EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS (B AND Zn) AND SEAWEED EXTRACT (*Ascophyllum nodosum*) ON THE GROWTH, YIELD AND BIOCHEMICAL PARAMETERS OF TOMATO (*Solanum lycopersicum* L.)

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Vegetable Science

By

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DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of Dr. Monisha Rawat, working as Assistant Professor, in the Department of Horticulture of Lovely Professional University, Phagwara, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled **"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Horticulture, School of Agriculture, is a research work carried out by Diksha Choudhary, 12014052, is bonafide record of her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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This is to certify that the work reported in the Ph.D. thesis entitled **"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"** submitted by **Diksha Choudhary (Registration no. 12014052)**, to Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the discipline of **Vegetable Science** has been approved by Advisory committee after oral examination of the student in collaboration with an external examiner.

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ABSTRACT

Title:	"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"
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The current study entitled **"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"** was conducted at the Horticulture Research Farm of Lovely Professional University, Phagwara, Punjab, India during the crop year 2022 and 2023. A field experiment using factorial randomized block design with three replications was carried out comprising two factors, factor A, *i.e.*, 12 treatment combinations of *Ascophyllum nodosum* extract (0.2% and 0.4%), Zinc (0.2%) and Boron (0.2%) applied at 15, 30 and 45 days after transplanting as a foliar spray and factor B, *i.e.*, two hybrid varieties of tomato *viz.*, Tomato no. 575 (red) and Yellow Jubilee (yellow). Various growth and yield as well as biochemical parameters were studied under the influence of different treatment combinations for two consecutive cropping years. As per the results treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} showed maximum positive outcomes for growth attributing traits mamely plant height (126.39 cm), number of leaves (223.35), number of branches

(16.46), stem diameter (20.74 mm), stem girth (65.12 mm), leaf chlorophyll index (78.72), days to flower initiation (35.34) and days taken to 50% flowering (40.60), to fruit initiation (47.48) and to first picking(72.49). Similarly treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} showed highest positive observations for yield attributes *viz.* diameter of fruit (polar (71.81 mm) and equatorial (69.01 mm)}, number of locules (7.04), number of fruits per plant (26.02), average fruit weight (167.89 g), yield per plant (2.47 kg) and total marketable yield (914.84q/ha). Whereas for biochemical parameters all the studied parameters showed varied results *i.e.* maximum TSS content (6.05 8Brix) in T_7V_2 {(Zn @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)}, total soluble sugars (3.323 mg/g), reducing sugars (1.519 mg/g), non reducing sugars (2.142 mg/g) in $T_{12}V_1$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)}, total soluble protein content (11.03 mg/g) and lycopene content in T_9V_1 {(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)}, ascorbic acid content (11.41 %) in T_8V_2 {(Zn @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, carotenoid content (0.086 mg/g) in $T_{11}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)}, except total phenol content (31.68 mg/g) which was found maximum in $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}. As per the economics of the crop despite having higher input cost leading to the highest cost of cultivation (₹413775/ha) among all the treatment combinations maximum gross returns (₹1290773) and net returns (₹876998) were observed in treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} resulting in maximum benefit cost ratio (2.12). Therefore, it can be presumed that the administration of micronutrients and seaweed extract in combination can significantly improve both yield and quality of tomatoes, offering a viable strategy for sustainable cultivation of various tomato varieties.

Keywords: Tomato, *Ascophyllum nodosum*, zinc, boron, *Solanum lycopersicum* L., foliar spray, biostimulant, growth, yield, economics.

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LIST OF ABBREVIATIONS

Abbreviated Form	Full form
%	Per cent
/	Per
@	At the rate
e.g.	Example
et.,al	et ail (and other)
DAT	Days after transplanting
^{o}Brix	Degree Brix
Cm	Centimeter
cv.	Cultivar
g	Gram
ha	Hectare
i.e.	That is
kg	Kilo gram
l	Litre
m^2	Meter square
Msl	Mean sea level
mg/g	Milligram / gram
mm	Milli meter
ml	Milliliter
MT	Metric ton
mg	Milli gram
SES	Seaweed extract
Zn	Zinc
B	Boron
RDF	Recommended Dose of Fertiliser
pH	Potential of hydrogen
q/ha	Quintal per hectare
FRBD	Factorial Randomized Block Design
ANSE	*Ascophyllum nodosum* seaweed extract
sq.m	Square meter
RH	Relative humidity
T	Treatments
V	Varieties
TSS	Total soluble solid
R	No. of replications

T	No. of treatments
d.f.	Degree of freedom
SSR	Sum of replication square
SST	Sum of treatment square
SSE	Sum of error square
SST	Sum of treatment square
MSSR	Mean of square of replication
MSST	Mean of square of treatment
MSSE	Mean sum of square of error
SSR	Sum of replication square
SE (m)±	Standard error of means
SE diff	Standard error of difference of mean
GM	Grand mean
C.D.	Critical difference
₹	Rupees
rpm	Rotations per minute
N	Normal
M	Molar
NPK	Nitrogen, Potassium, Phosphorous
etc.	Et cetera
viz.	Namely
t	Tonne
No.	Number

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) traditionally acknowledged as "*Vilayati baingan"* is one of the most significant vegetable crops, belongs to the Solanaceae family and originated from South America. Ascribed to its wide adaptability to varied agro-climatic conditions, it is a leading vegetable crop cultivated across the country. It is popular among both the poor and affluent and posess great nutritional value. It is ranked next to potatoes in terms of area, but ranks first in the world among processing crops. With an ideal growing temperature being in between 25°C to 29°C, tomatoes are classified as annual plants that are grown during the warm season. (Ejaz *et al.*, 2011).

India holds second rank in worldwide vegetable production after china with a production of 212.55 Million Tonnes with overall tomato production of 204.25 Lakh Tonne. Madhya Pradesh is the leading producer of tomato in India with a production of 3498.26 kilotonnes and contributes 16.40% of overall tomato production in the country. Punjab ranks 17 in the production of tomato among all the states with 256.88 kilotonnes and contributes 1.25% of overall production in the country. (NHB 2022-23 third advance estimate).

The exceptional nutritional and health benefits of tomatoes are well known. These bright red fruits have a wide-ranging culinary and medicinal appeal since they contain vital minerals and bioactive substances. They are a great source of vitamin C, which supports collagen synthesis and immunological function, and vitamin A, which is essential for skin and eye health. Potassium, a mineral crucial for preserving fluid balance, neuron function, and muscle contractions, is abundant in tomatoes. Lycopene, beta-carotene, and flavonoids, which give tomatoes their rich red colour, provide a robust defence against oxidative stress and lessen the risks of chronic illnesses like heart disease and various types of cancers. Additionally, its high dietary fibre content promotes digestive health and helps control blood sugar levels. In addition to its nutritional importance, it also contain bioactive substances with therapeutic uses, such as lycopene, associated with improving prostate health and lowering the chance of developing prostate cancer. Components like beta-carotene and quercetin also suggest that they have anti-inflammatory and immune-modulating capabilities. Adding tomatoes to the diet adds necessary nutrients and a variety of substances that improve well-being in general. Furthermore, tomato holds a major nutritional status, as per 100 g of it contains around 48 mg calcium, 20 mg phosphorus, 27 mg AAC, 3.6 g carbohydrates, 800 mg fibre, 0.4 mg iron, 200 mg fats, 900 mg proteins, and 20 K calories of energy. In addition to these minerals, it contains carotenoids and lycopene. It also keeps blood vessels healthy and prevent scurvy (Ejaz *et al.*, 2011).

Tomatoes is a nutrient-dense crop and an important part of human diet which highlights how closely agricultural practices and human health are related. Farmers should grow nutrient-dense crops and ensure a steady supply of wholesome foods that improve the health of consumer by balancing effective fertilization techniques and sustainable farming practices. Crop fertilization is a popular cultural practice used by farmers to increase output. Fertilizing farmlands under crop production is currently becoming mandatory due to intensive land use and agricultural innovation to attain sufficient yield. We can grow a good quantity of quality produce from various crops by carefully managing the nutrient application in a balanced sustainable approach.

A crucial prerequisite for robust and healthy crops is the effective management of crop nutrition. Hence, one of the key drivers of increased yields is crop nutrition. Crop nutrition should be prioritized in the effort to meet global food demand. Ultimately, yields wouldn't be possible in the absence of vital macro and micronutrients. Micronutrients, on the other hand, are as important as macronutrients. Micronutrients are necessary components for crop growth but are needed in comparatively small amounts. Even though the need for micronutrients is minor, these nutrients have a direct impact on crop growth and development. Most of the farmers focus primarily on macronutrient application. Crop growth and quality, on the other hand, will suffer if it is lacking. Micronutrients include elements such as nickel, boron, molybdenum, copper, iron, chlorine, manganese, zinc and calcium. Each micronutrient serves a distinct function in the plant structure. The most significant micronutrients, however, are boron and zinc.

It also affects how calcium is metabolized; its shortage can lowers the amount of calcium uptake linked to the components of pectin. Insufficient amounts of boron cause wilting and leaf drop, which negatively impacts the quality and productivity of tomatoes. When plants are growing, especially in their reproductive growth stage, their boron requirement can be met by both foliar application and soil amendments. (Haleema *et al.*, 2017). It serves a variety of important tasks, including:

• *The development of cell walls*: Boron is required for the production of pectin, a substance found in cell walls. A healthy cell wall composition aids the extension and division of cells. The production, integrity, and RNA metabolism, carbohydrates, phenol, and IAA, as well as respiration and cell membrane integrity, are all impaired.

• *Pollination and fruit development*: Boron is required to form pollen tubes as well as effective fertilization. It also affects development of fruits and seeds.

• *Sugar Transport*: Boron facilitates the easier transport of sugar throughout plants. The distribution of energy resources among the various plant parts depends on this.

