed fresh across the tropical and subtropical regions. After adding a bit of salt and black pepper to the fruit juice, it is also drunk. The juice is tasty and nourishing, and it helps to chill you down during the hot summer months.

Among the plant required micronutrients boron has the important role in yield and nutrients in watermelon. Being a heavy feeder and exhaustive crop, it removes a substantial amount of micronutrients from soil. To maintain its sustainability in its production and nutritive value, it is becoming very essential to substitute the application method through foliar application to meet the immediate need of the crop. Foliar application is the most effective way to increase yield and plant health

Keeping the view of the fact a field experiment is conducted entitled "Effect of Boron application on growth and yield of Watermelon (*Citrullus lanatus*)" during Rabi 2020-2021 at central farm, OUAT, Bhubaneswar with 10 treatments of boron as soil application @ 1 kg/ha and foliar spray of 0.25%, 0.5%, 0.75%, 1.0 % applied as once at 30 DAS and twice at 60 DAS. The experiment was carried out in a randomized block design (RBD) with three replication. The present investigation was carried out to known the effect of foliar application of boron on morphological and physiological parameters, nutritional quality and yield attributing characters as compared with soil application and controlled one. The evaluated results of present investigation are summarized in this chapter.

In morphological parameters like vine length, no of leaves, branches per plant, leaf area increases significantly due to application of boron. The foliar spray of 0.5% borax twice recorded higher performance might be due to the enhancement of vegetative growth which was result of activated physiological process by stimulating factor in the metabolism and growth of plant. No. of days to 1st flowering and fruiting was found significantly influenced by application of B levels. The effect of FS@

0.5% twice was found to be significant due to its role in improved physiological activity and different enzyme and hormone regulation. The physiological growth parameters like CGR, RGR, total biomass were highest with application of FS 0.5% borax twice due to higher photosynthetic rate produce more dry matter in plants.

The biochemical characters like chlorophyll content and lycopene showed marked improvement in application of foliar spray @ 0.5% borax twice. Chlorophyll content directly related to the availability of physiologically active B in plant available form.

The nutrients content was positively influenced by soil and foliar application of B. The significant increase in N, P, K , B Ca and Mg was recorded highest in FS @ 0.5 % borax twice and lowest in control. Also uptake of boron increase in T_8 might be due to easy absorption through foliage compared with soil application which is less availability to plants.

Yield and yield attributing character like no of flowers per plant, no of fruits, fruit weight, avg. fruit weight, fruit length and yield per plant, HI (%) were favorably influenced by application of boron with FS @ 0.5% borax twice. The increasing in no. of fruits and fruit weight may be due to translocation of carbohydrates from site of synthesis to storage tissues. The yield per plant (38.15 t/ha) in the T_8 than T_1 control (24.35 t/ha). The higher yield might be due to active absorption and uptake of boron. The increasing in HI (%) may be due to increasein the economical yield.

CONCLUSION

It is concluded from the present study that the application of B @ 0.5% borax twice through foliar spray at 30 DAS and 60 DAS along with recommended dose of NPK fertilizers may be considered for better morpho physiological characters and nutritional quality of watermelon which leads to higher yield with better quality fruit. From the above findings revealed that application of B by foliar spray twice is more effective than soil application and foliar spray once. Boron applied through foliar spray made continuation supply to plants where they required for better growth and development at their most required time. On the other side soil applied might be less advantages due to little translocation to above growth portions of watermelon crop and more boron content in soil application than other form of boron application, as boron in soil relatively immobile in nature.

REFERENCES

Al - Amery MM, Hamza JH, Fuller MP. 2011. Effect of boron foliar application on reproductive growth of sunflower (*Helianthus annuus* L.), *International Journal of Agronomy* **2**(11) 1-5.

ALI Raza Gurmani *et al.*, Biochemical attributes, plant growth and yield of tomatoes affected by boron application rates. *J. Chem. soc.pak.* Vol: 34, No. 4. 2012.

Ankush, J.A., Hargitai, L., Biasc, P A and Daood, H.G. 1990. Influence of boron on quality attributes of tomato fruit. Acta Aliment **19**(1):63-72.

Ansari, M.A., Prakash, N., Singh, I.M., Sharma, P.K. and Punitha, P. (2013). Efficacy of boron sources on productivity, profitability and energy use efficiency of groundnut (*Arachis hypogaea*) under north east hill regions. *Indian Journal of Agricultural Sciences*, **83**(9): 959-63.

AOAC. 1960. Official methods of analysis (9^{th} Edition). Association of Official Agricultural Chemists, Washington, D.C.

Asad A, Blamey EPC and Edward DG. 2003. Effect of boron foliar application on vegetative and reproductive growth of sunflower, *Annals of Botany*, **92**:565-570.

Asraf MI, Sajad S, Hussain B, Sajjad M, Andan M and Ismail M. 2018. Foliar application effect of boron, calcium and nitrogen on vegetative and reproductive attributes of tomato (*Solanum lycopersicum* L.), *Journal of Agriculture Science and Food Research*, **9**:1.

Babu N. 2002. Response of foliar application of boron on vegetative growth, fruit, yield and quality of tomato var. Pusa Ruby, *Indian journal of hill farming*, **15**(1):109 112.

Bajpai S, Chouhan SVS and Bajpai S. 2001 Effect of zinc, boren and manganese on yield of okra (*Abelmoschus esculentum*), *Indian foumal of agriculture science*, **71**(5):332 333.

Basavarajeswari CP, Hosamar RM, Ajjappalavara PS. Naik BH, Smitha RP and Ukkund. 2008. Effect of foliar application of micronutrients on growth, yield components of tomato (*Lycopersicum esculentum* Mill.), *Karnataka Journal of Agriculture Science*, **21**(3):428-430.

Berger KC and Truog E. 1939. Boron determination in soil and plants. *Indian Eng. Chem. Anal. Ed*, **11**:540-545.

Bhatt L. And Srivastava, B.K. 2006. Effect of foliar application of micronutrients on the nutritional composition of tomato. *Indian Journal of Horticulture*, **63**(3):286-288

Bhattacharya A and Laxmi V. 2015. Method and technique in plant physiology. NIPA, page no 186-189.

Blevins DG and Lukaszewskikm. 1998. Boron in plant structure and function, Annual review of plant physiology and molecular biology, **49**:481-500.

Bose, U.S. and Tripathi, S.K. 1996. Effect of micronutrients on growth, yield and quality of tomato C.V. Pusa Ruby in M.P. Crop Res. **12**(1):61-64.

Cardozo VP, Pizetta NV and Teixeira NT. 2001. Manuring to foliate with calcium and boron in the culture of the tomato (*Lacopersicon esculentum* Mill) cv. Debora Max, ecossisttema, **26**(1):39-41.

Chandra A and Verma BK. 2003. Effect of boron and calcium on plant growth and seed yield of tomato, Research *Journal*, **37**(2)13-14.

Dannel F, Pfeffer H, Romheld V. 2000 Characterization of root boron pool, boron uptake and boron translocation in sunflower using the stable isotopes 10B and 11B, *Australian Journal of Plant Physiology*, **27**:397-405

Dannel F. Pfeffer H, Romheld V. 2002. Uptake on boron in higher plant- uptake, primary translocation and compartmentation, *Plant Biology*, **4**:193-204.

Davis, J.M., Sanders, DC. Nelson, P.V. Lengnick,, L. and Sperry, W.J. 2003 boron improves growth, yield, quality and nutrient content of tomato. *Journal of the American society for horticultural science,* **128**(3):441-446.

Dubey G.D. 2004. Effect of zinc and boron nutrition on growth, yield and quality of tomato ev Naven. M. Sc. (Agri.) thesis. Dr YSPUHF, Solan (HP).

E Heuvelink, M.J. Bakker, A Elings, R.C. Kaarsemaker, L.F.M. Marcelis, Effect of leaf area on tomato yield, *International society for horticultural science*. 2005.691.2.

Gauch HG and Dagger WM. 1954. The physiological action of boron in higher plants: review and interpretation, University Maryland AES Tech Bulletin, **80**:143.

Geetanjali K, Ashoke RT, Narasimha RKL, Madhuvani P. 2015. Effect of foliar application of etherel and boron on morphological parameters, growth characteristic and yield in groundnut (*Arachis hypogaea* L) *International journal of food, agriculture and veterinary sciences*, **5**(1):120-125.