Several detrimental impacts on growth and development might result from a lack of boron in tomato plants. A lack can cause weaker cell walls, resulting in structural abnormalities in different plant tissues. This can appear in tomato plants as swollen, bent, and brittle stems and leaves. Symptoms like twisted and deformed leaves tend to be a result of it. The leaves may shrink, thicken, and develop wrinkles or crinkles. In severe cases, the leaf edges may show tissue death or necrosis. Also, it contributes to poor blossom development and fruit ripening. Pollen viability and pollen tube growth in flowers may be diminished, leading to less fruit production. The formed fruits are also more prone to cracking, particularly in the calyx region where the stem attachment is located. Fruit quality may suffer, and the fruits may become more disease-prone. Corky lesions may appear on fruit surfaces and stems due to its deficiency. These lesions may affect the fruit's flavor and appearance and cause hollow fruit to form in which the inner tissue remains partially developed. As a result, the fruit may have an uneven shape and lower market value. The distribution of carbohydrates and other nutrients throughout the plant is aided by boron. (Sultana *et al.*, 2016) Its lack can hinder nutrient transport, reducing nutrient uptake and distribution throughout the plant. This can harm the functioning and growth of root, restricting the water and nutrient absorbing ability of roots. Because of their lower defense mechanisms and poor structural integrity, plants with boron deficiencies are more prone to various diseases and infections.

Another critical element for the growth of plants is zinc. Zinc is a crucial micronutrient for the growth and development of tomato. It is necessary for several plant physiological and biochemical activities. It is found in several enzymes. Furthermore, it is a crucial factor in the early phases of plant growth and the development of roots, fruits, and seeds; it also aids in photosynthesis, plant hormone balance, and auxin activity. When taken as a supplement, zinc can:

• *Promote Photosynthesis*: Having enough zinc levels boosts the efficiency of photosynthesis, which increases the energy available for plant growth.

• *Increased Enzyme Activity*: Zinc is necessary for the regular operation of several enzymes inducing metabolic activities. Proteins, carbohydrates, and other essential molecules are produced by these enzymes.

• *Affect Hormone Levels*: Zinc has an effect on the synthesis and operation of plant hormones, which regulate growth mechanisms. A healthy hormonal balance can promote both root and shoot growth.

Symptoms of zinc deficiency vary based on the type of crop, but the most typical ones are smaller young leaves, reduced internode length, stunted growth, and yellowing of the lower leaves. Zinc is essential for the formation of enzymes & proteins that aid in nucleic acid production and cell wall formation. It also aids in the regulation of natural oxides and defence mechanism for cells (Amiri *et al.*, 2016). For plants, zinc is a crucial micronutrient. It is essential for various physiological activities, such as the activation of enzymes, the production of hormones, and photosynthesis. Zinc is a component of chlorophyll, the pigment that is responsible for photosynthesis. A deficiency may decrease photosynthetic activity, affecting the plant's capacity to synthesise carbohydrates and energy. This can appear as interveinal yellowing in tomato plants when the veins turn yellow while the tissue between the veins remains green. It can have a negative effect on plants' ability to produce flowers and fruit. A reduction in the number of flowers and a disturbed pollination cycle can reduce the amount of mature fruit produced. Even if a fruit does manage to grow, it may be smaller in size and have an atypical shape. This is because a zinc deficiency can disrupt cell proliferation and division, resulting in deformed fruit growth and impeding the establishment a robust root system. This might decrease plant’s ability to imbibe nutrients and water and the transportation of other crucial nutrients, which would exacerbate the total nutrient imbalance and cause problems with growth and development. Plants that lack certain nutrients are frequently more prone to various illnesses and pests. Their compromised physiological condition renders them less able to fight off viruses, endangering the health of the entire plant.

Micronutrients are frequently overlooked. Applying macronutrients like potassium, phosphorus, and nitrogen tends to be the main focus of farmers. Furthermore, many farmers use micronutrients only when there is initial evidence of deficiency symptoms. This action could result in decreased yields and lower quality. Effective farm management is crucial from the start of the crop's life cycle to the finish. Providing micronutrients to crops is advantageous and essential in achieving higher yields.

Biostimulants helps the plant to get both micro as well as macro nutrients by increasing the nutrient uptake efficiency of plant. Plant growth, productivity and their chemical composition can all be positively impacted by biostimulants, a broad family of molecules that also include substances or microbes that enhance abiotic and biotic stresses tolerance among plants. The primary plant biostimulants are protein hydrolysates obtained from plants and animals and other compounds containing humic components, silicon, phosphite, biopolymers, microbial chemicals, nitrogen, and seaweed extracts. Depending on the compound along with crop, there are a variety of mechanisms underlying the vigilant effects of biostimulants. Improved aspects of physiological and morphological aspects, such as improved root formation and elongation, seed germination rates, crop establishment and improved nutrient uptake, improved cation exchange capacity, reduction in leaching, mechanisms pertaining to stomatal conductance, detoxification of heavy metals and transpiration, activation of immune systems for stressors, are the main sources of these mechanisms (Shahrajabian, 2021).

One of the most widely used vital sustainable biostimulants is seaweed extract. Seaweed extracts are made from several types of seaweed which consists a variety of bioactive compounds, such as cytokinins, auxins, GA_3, and different amino acids. The following characteristics of these chemicals can support in the development of plants:

• *Stimulating Growth:* Seaweed extracts contain plant growth regulators that can promote cell elongation and division, promoting increased growth rate of plant parts.

• *Improving Nutrient Uptake:* Seaweed extracts can raise the absorption of nutrients from the soil by encouraging the root development and nutrient uptake mechanisms in plants.

• *Increasing Stress Tolerance:* Chemicals in seaweed extracts can make plants more resilient to many abiotic stresses, including salinity, drought, and extreme temperatures.

From the earliest days of plant breeding, seaweed extracts are used as biostimulants in agricultural techniques. Algal cells, regardless of whether they're microalgae or seaweeds, are rich in biological components and a treasure trove of nutrients, including minerals, antioxidants, proteins, lipids, poly-unsaturated fatty acids, polysaccharides, and colors. This significant benefit has driven seaweeds to the top of the plant biostimulant list, facilitating numerous plant treatment processes, mostly for serving and supporting sustainable and organic agriculture (Petropoulos *et al.*, 2020). Some unidentified physiologically active chemicals in seaweed extracts can frequently trigger plants to create natural plant hormones via internal metabolic pathways (Del Buono, 2021). The application of SES via foliar application has been researched in conjunction with its speedy and simple handling technique, with an emphasis on revitalizing growth and boosting the production of several major crops for vegetables, such as cucumber. They are biologically distinct from chemical fertilizers. These are biodegradable and safe, making them environmentally beneficial materials without chemical traces or dangers. Some of the most often used extracts are *Pterocladia capillacea* (Del Buono, 2021), *Ascophyllum nodosum* (Pereira *et al.*, 2019), *Ecklonia maxima, Sargassum spp.* (Bertrand *et al.*, 2021), *Ulva lactuca, Padina gymnospora, Caulerpa sertularioides, Sargassum* *liebmannii* (Rouphale and Colla, 2021), *U. lactuca, C. sertularioides, P. gymnospora, S. liebmannii, Laminaria spp., Durvillaea potatumum and S. johnstonii.*

The brown seaweed species *Ascophyllum nodosum* has attracted considerable attention for its extraordinary potential as a biostimulant in agriculture. *Ascophyllum nodosum,* commonly known as knotted kelp or egg wrack, is a perennial brown seaweed found in cold-temperate intertidal zones of the North Atlantic, widely dispersed along northwest coast of Europe and North northeast coast of America (Moreira *et al.,* 2017). It is easily recognizable by its olive-brown, leathery fronds, which feature distinctive air bladders for buoyancy and swollen reproductive structures called "knots." It can grow up to 2 m long. *A. nodosum* reproduces both sexually (through dioecious conceptacles in its knots) and asexually via fragmentation, with a slow growth rate of just 5–10 cm per year. However, sustainable harvesting practices are crucial such as selective frond cutting, as this slow-growing seaweed takes years to regenerate. It is one of the most valuable seaweeds used in organic farming due to its rich composition of bioactive compounds that enhance plant growth, stress tolerance, and soil health. It is commercially harvested for liquid extracts that serve as potent biostimulants. In 2011, Craigie examined the distinct properties of *A. nodosum* as a major source of biostimulants. Its fronds contain high levels of natural plant growth regulators, including auxins, cytokinins, and gibberellins, which promote root development, flowering, and fruit set in crops. Additionally, *A. nodosum* is a rich source of polysaccharides like alginates and fucoidans, which improve soil structure, water retention, and microbial activity, while also inducing systemic resistance against pathogens. The presence of micronutrients (iron, zinc, magnesium) and organic osmolytes (mannitol, betaines) further enhances crop resilience to drought, salinity, and temperature stress. Farmers favor *A. nodosum*-based extracts for their ability to boost nutrient uptake, increase yields, and reduce dependency on synthetic fertilizers. Modern extraction techniques—such as cold processing and enzymatic hydrolysis—are employed to preserve its bioactive integrity, ensuring maximum efficacy in foliar sprays, soil drenches, and seed treatments. Its proven benefits in improving germination rates, crop vigor, and post-harvest shelf life make *A. nodosum* a cornerstone of sustainable agriculture and organic farming systems worldwide.