Ghosh SK and Hasan MA. 1997. Effect of boron on growth and yield of cauliflower, *Annals of agriculture Research*, **18**(3):391-392.

Giovannucci E. 1999. Tomatoes, tomatoes-based products, lycopene and cancer: review of epidemiologic literature, *Journal of National Cancer Institute*, **91**:317-331.

Gitte AN, Patil SR and Tike MA. 2005. Influence of zinc and boron on biochemical and yield characteristics of sunflower, *Ind. J. of plant physiology*, **10**:400-403.

Goldbach HE and Wimmer MA. 2007 Boron in plants and animals, *J plants Nutri. Soilsci.* **170**(1):39-48.

Gomez KA and Gomez. AA. 1984. Statistical procedure for Agriculture research, Johan wielyand son's publication, New York ISBN 0-431-87092-7.

Gulumser A, Odabas MS and Ozturan Y. 2005. The effect of soil and Foliar application of boron at different rates on the yield and yield components of common bean (*Phaseolus vulgaris* L.), ZiratFakultesiDergisiAkdeniz Universities, **18**(20):163-168.

Gupta UC. 1979. Boron nutrition of crops. In NC Brady (Ed) Advances in Agronomy, Academic press, Inc., New York, 31.

Gupta UC., McLeod and Cutcliffe JA. 1982. Factors affecting the boron concentration of crops grown on podzol soils. 12th International congress of Soil Science, New Delhi, No. **427**:81.

Haleema B, Rab A and Hussain A. 2018. Effect of calcium, boron and zinc foliar application on growth and fruit production of tomato, *Sarbad Journal of Agriculture*, **34**(1):19-30.

Hansaven, M.R., Kurdikeri, M.B., Shekhargouda, M. Shashidhara S.D. and Dharmatti, P.R., 2003. Effect of gypsim and boron on seed yield and quality of tomato cv Megha. *Karnataka Journal of Agricultural Sciences*, **16**(3):457-459.

Harris K.D. and Lavanya L. July 2016. Influence of foliar application of boron, copper and their combinations on quality of tomato (Lycopersicum esculentum Mill.). *Research journal of agriculture and forestry sciences*, E-ISSN 2320-6063 vol. **4**(7):1-5.

Hosseini S M, Maftoun M, Kariman N, Ronaghi A and Emam Y. 2007. Effect of zinc and boron interaction on plant growth and tissue concentration of corn. *Journal of Plant Nutrition* **30**: 773-781.

IOSR journal of agriculture and veterinary science (IOSR- JAVS) e-ISSN:2319-2380, p-ISSN: 2319-2372. Volume 8, issue 1 ver. 11 (jan. 2015), PP 09-19.

Jackson ML. 1958. Soil chemical analysis, prentice Hall. Inc. Englewood, Cliff, N.J. 372-374.

Jackson ML. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

JB Kadu, MC Kasture, PB Tapkeer, RV Dhopavkar and MVVI Annapurna. Effect of soil application of potassium and foliar spray of zinc and boron on yield, yield contributing character and quality of watermelon [*Citrullus lanatus* (thunb.)] in lateritic soils of Konkan, *International Journal of Chemical Studies*, 2018: **6**(3): 07-12.

John MK, Chuah HH and Neufeld JH. 1975. Application of improved azomethine-H method to the determination of boron in soils and plants, *Analalytical Letters*, **8**:550-68.

Journal of Pharmacognosy and Photochemistry, Role of micronutrients in vegetable production: A review 2019, SPI: 332-340.

Jyolsna VK and Mathew usha. 2008. Boron nutrition of tomato (*Lycopersicum esculentum*) grown in the laterite soils of southern Kerala, *journal of tropical agriculture*, **46**(1-2):73-75.

K. Amrendra. and A. Kumat. 1997. Response of tomato to boron application in chhotanagpur region.j. Of res**. 9**(2):145-147.

Kabir R, yeasmin S, Islam AM, Sarkar MAR. 2013. Effect of phosphorus, calcium and boron on growth and yield of groundnut (*Arachis hypogea* L), *International journal of bioscience and bio-technology*, **5**(3):51-60.