This seaweed extract has become recognized as a potent natural remedy that improves plants' growth, development, and overall health. *Ascophyllum nodosum* extract gives plants various advantages due to its abundance of bioactive chemicals. Its abundant supply of plant growth hormones, including auxins, cytokinins, and gibberellins, causes favorable reactions at several stages of plant development, from root establishment and nutrient uptake throughout blooming and fruiting. Additionally, findings demonstrated that certain fungi generated from *M. ascophylli*, which were found in the ethyl acetate derivative of *A. nodosum*, reduced the salinity stress impact on plants. It was observed to improve production of agricultural crops by increased nutrient uptake (Khan *et al.*, 2009; Craigie, 2011; Sharma *et al.*, 2014; Van Oosten *et al.*, 2017.

The potential of *Ascophyllum nodosum* seaweed extract to enhance soil structure and microbial activity is one of its most notable characteristics. It increases nutrient cycling and availability, supporting a more nutrient-rich and balanced soil environment by encouraging the establishment of advantageous soil microbes. As a result, plants are more effective at absorbing nutrients, which improves crop yield and quality. Applying *A. nodosum* extract has also improved the plant's water-use efficiency, enabling it to flourish even in water-scarce conditions. The extract's innate capacity to improve cell walls' permeability and structure results in excellent water absorption and lessened water stress. Several researches have demonstrated that crop plants treated with seaweed extracts have better growth and yield metrics. It stands out as a greener substitute for synthetic growth promoters in sustainable and ecologically friendly agriculture practices. Its naturally occurring ingredients align with the rising demand for organic and environmentally friendly farming practices. Farmers may grow better plants, use less chemical inputs, and improve the general health of agricultural ecosystems by using the potential of this biostimulant. As the agricultural sector looks for new ways to solve issues with food security and the environment, *Ascophyllum nodosum* seaweed extract stands out as a significant resource because it represents how nature and science can work together to improve crops, soils, and the ecosystem. Many studies have indicated several favorable benefits of seaweed extracts on plants, including quicker germination of seeds and crop establishment and yield, generating resistance towards both biotic as well as abiotic stress, and many more. *Ascophyllum nodosum* has been shown to boost agricultural crop growth and productivity by enhancing nutrient availability and uptake.

Seaweed extract, zinc, and boron all three of these have additive impact on plant growth and production when applied together. Micronutrients like zinc and boron are necessary underlying a variety of physiological processes that affect a plant's overall health and productivity. Seaweed extracts can increase nutrient absorption and stress tolerance, which can further boost the utilization of zinc and boron. Hence the present study was undertaken to observe the effects of boron, zinc and seaweed extract on the growth, yield and biochemical properties of tomato (*Solanum lycopersicum* L.) when applied as a foliar spray with the following objectives:

1. To analyze the effects of foliar application of boron, zinc and seaweed extract on growth and yield parameters of tomato.

2. To examine the effects of foliar application of boron, zinc and seaweed extract on biochemical parameters of tomato.

3. To workout the economics of tomato cultivation with foliar application of boron, zinc and seaweed extract.

CHAPTER II

REVIEW OF LITERATURE

The available publications on the effects of micronutrient application, specifically boron (B) and zinc (Zn), and the use of extracts derived from *A. nodosum* on the growth, yield, and biochemical parameters of tomato (*Solanum lycopersicum L.*) and other crops from the Solanaceae family has been reviewed. The findings are organized and summarized under appropriate headings according to the research objectives.

2.1. Effects of boron, zinc and seaweed extract as foliar spray on growth and yield parameters of tomato.

2.1.1 Effects of foliar application of boron, zinc

Sandilya *et al.*, 2023 investigates the impact of Zn and B on the growth, productivity and quality of Cherry tomatoes. [*Solanum lycopersicum* var. *cerasiforme* (Alef.) Fosberg] cv. 'Pusa Cherry-1' in Prayagraj, India. The purpose of the experiment was to analyse the crop in terms of various parameters. The nine treatments including control were applied, Zinc at different concentrations (50 and 100 ppm), and Boron at different concentrations (50 and 100 ppm). Based on the study's findings, cherry tomato growth and output were considerably enhanced by the application of zinc and bronze. The plants treated with a 100 ppm zinc and 100 ppm of boron doses showed the supreme fruit yield & weight, TSS, and titrable acidity for the treatment.

Ahmed *et al.*, 2023b laid outa pot experiment at glasshouse conditions to analyze the effectiveness of zinc on growth, nutrient uptake, productivity, and fruit quality of tomato plants. Fourteen treatment combinations viz. (control), Zinc nutrient (1500 ppm (mg/L), 2000 ppm (mg/L), 2500 ppm (mg/L) and ZnO-Nanoparticls (75 ppm, 100 ppm and 125 ppm) along with two tomato varieties. Results indicate that ZnO-NPs @ 100 ppm when applied as foliar spray depicted supreme outcomes in terms of physiological traits, growth and yield attributing characteristics, as well as quality caharacters of tomatoes and highest yield increment (200%) over control.

Saha *et al.*, 2023 conducted a field study using graded dosages of B (soil application) and Zn (soil and soil + foliar treatment) with or without FYM for the two years in a row (2012 and 2013). The results showed that the administration of zinc and boron greatly increased tomato plant tissue concentrations of these elements as well as fruit yield and many growth metrics. The concurrent spray with Zn and B (2 kg ha^{-1}), and FYM produced the largest hike in fruit output over control (27.6%).

Khatri *et al.*, 2022 performed a study to examine the tomato under zinc and boron foliar application in RCBD using var. Manisha with four replications which consists of treatments. The treatments included two levels of borax (30 and 60 ppm) given in two segments (15 and 35 DAT), two levels of chelated zinc (30 and 60 ppm), and control (T0). With zinc at 30 ppm foliar spraying, the results demonstrated a significant increase in metrics including plant's height (cm), no. of leaves, branches, clusters, fruits, fruit weight, fruit diameter and yield. In addition, early blooming was also noticed with 30 ppm borax dose. The results clearly show that employing readily available sources of boron and zinc, such as borax and chelated zinc, can boost production of tomato cv. Manisha.

Ahmed *et al*., 2021 investigated the impact of zinc oxide nanoparticles on a range of crops, including tomatoes. The most significant outcomes in terms of optimal planting characteristics, such as plant height, early blooming, and fruit yields, were obtained from foliar application of ZnO-NPs. Foliar spraying with zinc is one of the efficient methods that can raise crop production and quality. As a result, additional focus should be placed on increasing the quantity, quality, and nutrient utilisation efficiency of zinc oxide nanoparticles and zinc in tomato production.

Gopal and Sarangtham, 2021 administered a field study to assess the impact of boron on tomato yield in acidic soil during the Rabi seasons of 2016–18, respectively. According to experimental data, compared to the boron and control (T1) plot, the soil treatment at 2.0 kg Boron/ha (T4) produced the greatest fruit count $plant^{-1}$, maximum weight of fruits, and yield ha^{-1}, respectively. Accordingly, it was determined that, out of all the treatments used in the experiment, the soil application of 2.0 B kg/ha was the most beneficial in growing tomatoes in acidic soil during Rabi 2016–18.

Xu *et al.*, 2021 examined how various boron concentrations affected the tomato cultivar Jinpeng No. 1's growth, fruit quality, and flavour in a greenhouse setting. There were seven treatments with 4 boron doses (0, 1.9, 3.8, and 5.7 mgL^{-1} H_3BO_3) and two application techniques (leaf and root application). When compared to other treatments, 1.9 mg-L-1 H_3BO_3 leaf spray was more successful in enhancing tomato plant growth and photosynthetic indices. Thus, proper boron application can significantly enhance tomato growth and productivity.

Dixit *et al.*, 2021 performed a study to examine the effects of plant nutrient foliar spray and its various combinations on tomato yield and quality. The four nutrients copper, calcium, magnesium, and boron were added to tomatoes in varying amounts. Under the first fruit harvesting, the application of micronutrient management greatly improved yield metrics in the overall recorded treatment, with treatment T10 (Ca @ 2g/l + Mg @ 1.5g/l) showing a substantial advantage. Fruit weight, diameter, pericarp thickness, fruit clusters, number of fruits/plant, and fruit output per plant (g) were all noticeably better in treatment T10.

Mallick *et al.*, 2020 laid out an experiment using pots to optimise various Zn and B levels for improved tomato (cv. Ruma VF) growth and yield characteristics. Factor I, which contained control, Zn- 4, 6, and 8 kg ha^{-1}, and factor II, which included control and Boron @ 2 and 3 kg ha^{-1}, were both included in the experiment. According to the study, applying Zn - 4 + B - 2 kg ha^{-1} together generated maximum tomato yield, flower clusters count, fruits count per cluster, length and diameter of fruit, fruits count and fruit weight per plant.

Roy and Monir (2020) evaluated the effects of two factors, for instance: two boron foliar sprays of boric acid @ 100 and 200 ppm, in comparison to control with no treatment; and 3 distinct tomato lines, BARI Tomato-15, Exotic Tomato Line-1 and Line-2 . 100 ppm boric acid concentration had significantly higher fruit setting, yield, and total soluble solids (TSS) than 200ppm boric acid concentration. BARI Tomato-15 with100 ppm boric acid produced the largest yield in the interaction effect in comparison to other interaction treatments.

Sanjida *et al*., 2020 examined the effectiveness boron doses and varieties on the growth and productivity of summer tomatoes. This experiment included 15 treatments consisting of BARI tomato 4, 8, and 10 three summer tomato varieties and 4 levels of boron as 1, 2, 3, and 5 kg ha^{-1} of boric acid in all possible combinations and control. Among the varieties, BARI tomato 8 had the largest height, no. of leaves, number of flowers, number of branches, fruit quantity, weight of each individual fruit, and weight of all fruits. The results indicate that BARI tomato 8 could be suggested as one of the favorable varieties. Among the boron levels early flowering, fruit count, and weight per fruits were noted in the 2 kg B ha^{-1} treatment; tallest plant, higher branch and leaf count, and weight of fruit were obtained in the 3 kg B ha^{-1} treatment as compare.