Karchi, Z., Growers, A. and Neubeuer, Y. (1977). Comparative effect of organic manure and N, P fertilizers on yield parameters of honey dew melon Cv. Noy. Amid. *J. Hassadesh*., **57**(9):1671-1675.

Khamvaree N, Khurnpoon L. Effect of calcium, Boron solution and non irrigation before harvesting on growth and quality in muskmelon (*Cucumis melo* L. Var. *reticulata*). *International Journal of Agricultural Technology*, 2016; **12**(7.1):1297-1305

Kuntoji A 2017. Studies on the effect of different sources and levels of boron on soil properties, growth and yield of tomato. M..Sc. (soil science) University of agricultural sciences, Bangaluru.

L.C. Hoportioning of assimilates in fruiting tomato plants. plant growth regulation 2,277-285 (1984).

Leopold, A.C. and Kridemanann, P.E. 1975. The dynamics of growth, plant-growth and development. Tata Nc. Grawzholl.publishing Co. Ltd. pp.78.

Liu D, Jiang W, Zhang L, Li L. 2000. Effects of boron ions on root growth and cell division of broadbean (*Vicia faba* L.), *Israel Journal of Plant Sciences* **48**:47-51

Loomis WD and Durst RW. 1992. Chemisrty and biology of boron. Biofactors, **3**:229-239.

M.R.Ali, H.Mehraj and A.F.M. Jamal Uddin. 2015. effects of foliar application of zinc and boron on growth and yield of summer tomato. Journal of bioscience and agriculture research. Vol. 06, issue **01**:512-517.

MauryaKR, Devi B. 2016. Effect of boron on growth, yield, protein and ascorbic acid content of radish (*Raphanus sativus Linn*.), *European journal of biotechnology and Bioscience*, **4**:33-34.

Meena RS. 2010. Effect of boron on growth, yield and quality of tomato grown under semi-arid conditions, *International journal of chemical engineering research,* **2**(2):167-172.

Mengel K and Kirkby EA. 2001. Principles of plant nutrition, *Annals of Botany*, **94**(4), 479-480

Mishra B.K. and Nandi A.K. 2007. Effect of micronutrient spray on growth and yield of tomato cv. Utkal Urbashi(BT-12). *Orissa journalHorti.* 35(2).

Mondal, C., Bandopadhyay, P., Alipatra, A. and Banerjee, H. (2012). Performance of summer mungbean [*Vigna radiata* (L.) Wilczek] under different irrigation regimes and boron levels. *Journal of Food Legumes*, **25**(1): 37-40.

Muntean DW. 2009. Boron an essential element soil and plant, *Journal of soil plant nutrition*, **48**(3): 357-364.

Murlee Y, Singh DB, Chaudhary R and Resi TA. 2006. Effect of boron on yield of tomato (*Lycopersicum esculentum* Mill.),cv DVRT-1, plant archives, **6**(1):383-384.

N. Senthilkumar (2019). Effect of foliar spray boron on growth and yield in tomato (CV.,PKM-1) vol.19 No.2.2019 p.3155-315.

Nable RO, Banuelos GS, Pall JG. 1997. Boron toxicity, *Plant and Soil*, 193:181-198.

Naga SK, SwainSK, Sandeep VV and Raju B .2013. Effect of foliar application of micronutrients on growth parameters in tomato (*Lycopersicum eculentum Mill.) Journal of agriculture and food sciences*, **1**(10):146-151.

Narayanamma M, Lalitha Kameswari P, Radha Rani K, Anitha V. Effect of integrated nutrient management in bottle gourd. *Orissa J Horti*. 2009; **37**(1):4-8.

Narresh B.2002. Response of foliar application of boron on vegetative growth, fruit yield and quality of tomato var. Pusa ruby, *Indian journal of hill farming*, **15**(1):109-112.

Naz RMM, Muhammad S, Hamid A and bibi F.2012. Effect of boron on the flowering and fruiting of tomato, *Sarhad Journal of Agriculture*, 28:1.

NHB (Data base). www.agricoop.nic.in (Horticulture at a glance 2018, net upload pdf).

Oyinlola EY and Chude VO. 2004. Response of irrigated tomato *(Lycopersicum esculentum* Mill) to boron fertilizer: yield and fruit quality,*Nigerian journal of soil research*, 591) 53-61.