Kaur and Kaur (2020) carried out a study on tomatoes using ten treatments: boric acid and zinc sulphate (200, 300 and 400 ppm each), potassium sulphate (0.50%, 0.75%, 1.00%), and control (water). Regarding micronutrients, zinc sulphate (400 ppm) and boric acid performed better than the other concentrations, i.e., were more successful in raising quantitative characteristics when compared to the control. Thus, the best treatments to increase tomato growth and yield are foliar sprays with boric acid (400 ppm), potassium sulphate (0.75%), and zinc sulphate (400 ppm).

Ashraf *et al.*, 2020 examined the effect of foliar application of Zn and B and the results reported that maximum height, fruit weight, stem thickness, seed count, seed count per fruit, TSS value and pH value of the plant and fruit was observed in T_9 ($ZnSO_4$ + B_2O_3, 1.0 + 0.8g/L of water) while T_8 ($ZnSO_4$ + B_2O_3, 0.75 + 0.6g/L of water) had maximum branch count, pedicel length, fruit length, yield per plant and per hectare, test weight, thus, it was assumed that foliar spraying of plants with Zinc and Boron @ 0.75 + 0.6g per liter increased yield characters up to maximum.

Osman *et al*., 2019 examined the impact of Zn & B on tomato growth and peoductivity. Three concentrations of zinc (1, and 2 kg $ZnSO_4$ ha^{-1}) and boron (1, and 2 kg H_3BO_3 ha^{-1}) along with the control were used as treatments. According to the results, boron significantly influenced tomato yield and all other yield parameters. Combining H_3BO_3 with $ZnSO_4$ @ 2 kg ha^{-1} produced the maximum tomato output by producing the most fruits in each plant, the peak fruit weight per plant, and the longest and widest fruits. Thus, the optimal treatment for tomato growth and yield was to apply 2 kg H_3BO_3 and 2 kg $ZnSO_4$ ha^{-1}.

Haleema *et al*., 2018 to observed the impact of foliar applications of Boron, Cacium and Zinc on tomato growth and fruit output. Zinc (0, 0.25, 0.5%), boron (0, 0.25, 0.5%), and calcium (0, 0.3, 0.6, and 0.9%) were sprayed on the leaves three times. The primary and secondary branch count, leavf count, area of leaf, and fruit per plant all increased with the application of calcium, boron, and zinc at 0.6, 0.25 and 0.5 % respectively. For the majority of the qualities, the interaction between Ca, Zn, and B also produced interesting results. Therefore, to increase tomato production, a foliar spray containing 0.6% Ca, 0.25 B, and 0.5% Zn can be used alone or in combination.

Gopal and Sarangthem, 2018 conducted a field study that included four replications and four treatments, taking into account four different zinc levels (0, 2.5, 5, and 10 Zn kg/ha through $ZnSO_4.7H_2O$). The experiment's findings showed that applying varying doses of zinc considerably enhanced tomato plant growth and yield. For both years, Zn 10 kg/ha establish the maximum height of plant (cm), branch and leaf count/plant, flowering, fruit count, fruit weight and production.

Singh *et al*., 2017 observed the results for how foliar spraying of zinc and boron influence the production and growth of Cherry Tomato. The treatment with B + Zn each 2.0g/l resulted with, maximum height, leaf count was, flower count per cluster. The utmost fruit count, fruit weight, No. of fruit per plant, yield per plant and per ha. According to these findings, the integrated foliar treatment of zinc and boron had a greater influence on growth and yield for cherry tomatoes than each foliar application individually.

Sultana *et al*., 2016 executed a two-year field study to examine the impact of foliar spray and soil amendment with micronutrient on tomato (*Lycopersicon esculentum* Mill.) yield. Zinc as $ZnSO_4.7H_2O$ (0.05 %) and boron as boric acid H_3BO_3 (0.03%) were applied as foliar spray. Among varied treatments, foliar spraying with B - 0.03 % + Zn - 0.05 % noted maximum yield, while the control produced less which was statistically in coordination with soil amendment with zinc and boron at 2 and 6 kg ha^{-1} each. The hike of production was upto 31.1% and 18.3%, respectively, over soil amendment and control.

Meena *et al*., 2015 presented an experiment to determine how zinc and boron affect tomato cultivar Azad T-6 growth, yield, and quality. The experiment consists of 12 distinct zinc and boron treatment combinations at concentrations of 50, 100, and 150 ppm each. Consequently, the application of zinc and boron was found to positively boost growth parameters, including plant height and branch density at 30, 60, and 90 DAT. Therefore, the study demonstrates that the use of zinc and boron, either individually or in combination, has been shown to be advantageous for tomato growth, blooming and fruit formation as well as for improving tomato quality.

Ali *et al*., 2015 used foliar B and Zn application with $ZnSO_4$ and H_3BO_3 : control, Zn -25 ppm, B - 25 ppm, Zn - 12.5 ppm + B - 12.5 ppm to hype up the production of BARI hybrid tomato 4, which is grown in Bangladesh during rabi season. Foliar application of Zn - 12.5 ppm + B - 12.5 ppm resulted in the highest plant height, leaf area (48.2 cm2), leaf and branch count, fruit quantity, clusters, fruit diameter, weight, and yield, while the control group showed the lowest. Application of Zn - 12.5 ppm + B - 12.5 ppm also emerged in early flowering and a minimum number of sick infested plants. Therefore the combined foliar spraying of zinc and boron had a greater impact on growth and productivity than either fertilizer alone.

Ullah *et al*., 2015 laid out a study to check the outcomes of foliar spray at four boron (0, 0.05, 0.10, and 0.15 percent) and zinc (0, 0.2, 0.4, and 0.6%) doses. Clusters per plant, branch count and fruit quantity were significantly increased with zinc at 0.4 % and boron at 0.15 %, among other levels. Based on the foregoing findings, it is recommended that Zn at 0.4% + B at 0.15% improved growth and output.

Naga Sivaiah *et al.*, 2013 performed a research to determine the impact of foliage spraying of micro-nutrients on growth and production aspects in 2 public sector varieties of tomato, Utkal Raja and Utkal Kumari during rabi season of year 2010. The study was designed in RBD with 3 replications, and the treatments included boron, molybdenum, zinc, iron, copper, manganese, a combination of all of these, along with control. The treatment of zinc exhibited the highest growth rate in tomato cv. Utkal Kumari, followed by the application of micronutrient mixture and boron. The production per plant raised upto 1.336 kg and 1.867 kg, whereas in Utkal Raja, 1.967 kg. The highest fruit yield was achieved in both kinds when micronutrients were applied in combination.

Gurmani *et al.*, 2012 performed an experiment including pots to investigate tomato cultivars, VCT-1 and Riogrande, growth by soil amendment of zinc (5, 10, and 15 mg kg^{-1}) in terms of growth, productivity and quality characteristics. In both cultivars, zinc treatment boosted fruit yield and plant growth. Zn amendment at 10 mg kg^{-1} soil produced the highest levels of plant growth and fruit production. Zn administration at 10 mg kg^{-1} increased fruit produce upto 54%, whereas 15 mg kg-1 increased fruit upto 48%, respectively.

Patil *et al.*, 2010 investigated how foliar micronutrient application affected tomato (Megha) development and yield in 2005–07. Out of 9 distinct approaches, the use of boric acid at a concentration of 100 ppm produced the highest branches count, yield per plant, and fruit production, according to the results based on a two-year mean. The combination of micronutrients (Bo, Zn, Mn, and Fe @ 100 ppm and Mo @ 50 ppm) produced the highest fruit yield when compared to the control.

Sathya *et al.*, 2010 performed a field trial to examine the impact of boron amendment on the PKM 1 tomato's growth, quality, and fruit yield. The soil amendment and foliar spraying of boron had a substantial impact on the characters, such as plant height and branch number. While borax @ 20 kg ha-1 created taller plants with more branches among varied levels of foliar spray of 0.25 % boron as borax produced tallest plants with higher count for branches among the varied doses of soil boron application. Additionally, the results showed that the treatment that was applied with boron 20 kg ha^{-1} produced the maximum fruit production of 33 tonnes per hectare, which was 33.6 percent higher than the control and much better than the other treatments.

2.1.2 Effects of foliar application of seaweed extract

Subramaniyan *et al.*, 2023 evaluated the effects of plant extracts, *Ascophyllum nodosum*, a seaweed that contains biostimulants and Kendal Root on tomato phytomorpho-physiology, yield, and quality in a field experiment. Kendal Root was soaked into the soil at three different doses (2.5, 5.0, and 10 L ha^{-1}), and the outcomes were contrasted with the control. Kendal Root 5.0 L ha1 considerably enhanced the tomato plant growth and physiological characteristics, including plant height, stem and root dry weight, leaf area, chlorophyll index, and gaseous exchange, when compared to the other three concentrations. The Kendal Root 5 litre ha^{-1} considerably increased the amount of tomato fruits, yield per plant, and hectare while taking yield features into account. Thus, Kendal Root biostimulant included into tomato an boost its production.

Ahmed *et al.*, 2023a evaluated the integrated approach of ANSE and Si on tomato growth, water productivity, fruit output, and fruit quality during water stress. Under 3 soil moisture conditions 50, 75, and 100 percent field capacity and 4 ANSE doses (1.25, 2.5, 3.75, and 5 ml/l^{-1}) were applied in conjunction with 60 kg ha^{-1} soluble Silicon in the form of Mono-silicic acid and a control. Regardless of soil moisture conditions, plants fed with 0.5% ANSE and 60 kg ha−1 soluble Si showed a continuous trend of increased fruit yield and water productivity. Similarly, even under extreme water stress of 50% FC, individual silicon amendment at 60 kg ha^{-1} was successful and increased fruit yield by 207% when compared to the control. *Ascophyllum* extarct and Si applied together, however, produced more encouraging outcomes than Si applied alone. Under moderate to considerable soil moisture availability, remote soil amendment of ANSE at 5 ml/l^{-1} and soluble silicon at 60 kg ha^{-1} shows potential for better productivity.