Paithankar DH, Sadwarte KT, Manhorkar KV and Dipall D. 2004, Effect of foliar application of boron and DAP fertilization on quality of tomato (*Lycopersicum esculentum Mill.) Journal of soils and crops*, **14**(1):46-49.

Panda KL. 2019. Effect of growth regulators and nutrients on performance of tomato (*Solanum lycopersicum* L.) hybrid ArkaRakshak. M.Sc. (Hort) Thesis, odisha university of agriculture and technology, Bhubaneswar.

Passam HC, KarapanosIC, Bebeli PJ and Savvas D. 2007. A review of recent research on tomato nutrient, breeding and post-harvest technology with reference to fruit quality, *The European Journal of plant science and biotechnology*, **1**:11-21.

Patil BC, Hosamani RM, Ajjappalavara PS, Naik BH, Smith RP and Ukkund KC. 2008. Effect of foliar application of micronutrients on growth and yield components of tomato (*Lycopersicum esculentum* Mill.,) *Karnataka Journal of agriculture science*, **21**(3):428-430.

Piper CS. 1966. Soil and plant analysis, academic press, New York (USA), 47-77.

Prabha K., and singaram P. 1996. Effect of boron on the content and uptake of nutrients in tomato. *Madras Agril J*. **83**(11):745-746.

Rab A, and Haq- Ihsan-U1, 2012. Foliar application of calcium chloride and borax influences plant growth, yield and quality of tomato (*Lycopersicum esculentum Mill)* fruit. *Turkey Journal of Agriculture and Forestry*, **36**:695-701.

Radford DJ. 1967. Growth analysis formulae, their use and abuse, crop sci., **7**:171-175.

Rastogi S, Abidi AB. Biochemical evaluation of new muskmelon (*Cucumismelo* L.) varieties grown in eastern UP. *Indian J. Agric Biochem*. 2006; **19**(1):37-38.

Reddy PD, Reedy SS and Reedy C, 2018. Effect of foliar application of micronutrients on growth and yield parameters in tomato (*Solanum Iycopersicum* L.). *International Journal of pure applied and bioscience*, **6**(2):929-934.

Research article on Effect of micronutrients on growth, flowering and yield of tomato *(Solanum lycopersicum* L.) cv. PKM 1. *International Journal of agriculture sciences,* ISSN:0975-3710 & E-ISSN:0975-9107, volume 10, Issue 7, 2018, pp-5734-5736.

S. Sathya 2006. Studies on application of boron on yield and quality of PKM 1 tomato. M.Sc (soil science and environment), Tamilnadu agriculture university, Madurai.

Saboo PP. 2019. Soil application and frequencies of foliar spray of boron on growth and yield of cauliflower (*Brassica oleracea var. Botrytis*) cv. Shobha F1. M.Sc. Thesis (plant physiology) odisha university of agriculture and technology, Bhubaneswar.

Salam MA, Sissique MA, RahimMA, Rahaman MA and goffer MA. 2011. Quality of tomato as influenced by boron and zinc in presence of different doses of cowdung, Bangladesh. *Journal of agriculture research*, **36**(1):151-163.

Saravaiya SN, Wakchaure SS., Jadhav PB, Tekalegs, Patil NB and Dekhane SS. 2014. Effect of foliar application of micronutrients in tomato (*Lycopersicum esculentus* Mill.) cv. Gujarat tomato-2, *The Asian journal of horticulture*, **9**(2):297-300.

Sarkar, S., Banerjee, H., Ray, K. and Ghosh, D. (2018). Boron fertilization effects in processing grade potato on an Inceptisol of West Bengal, India. *Journal of Plant Nutrition*, **41**:11, 1456-1470

Sathya S, Mani S, Mahendran PP, Anilmozhiselvan K, 2010. Effect of application of boron on growth, quality and fruit yield of PKM 1 tomato. *Indian Journal of Agricultural Research*, **44**(4):274-280.

Shaimaaabd El-Hameed Abo- Hamad and Soadsoliman El-Feky, Effect of boron on growth and physiological activities of tomato plant. *Life science journal* 2014, **11**(7).