Di Mola *et al.*, 2023b conducted an experiment comparing three mulch treatments (biodegradable film Ecovio and MaterBi®; bare soil) and four biostimulant treatments (bio (*A. nodosum*); microbial (*Trichoderma afroharzianum*); a integration of both—M-B; not treated—Control) and assessed their influence on productivity and quality of processing tomatoes. The results demonstrate that using microbial biostimulants derived from *T. afroharzianum* extract and A. nodosum, both separately and in combination, is a sustainable method of improving the production and quality characteristics of processing tomatoes.

Villa *et al.*, 2023 in a study with the goal of examining the morphological and yield characteristics of the tomato crop's biostimulant response to *Ascophyllum nodosum* extract (ANE) application. In addition to the control, ANE (0.2%) was sprayed on the leaves and drenched into the soil in three different treatments. during the tomato crop five times. ANE applications enhanced yield and growth traits of plant. As a result, applying ANE (0.2%) to tomato crops encourages increases in plant growth and yield components, making it a sustainable input that advances agriculture. When compared to foliar sprays, soil applications of ANE proved to be more successful.

Rajendran *et al.*, 2022 treated sweet pepper plants grown in grow box home gardens with a 0.5% *Ascophyllum* seaweed extract (ASWE) seed treatment, foliar application, and soil drench. According to the results the foliar treatment improved the plant growth characteristics, produced more fruits, and extended the longivity of the sweet pepper fruits. Compared to foliar treatment, ASWE was less effective when applied in the soil. Priming the seeds in 0.5% ASWE considerably improved the seedlings' shoot and root lengths as well as their germination rate. Because it would be extremely environmentally friendly and support the organic farming system, this experiment shows that SES can be easily implemented in home garden setups.

Sîrbu *et al.*, 2022 presented a study consisting a Codified Bios is a biostimulant that contains hydrolysed proteins, humic compounds, and algae extract (*Ascophyllum nodosum*) that affects plant growth and mineral nutrition. Its use indirectly encouraged the plants to absorb more nutrients and to improve the rate at which photosynthesis occurs. When the Bios product (a 0.5% solution) was applied topically, the amount of tomato and wheat crop produce increased in comparison to the unfertilised control. In the treated plants, tomato and wheat yield increased by 50.12% and 36.46%, respectively.

Cozzolino *et al*., 2021 laid out a field investigation in order to confirm the possible positive impact of 3 plant biostimulants on the growth, production, and the biostimulants used in the experiment were a brown seaweed extract (SES), a plant extract and a protein hydrolysate (LDPH). The yield increased upto 18.3% than the control and the unmarketable output decreased by an average of 41.3% as a result of the foliar spray of biostimulants, particularly seaweed extract and protein hydrolysates. The results also show that the fruits of the treated plants had increased dry matter accumulation and firmness (+10.9% and +14.1%, respectively) over control.

Hussain *et al.*, 2021 examined the impacts of SES derived from the brown algae *D. potatorum* and *A. nodosum* on as foliar spray and soil amendment. When SWE was applied in soil, two outcomes were seen. SWE enhanced plant production (yield and quality) and growth (count of flower, flower clusters, fruit quantity, length of root, root and shoot dry weight). Innovative methods for sustainable food production might be revealed by a deeper comprehension of how SWE affects the plant-soil ecology.

Dookie *et al.*, 2021 found that when extracts from *A. nodosum* and *Sargassum* sp. are applied topically to tomato plants, the quantity of flower buds, flowers, and fruits has grown dramatically. The current study supports the sustainable use of seaweed extracts in horticultural crops by demonstrating their possible contribution to the improved flowering phenomenon seen in tomatoes.

Fakhrabad *et al.*, 2019 carried out a factorial RCBD experiment with four replications to examine the effects of seaweed extract (foliar spray) as a biostimulant agent on a few tomato quantitative and qualitative attributes. The treatments included cultivars in three levels: Hungarian Mobil, Mobil's Dutch, and Super Queen, and seaweed extract at four levels (distilled water) of 1.2 and 3 ml/l (seaweed extract with Stimplex brand). The findings showed that the number of internodes, flowering date, and quantity of fruits per panicle varied significantly at a concentration of 2 ml/l. The cultivars in this study differed significantly from one another, but no other features under investigation showed any discernible changes.

Di Stasio *et al.*, 2018 conducted a greenhouse study on tomato to assess the impact of two algal derivatives based on *Ascophyllum nodosum*, Super Fifty and Rygex, on a tomato exposed to reduced nutrient availability and salinity. Regardless of the salinity treatment, Super Fifty treatment showed a 13% increase in growth following a full-strength feeding diet. Rygex and Super Fifty treatments improved the aggregation of antioxidants, minerals, and key amino acids in tomato fruits, improving their total nutritional value even though they had no discernible effect on plant growth and yield under salt treatment.

Ali, 2018 conducted an experiment in which tomato plants were applied with ANSE (0.2% or 0.5%) every 15 DAT. The higher concentration of seaweed extract (0.5%) was more productive than the lower concentration (0.2%) foliar spray was more effective than the soil drench and their combined approach. The treatment outcomes in the significant improvement in plant’s height and yield (37% and 95% respectively), plant biomass, root to shoot ratio.

Murtic *et al.*, 2018 investigated ANSE (0.2%) foliar spray on cherry tomato growth, productivity and quality under stress and non-stress conditions. It was found that cherry tomato seedlings treated with seaweed extract had higher leaf water potential and lower proline content than untreated planting material under stress, suggesting that the application of this fertilizer helps cherry tomato seedlings adapt better to stress.

Ali *et al.*, 2016 applied an alkaline seaweed extract derived from *Ascophyllum nodosum* (ANSE) to tomato plants growing in tropical climates. In contrast to control, foliar spray with 0.2% ANSE exhibited a substantial increase in plant height (10%) and fruit output (51%). Higher concentrations of ANSE, such as a 0.5% spray, significantly increased plant's height (37%) and yield (63%), in comparison to control plants. Overall, under tropical growth conditions, the use of ANSE showed noticeable increases in tomato fruit yield and quality.

Javanmardi and Sattar, **2016** evaluated the impacts of biological fertilizers, such as seaweed extract and amino acids, and their mixture, on five greenhouse tomato cultivars in a soil culture system under greenhouse conditions (EDU, Sweet Million, M09, Golden Cherry, and Guiza). Fruit length, width, and weight of cherry tomatoes (Sweet million, Golden cherry, M09) were not as impacted by fertilizers containing amino acids or seaweed extract as giant tomatoes (Guiza and EDU), according to research on the effect of tomato cultivar on fertilizer response.

Sasikala *et al.*, 2016 experimented to observe the effects of seaweed extract by at different concentration of SES (0.2%, 0.4%, 0.6%, 0.8% and 1%). SES was applied to plant under 3 varied conditions- as soil amendment, foliar application and seed treatment. On the basis of experimental findings, it became evident that utmost growth and productivity of the tomato plant can be derived at a concentration of 0.6%. Although the leaf count and leaf area was high with concentration 0.8 % which was not much different from 0.6%.

Hernández-Herrera *et al.*, 2014 in a study, investigated how tomato (*Solanum lycopersicum*) germination and growth were affected by liquid SES derived from *Caulerpa sertularioides, Ulva lactuca, Sargassum liebmannii and Padina gymnospora* as biostimulants in greenhouse settings using as foliar spray and soil drench. The findings showed that treating seeds with SES of *P. gymnospora* and *U. lactuca* at lower conc. (0.2%) exhibited enhanced germination. It was discovered that a soil drench application was more successful than a foliar spray application at affecting plant height. Plants that received LSEs of *P. gymnospora* and *U. lactuca* exhibited increased weight, root length, and branch length.

Zodape *et al.*, 2011 studied the The impact of seaweed, or *Kappaphycus alvarezii* sap, on tomato growth and yield in the field during the 2006–07 kharif season. When administered as a foliar spray (5.0%), K. alvarezii sap boosted tomato fruit yield (60.89%) in contrast to control. This increase was linked to the size and quantity of fruits produced per plant. Fruit quality as well as the content of macro (13.24-67.50%) and micro (23.84-42.61%) constituents rose with sap treatment. Foliar-applied plants demonstrated resistance to fruit borer, bacterial wilt, and leaf curl.

2.2. Effects of boron, zinc and seaweed extract as foliar spray on biochemical parameters of tomato.

2.2.1 Effects of foliar application of boron, zinc

Sandilya *et al*., 2023 investigates the impact of micronutrients on cherry tomato development, yield, and quality. [Pusa Cherry-1] cultivar of *Solanum lycopersicum* var. *cerasiforme* (Alef.) Fosberg in Prayagraj, India. The study's objective is to assess the plants according to a number of criteria. Control, zinc at various conc. (50 ppm and 100 ppm), and boron at various conc. (50 ppm and 100 ppm) are among the nine treatments used in the study. The study's findings show that applying zinc and boron considerably raised the quality of cherry tomatoes. The highest levels of ascorbic acid and TSS were seen in plants treated with 100 ppm zinc and boron.

Saha *et al.*, 2023 conducted a field experiment using graded dosages of Zn (soil and foliar + soil treatment) and B (soil treatment) with or without FYM over 2 years. The results showed that combining Zn and B can greatly boost essential quality indices such as carotene and ascorbic acid availability in tomatoes. Soil and foliar treatment together with Zn and B with 2 kg ha^{-1} resulted in increases in carotene content by 25 and 35%, and ascorbic acid content by 7 and 30% compared to the control. As a result, optimizing Zn and B dosages can improve tomato output and quality while also helping to address micronutrient deficiencies.

Prasad *et al*., 2021 conducted two outdoor tests in addition to one greenhouse experiment in order to evaluate the effect of zinc on tomatoes. According to the results, adding exogenous zinc in addition to RDF considerably improved all metrics in both sufficient and deficient soils. When compared to other treatments, the T9 treatment in high zinc soils greatly enhanced quality indices such as TSS (6.000 8Brix), vitamin C, titratable acidity, lycopene and shelf life. T9 had higher zinc uptake and usage efficiency than RDF, measuring 238.91 g ha^{-1} and 2.47%, respectively. In T10, the efficiency of zinc uptake and utilisation was increased.

Xu *et al*., 2021 examined varying boron doses on the quality of tomato in cv. Jinpeng No. 1. 4 boron levels using H_3BO_3 (0, 1.9, 3.8, and 5.7 mgl^{-1}) and two application methods (leaf and root application) were used. The 1.9 mgl^{-1} H_3BO_3 leaf spray was found to be more suitable in increasing tomato plant growth and photosynthetic metrics than rest of the treatments. Along with that, the application of 3.8 mgl^{-1} H_3BO_3 to the roots resulted in increased amounts of soluble protein, lycopene, carotene, the acid and sugar ratio, and unique aromatic components in the fruit, as well as higher overall fruit quality and flavor when compared to rest of the treatments.

Mallick *et al*., 2021 investigated the influence of varying zinc and boron doses on the primary quality and nutritional characteristics of tomato fruits using a pot experiment in a net house. The experiment contained 3 levels of B- 0, 2 and 3 kg ha^{-1}, and four levels of Zn- 0, 4, 6, 8 kg ha^{-1}. The findings showed that vitamin C and lycopene levels were maximum in B as 2 kg ha^{-1} application. Applications of these micro-nutrients together had a significantly substantial impact on tomato fruits' vitamin C, lycopene, and overall acidity levels. Eventually, the study concluded that the primary nutrients and biochemical characteristics of tomato fruits were significantly impacted by the conjugation of zinc and boron (4.0 and 2.0 kg ha^{-1}, each).

Roy and Monir, 2020 evaluated the impact of two factors, including two foliar spray levels of boron (100 & 200 ppm) using H_3BO_3, and three distinct tomato lines (BARI Tomato-15, Exotic Tomato Line-1 and Line-2). TSS was highest in L1, while vitamin C was highest in L3 when quality parameters were taken into account. In the interaction effect, B1L3 produced the highest yield, while B2L1 produced the lowest.

Singh *et al*., 2017 in the current study examining growth and productivity of Cherry Tomato as affected by foliar application of Zinc and Boron The study demonstrated that greater TSS and vitamin C were resulted from treatment B and Zn 2.0g/l each. These findings indicate that foliar applications of zinc and boron together were more beneficial to cherry tomato quality than either foliar application alone.

Abo Hameed *et al*., 2014 evaluated the potential effects of boron on tomato growth and certain plant activities at 9 to 30 days of growth through germination and pot studies. With the applied boron concentrations, the glutamate-oxoloacetate and glutamate-pyruvate transaminase enzymes' activity was markedly elevated. Additionally, as the concentration of boron grew, the amount of soluble proteins in the roots and shoots increased progressively.

Gurmani *et al*., 2012 investigate the influence of soil amendment of Zinc on the growth, productivity, and quality characteristics of two tomato cultivars, Riogrande and VCT-1. Applying zinc at doses of 10 & 15 mg kg^{-1} considerably raised the levels of soluble protein, sugar, chlorophyll in the leaves of both cultivars. The findings indicate that the biochemical characteristics and enzymatic activities of both tomato cultivars are certainly impacted by the soil application of Zn 10 mg/kg.

Sathya *et al*., 2010 in field experiment determine the impacts of boron incorporation on growth, yield and quality of PKM 1 tomato. The foliar spray and soil application of boron had a substantial impact on the growth attributing characters, like plant height and branch number. It was found that, out of all the different levels of boron application, borax @ 20 kg ha^{-1} significantly outperformed the other treatments and increased the quality of fruit, including lycopene content, crude protein, TSS and titrable acidity,.

2.2.2 Effects of foliar application of seaweed extract

Subramaniyan *et al.*, 2023 conducted a study where 3 doses of Kendal Root extract (2.5, 5.0, and 10 L ha^{-1}) were applied as soil drenching and the outcomes were compared. The study examined the effects of Kendal Root, a biostimulant ANSE, and plant extracts on tomato phytomorpho-physiology, productivity, and quality. Out of the three concentrations tested, Kendal Root 5.0 L ha^{-1} greatly enhanced the growth of tomato plants. While lowering the titrable acidity of tomato fruit, Kendal Root 5.0 L ha^{-1} raised tomato quality features such total soluble solids, ascorbic acid content, lycopene, and total sugars.

Di Mola *et al.*, 2023b performed an experiment comparing Three mulch treatments (biodegradable film Ecovio and MaterBi®; bare soil) and four biostimulant treatments (bio (*A. nodosum*); microbial (*Trichoderma afroharzianum*); a combination of both—M-B) were examined for their potency on tomato processing yield and quality characteristics. According to the results, biodegradable MaterBi® film (NOV) was linked to increased firmness and total soluble solids (TSS) values (averages of 1.30 kg cm−2 and 4.9 °Brix, respectively). The phenol concentration increased by 30% with each biostimulant application.

Rajendran *et al.*, 2022, conducted a field study in which sweet pepper plants were treated with 0.5% ASWE by foliar application, soil drench, and seed treatment in grow box home garden conditions. The findings pointed out that the foliar treatment enhanced the plant growth characteristics, higher number of fruits, and improved the shelf life of sweet pepper. When compared to foliar application, soil amendment with ASWE to plants was not much effective. As compared to the control, the ASWE spraying significantly raised the biochemical components, including the amount of chlorophyll, reducing sugars, phenol, and amino acids. This study shows that ASWE can be easily implemented in household gardens, which would be highly environmentally friendly and support the organic farming system.

Sîrbu *et al.*, 2022 presented a study consisting Codified Bios is a biostimulant that contains hydrolysed proteins, humic compounds, and algae extract (*Ascophyllum nodosum*) that affects plant growth and mineral nutrition. The addition of the biostimulant indirectly encouraged the plants to absorb more nutrients and to boost the rate at which photosynthesis occurs. In comparison to control and other treatments, the foliar application of the Bios product (as a 0.5% solution) increased the levels of carotene and chlorophyll a and b.

Murtic *et al.*, 2018 examined the effects of a 0.2% foliar spray of SES on the plant development, productivity, and quality of tomato seedlings under artificial stress and non-stress condition conditions. They discovered that the seedlings treated with seaweed extract had higher leaf water potential and a lower proline content than the untreated seedlings under stress, suggesting that the application of this fertilizer helps the cherry tomato seedlings adapt better to stress. When compared to untreated plants under the same conditions, cherry tomato quality improved with SES treatment under both conventional and drought conditions.

Javanmardi and Sattar, **2016** evaluated the effects of biological fertilizers, such as seaweed extract, amino acids, and their combination, on five greenhouse tomato cultivars in a soil culture system under greenhouse conditions (Guiza, Sweet Million, M09, Golden Cherry, and EDU). When fertilizers containing amino acids were employed, fruit quality attributes such as the percentage of titrable acidity, soluble solids content, and vitamin C were generally higher.

2.3. Effects of boron, zinc and seaweed extract as foliar spray on economics of tomato.

2.3.1 Effects of foliar application of boron, zinc

Sandilya *et al.*, 2023 investigates the effectiveness of Zn and B on the growth and productivity of Cherry tomatoes. [*Solanum lycopersicum* var. *cerasiforme* (Alef.) Fosberg] cv. 'Pusa Cherry-1' in Prayagraj, India. The study's objective is to assess the plants according to a number of criteria. Control, zinc and boron at 50 and 100 ppm each are among the nine treatments used in the study. The results show that the development and yield of cherry tomatoes were greatly enhanced by the administration of zinc and boron. When comparing the treated plants to the control, the benefit-cost ratio likewise increased. Overall, the study indicates that using B and Zn can be a sustainable and successful way to increase cherry tomato productivity and financial rewards.

Panjikar *et al*., 2023 conducted an On Farm Trial (OFT) along with Krishi Vigyan Kendra on 0.2% Zinc sulphate and 0.1% Boric Acid on yield and economics of tomato cultivation by controlling fruit cracking in district Sitamarhi (Bihar). The production of Tomato was recorded 355q/ha while farmers were growing average 255q/ha and fruit cracking was found only 5.6% while in the farmers field it was recorded average 54% fruit cracking. Therefore, the major objectives for quality tomato production by reducing the fruit cracking, spray of boron and zinc in tomato gave better performance in plant growth, good onset of flowers and fruits, minimized fruit cracking, increased fruit shining. This helps the vegetable grower to increase net return.

Kaur and Kaur, 2020 carried out a study on tomatoes using ten treatments: boric acid and zinc sulphate (200 , 300 and 400 ppm each), potassium sulphate (0.50%, 0.75%, 1.00%), and control (water). When it came to micronutrients, 400 ppm of B and Zn outperformed the other concentrations, meaning they were more efficient and produced higher economic returns than the control. Thus, the best treatments to increase tomato economic return are to spray the leaves with K_2SO_4 (0.75%), zinc sulphate and boric acid (400 ppm each),.

Prasad and Saravanan, 2014 found that combining zinc and boron (B + Zn 1.25 g L^{-1} each) increased tomato output by two and a half times that of the control. There was an increase in the plant height (2.93 cm), number of leaves (39.33), number of fruits (88.33), total yield (113.628 t ha-1), fruit quantity per greenhouse (3.342 t ha-1) and benefit cost ratio (4.05).