Shankhe GM, Sonue BA and Naphade PS. 2003. Influence of boron and molybdenum on yield and quality of groundmut, *Annals of plant physiology*, **16**(2):157-159.

Shekhawat, K. and Shivay, Y.S. (2008). Effect of nitrogen sources, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (Helianthus annuus). *Indian Journal of Agronomy*, **53** (2): 129-34.

Shnain RS, Prasad VM and Saravanan S.2014. Effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill) cv. HeemSona, under protected cultivation, Europian academic research, **3**:4572-4597.

Shrotriya, GC and Phillips M. 2002, Boron in Indian Agriculture, *Fert. News*, **47**(12): 95-99.

Shukla pc. 2017. Effect of foltar application of micronutrients on growth and yield of tomato (*Solanum lycopersicum* L.) MSc (Hort.) thesis, Indira Gandhi krishivishwavidyalaya, Raipur, Chhattisgarh.

Singaram P and prabha JC. 2000. Response of tomato to borax and boronated super phosphate in calcareous red soil, Madras agricultural journal, **86**(10-12):583-586.

Singh HM and Tiwari JK. 2013. Impact of micronutrient spray on growth, yield and quality of tomato *(Lycopersicum esculentum Mill). HortFloraResearch. Sectrum*, **2**(1):87-89.

Singh M, Bhatia AK, Batra VK, Singh V and Arora SK, 2003. Response of foliur application of micronutrients on tomato, *Hissar annals of vegetable science*, **30**(2)182-184.

Singh R, Yadav DS, and Maurya ML, 2002. Effect of B application on yield of pea and black gram in calcareous soil, Fert Nes, **47**(2):67-68.

Singh MV. 1999. Current status of micro and secondary nutrient deficiencies and crop response in different Agro-ecological regions, Fert News, **44**(4): 63-82

Singh AK, and Singh CS, 1996. Response of tomato to boron application. *Punjab horticulture journal*, **34**(1-2):86-89.

Subbaiah BV and Asija G. 1956. A rapid procedure for the estimation of available nitrogen in soils, *Curr. Sci*., **25**: 259-260.

Sumanth S. 2019. Impact of soil and foliar application of boron on physiological aspects of cabbage *(Brassica oleraceae var. capitata* L.) M.Sc. thesis (plant physiology) Odisha university of agriculture and technology, Bhubaneswar .

Tamilselvi P., Vijayakumar RM, and Nainar P. 2005. Studies the effect of foliar application of micronutrients on growth and yield of tomato. *South indian horticulture* **53**(1-6):46-51.

Verma AN, Ram K and Sharama RK 2000. Growth, yield and quality of tomato (*Lycopersicum esculentum* Mill.) as affected by foliar applications of boron in sand culture, *Mysore journal of agricultural sciences*, **7**:130-32.

Villanueva EE, (2018). An overview of recent studies of tomato (*Solanum lycopersicum spp*) from a social, biochemical and genetic perspective on quality parameters. Alnarp-swedwn: sverigeslantbruksuniversitet. (introductory paper, 2018).

Villarias J L, Garzon E and Ontanon A. 2000. Magnesium sulphur fertilizers cultivation beet root. *Agriculture Review Agropecuaria* **69**(819): 676-679.

Waghadhare DS, 2004. Boron nutrition for yield and quality in tomato. M. Sc. Thesis (soil science) Mahatma Phule Krishi Vidyapeeth, Rahuri.

Waghdhare DS, Kharche VK, Jadhav KA and Bhosale PC, 2008. Effect of boron application on yield and quality of tomato grown on alkaline calcareous soils, *Asian journal of soil science*, **3**(1):49-52.

Weerasingh KMS, BalasoriyaAHK, Ransingh SL, Krishantha CD, Brahakmange RS and Wijethilika LC. 2014. Effect of macro and micronutrients on growth and yield performance of tomato (*Solanum lycopersicum* Mill), *plant science and forestry*, **18**:150.

Wojeik P. (2005). Response of Primocane-fruiting polana red raspberry to boron fertilization. *J. Plant Nutri*.,28:1821-1832.

Yadav PVS, Tikkoo A and Sharama NK. 2001. Effect of zine and boron application on growth, flowering and fruiting of tomato, *Haryana jornal of horticulture schence*, **30**(1-2):105-107.