Patil *et al*., 2010 studied about spraying of plants with zinc and boron micronutrients, both separately and in combination, on tomato (Megha) growth and yield in 2005–07. based on the two years findings, among nine varied treatments, utmost benefit ratio (1.80) was seen with boron, which resulted in net returns of ₹ 97,850/ha, followed by the conjugation of micro-nutrients (1.74), which resulted in net returns of ₹ 88,900/ha, in comparison with control (1.40), that resulted in net returns of ₹ 53,250/ha.

Narayan *et al*., 2007a executed a field study to determine the impact of micronutrients such as boric acid, ammonium molybdate, zinc sulphate, copper sulphate, manganese sulphate, ferrous sulphate, conjugation of micronutrients as 100 ppm each. Boric acid produced the highest average plant height, while copper sulphate produced the highest average fruit count, fruit yield, returns (Rs. 103 243.50), and B:C ratio (1.93).

Santosh and Sharma, 2006 conducted a study to figure out the foliar spray results of B & Zn on tomato growth, fruit production, and seed yield. Starting 30 days after transplantation, all treatments were given at a dose of 100 ppm, and they were repeated twice at 10-day intervals. All treatments, received uniform application of the prescribed NPK rate (100:75:55 kg ha^{-1}). The maximum growth and seed output were obtained with foliar boron administration at 100 ppm, yielding returns of ₹ 150 811.44 ha^{-1} and a B:C ratio of 1:2.13.

2.3.2 Effects of foliar application of seaweed extract

Yao *et al*., 2020 used a novel SES derived from *Sargassum horneri* in, China (Shandong province), to examine the impact of several doses of SES (30, 60, and 90 kg ha^{-1}) on tomato productivity, quality, harvesting time, and net returns. According to the findings, applying SES considerably increased tomato yield by 4.6% to 6.9% when compared to the control. SES at 60 and 90 kg m^{-2} considerably raised tomato hardness by 10.2 and 19.8%, respectively, in comparison to control, which may assist minimise losses during storage and transit. Additionally, SES decreased the tomato's ripening period, and a high net return was obtained by timing the tomato harvest with the highest selling price.

CHAPTER III

MATERIAL AND METHODS

The research entitled "**Effect of foliar application of micronutrients (B and Zn) and Seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)**" was conducted at the Horticulture Research Farm, School of Agriculture, Department of Horticulture, Lovely Professional University, Phagwara, Punjab, in the years March to August 2022 & February to July 2023. The materials and the techniques acquired are narrated as under:

3.1. Experimental site

The field experiment was carried out from March to July 2022 and February to June 2023 at the Research Farm of School of Agriculture, Lovely Professional University Jalandhar, Punjab. The trial site's topography was nearly consistent, with ample surface drainage; it was located at an elevation of 252 meters above sea level, within the central plain zone of Punjab's agroclimatic zone, at latitude 31˚ 22'31.81'N and longitude 75˚ 23'03.02 E.

3.2. Location and climate

Fig. 3.1: Map of experimental site

The two most crucial elements that influence whether agriculture succeeds or fails are climate and weather. From planting to harvesting, weather affects agricultural operations, which is why it's critical to illustrate the climate differences across the growing season. Over the course of the crop-growing season, the average of weekly weather checks were noted. With summer temperatures ranging from 23°C to 43°C and winter temperatures ranging from 7°C to 19°C, it has a sub-tropical climate. In general, relative humidity ranges from 30% to 85%. The region experiences the most rainfall from mid-June to early-September, whereas winter rainfall is uncertain and frequent. The average yearly rainfall is approximately 686 mm. Throughout the growing season, temperatures ranged from 48°C to 6°C, with relative humidity ranging from 60 to 85%. Throughout the growing season, there was a total rainfall of 462 mm.

Table 3.1 Monthly meteorological parameters during the period of field experiment from March to July 2022 & February to June 2023

Month	**Highest temp. (˚C)**		**Lowest temp.(˚C)**		**Av. temperature (˚C)**		**Rainfall (mm)**		**Relative humidity (%)**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
January	19	15	6	8	12.5	11.5	107.5	45.3	55-86	44-46
February	22	21	7	11	14.5	16	16.5	55.3	48-86	46-48
March	34	27.5	9	12	21.5	19.75	0	67.9	38-62	49-51
April	44	38	22	20	33	29	0.5	41.4	20-53	25-39
May	43	37	24	27	33.5	32	11.2	37	18-44	26-36
June	48	40	27	29	37.5	34.5	70.6	65.9	34-52	45-58
July	44	35	24	25	34	30	255.8	231.3	55-77	55-69

3.3. Soil

The experimental field on which study was conducted is classified as sandy loam soil and following nutrient components were analyzed. The experimental field soil was inadequate in Phosphorus and rich in organic matter and potash.

Table 3.2 Physical and chemical properties of the experimental field soil

Sr.no.	Particulars	Values (0-30 cm depth)	Procedure followed
Physical properties			
1	Sand (%)	43.76 %	International pipette method (Piper, 2019)
2	Silt (%)	28.55 %	
3	Clay (%)	17.18 %	
4	Gravels (%)	10.51%	
Chemical properties			
1	Ph	7.65	Buckmoric pH meter (Piper,2019)
2	Electrical conductivity (dS/m)	0.26 dS/m	Jackson (1973)
3	Organic carbon (%)	0.25 %	Wet oxidation method (Jackson, 1957)
Available nutrient status			
1	Available N (kg/ha)	213.32 kg/ha	Alkaline per magnate method (Subbaiah and Asija, 1976)
2	Available P (kg/ha)	33.96 kg/ha	Olsen's method (Jackson,1957)
3	Available K (kg/ha)	235.40 kg/ha	Flame photometer method (Jackson,1957)
4	Zinc (kg/ha)	0.79 kg/ha	Atomic absorption Spectrophotometeric method (Kjeldhal *et al.*, 1883)
5	Boron (kg/ha)	0.14 kg/ha	

Table 3.3 Detailed information of experiment field

S.No	PARTICULARS	DETAILS
1	Location	Horticulture Research Farm, Lovely Professional University
2	Crop	Tomato (*Solanum lycopersicum* L.)
3	Variety	Tomato No. 575, Yellow Jubilee
4	Year	March to July 2022 & February to June 2023
5	Design	FRBD (factor A: 12 foliar sprays; factor B: 2 varieties)
6	Total number of treatments	12 × 2 = 24
7	Treatment intervals	3 (15 DAT, 30 DAT and 45 DAT)
8	Replication	3
9	Total experimental area	583.2 m^2
10	Spacing	60 cm × 45 cm
11	No. of plants per treatment	30
12	RDF	25 t FYM (per hectare), 150:62.5:62.5 kg/ha [PAU], Urea- 15.91 kg, DAP- 7.91 kg, MOP- 6.06 kg, Vermicompost- 2.89 q

Table 3.4 List of treatment material used

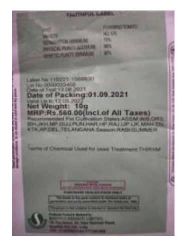
EXPERIMENTAL MATERIAL	PARTICULARS	CHARACTERISRTICS	IMAGE
Treatment spray	**Seaweed extract (*Ascophyllum nodosum*)**	*Type :* Biostimulant *Form:* Liquid *Concentration:* 2 and 4 ml/l (0.2 % and 0.4 %)	
	Zinc (Zinc sulphate monohydrate 33%)	*Type :* Micronutrient *Form:* Powder *Concentration:* 6.06 g/l (0.2%)	
	Boron (Boron 20%)	*Type :* Micronutrient *Form:* Powder *Concentration:* 10 g/l (0.2%)	
Varieties	**Tomato no. 575**	• *Variety:* Hybrid • *Fruit color:* Red • *Average yield:* 40-50 t/ha • *Fruit shape:* Oval • *Seed source:* Sungro seeds • *Seed required:* 10 g	 
	Yellow Jubilee	• *Variety:* Hybrid • *Fruit color:* Yellow • *Average yield:* 50-60 t/ha • *Fruit shape:* Round • *Seed source:* Gennext • *Seed required:* 10 g	 

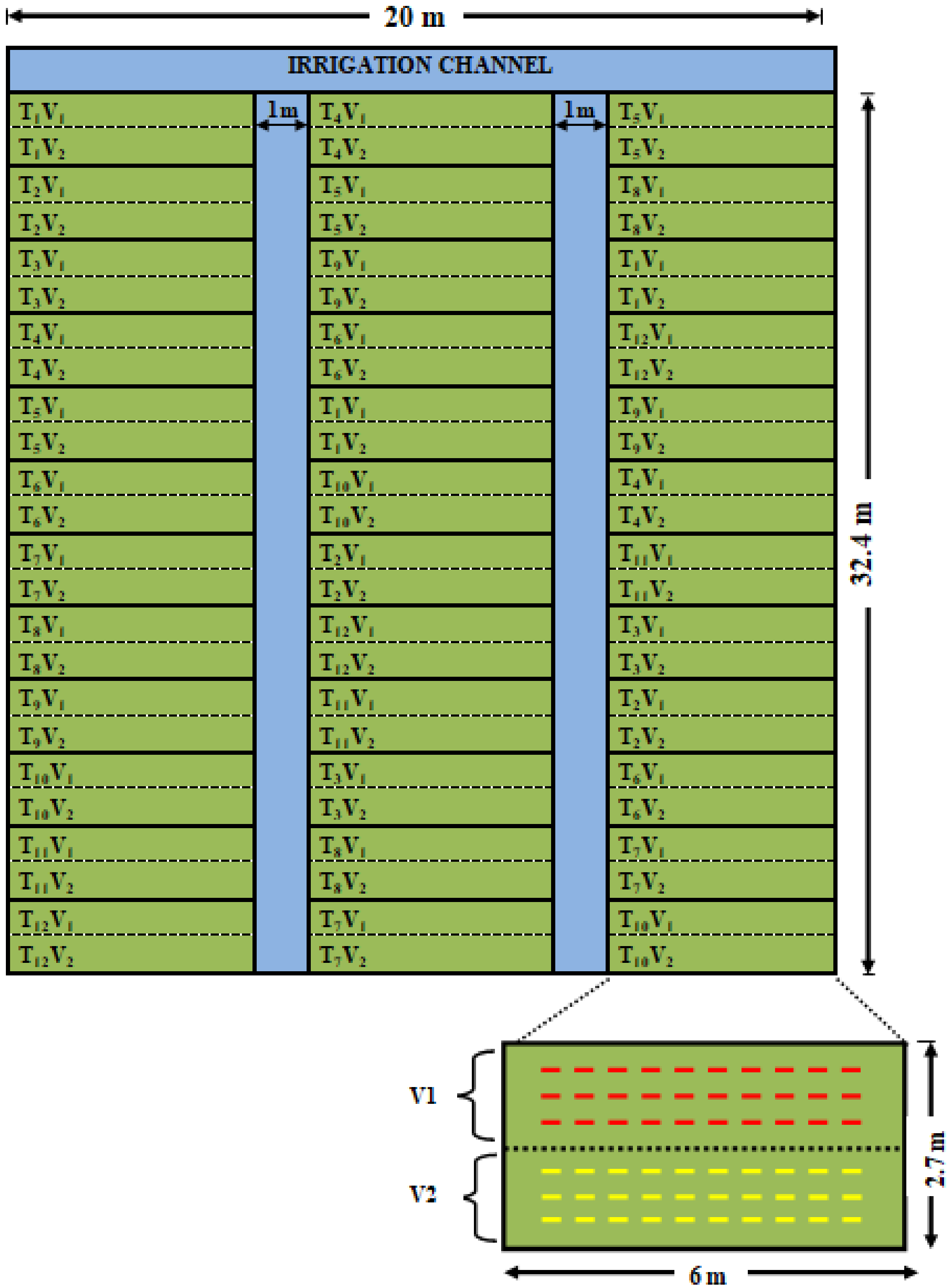
Table 3.5 Treatment Details

Factor A (Treatments with seaweed extract, Boron, Zinc: 12 foliar sprays)	
T_1	Control
T_2	Zn @ 0.2% (micronutrient)
T_3	B @ 0.2% (micronutrient)
T_4	*Ascophyllum nodosum* extract @ 0.2% (seaweed extract)
T_5	*Ascophyllum nodosum* extract @ 0.4% (seaweed extract)
T_6	Zn @ 0.2% + B @ 0.2%
T_7	Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%
T_8	Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%
T_9	B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%
T_{10}	B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%
T_{11}	Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%
T_{12}	Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%
Factor B (Varieties)	
V_1	Tomato no. 575
V_2	Yellow Jubilee

Table 3.6: Treatment combinations

S. NO.	TREATMENT	TREATMENT COMBINATION DETAILS
1	T_1V_1	(Control) + (Tomato no. 575)
2	T_1V_2	(Control) + (Yellow Jubilee)
3	T_2V_1	(Zn @ 0.2%) + (Tomato no. 575)
4	T_2V_2	(Zn @ 0.2%) + (Yellow Jubilee)
5	T_3V_1	(B @ 0.2%) + (Tomato no. 575)
6	T_3V_2	(B @ 0.2%) + (Yellow Jubilee)
7	T_4V_1	(ANSE @ 0.2%) + (Tomato no. 575)
8	T_4V_2	(ANSE @ 0.2%) + (Yellow Jubilee)
9	T_5V_1	(ANSE @ 0.4%) + (Tomato no. 575)
10	T_5V_2	(ANSE @ 0.4%) + (Yellow Jubilee)
11	T_6V_1	(Zn @ 0.2% + B @ 0.2%) + (Tomato no. 575)
12	T_6V_2	(Zn @ 0.2% + B @ 0.2%) + (Yellow Jubilee)
13	T_7V_1	(Zn @ 0.2% + ANSE @ 0.2%) + (Tomato no. 575)
14	T_7V_2	(Zn @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)
15	T_8V_1	(Zn @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)
16	T_8V_2	(Zn @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)
17	T_9V_1	(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)
18	T_9V_2	(B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)
19	$T_{10}V_1$	(B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)
20	$T_{10}V_2$	(B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)
21	$T_{11}V_1$	(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Tomato no. 575)
22	$T_{11}V_2$	(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)
23	$T_{12}V_1$	(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)
24	$T_{12}V_2$	(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)

3.4: Experimental field Layout



3.5 Field Operations

3.5.1 Nursery Raising and Transplanting

Two hybrid varieties named Tomato no. 575 and Yellow Jubilee were used for the study. Seedlings were raised in a high-tech polyhouse in pro trays using a mix of cocopeat, perlite, and vermiculite in a ratio 3:1:1 with complete supervision. These seedlings were transplanted in the main field, spaced at 60 × 45 cm in both experimental years. The transplanting was done in the evening, followed by immediate light irrigation, and gap fillings were done 5-7 days later. All cultural practices adopted were adhered to the guidelines provided by Punjab Agriculture University.

Table 3.7 Detailed calculated information of experimental cultural practices with date:

S.No.	PARTICULARS	YEAR 2022	Year 2
1	Field preparation	20-Mar-22	20-Feb-23
2	Pre transplant irrigation	22-Mar-22	21-Feb-23
3	Pre emergence herbicide	24-Mar-22	25-Feb-23
4	Transplanting	27-Mar-22	27-Feb-23
5	Irrigation	Weekly irrigations from transplanting till first picking and during harvesting irrigation was given at 9 -10 days interval.	
6	Treatment spray (3 sprays at 15 days interval after transplanting)	15 DAT - 11-April-22	15 DAT - 14-Mar-2023
		30 DAT - 28 April 22	30 DAT - 29-Mar-2023
		45 DAT - 13-May-22	45 DAT -13-Apr-2023
7	Earthing up	Earthing up was done twice first at 30 DAT and second at 40 days after first earthing up.	
8	Staking	Last fortnight of may	First fortnight of may
9	Data collection (30, 60, 90 DAT and at 1st harvest)	30 DAT - 27-Apr-22	30 DAT - 28-Mar-23
		60 DAT - 27-May-22	60 DAT - 27-Apr-23
		90 DAT - 26-Jun-22	90 DAT - 29-May-23
		At 1st harvest- 10-Jul-22	At 1st harvest- 8-Jun-23

3.5.2 Field Preparation

Deep ploughing one month prior to the transplanting was done and field was left for irradiation of harmful pathogens. A weak prior to the transplanting ploughing and levelling was done with the fertilizer application. 25 tons FYM (1/3rd of the given nitrogen dose *i.e.* 10.28 kg) and full dosage of phosphorous (14.52 kg) and potassium (10.5 kg) were applied as basal dose. After levelling of the soil the field was prepared according to FRBD layout consisting of three replications each containing 24 treatments. After the preparation of field pre irrigation was given to moist the soil prior to transplanting and pre-emergence herbicide Pendimethalin @ 3 ml/l was sprayed. After two days transplanting was done on moist soil followed by a light irrigation.

3.5.3. Fertilizer application

Fertilizer application was done in three splits one as a basal dose (as recommended by PAU N:P:K @ 150:62.5:62.5 kgha^{-1} during the field preparation which included 1/3rd of the total nitrogen required (5.30 kg Urea) and full dosage of phosphorous (7.91 kg DAP) and potassium (6.06 kg MOP). And rest of the nitrogen dose as urea was solicited in two splits, first after one month of transplanting (5.30 kg) and second during flower initiation (5.30 kg).

3.5.4. Treatment application

Treatment sprays were given three times each after 15 days interval between each application, which was 15 days after transplanting (DAT), 30 DAT and 45 DAT respectively. To achieve even distribution and complete coverage, the treatment spray was applied with a knapsack sprayer.

3.5.5. Weeding

Due to the application of pre emergence herbicide lesser weeds were found during the primary growth period, after the beginning of reproductive stage monthly weedings were done till the first harvest. Weeding was done manually by uprooting of weeds to maintain proper field condition without weed competition which helped in better growth.

3.5.6. Irrigation

Tomato crop requires adequate moisture in the soil for uniform growth; light irrigation is done after transplanting. Too much moisture in the soil can cause damage to the root and causes collar rot which can damage the crop. Frequent irrigations were given for better establishment. Due to the high temperature irrigation was given at weekly intervals till two weeks before the first harvest, during the time of harvestings it was given at an interval of 9-10 days to avoid excess moisture for better fruit quality. Water logging should be avoided.

3.5.7. Earthing up

Earthing up is an essential cultural practice in tomato for providing physical support to growing plants. This practice should be done after plant reaches the height of 30 cm or more. The earthing up was performed manually at 35 DAT, and the second earthing was done at 40 days after first earthing up by covering 5-6 cm height of the plant stem to provide support and better growth to root system.

3.5.8. Staking

Staking is an important practice used in tomato for better plant support and growth as the stem of tomato is not strong enough to withstand the weight of fruits during the fruit formation and to keep the branches up from the soil to avoid fungal disease in plants and fruits. It is usually done when the plant attains its primary growth and well established just before the start of flowering. Staking was done at 45 DAT using bamboo sticks using "Florida weave" method of staking which includes two sturdy staking sticks (strong enough to withstand the weight of 10 plants) on each sides of the row followed by weaving of the staking threads through the plants after each two plants and keep adding layers at a height of 20 cm from the previous layer as plant grows. It provides support to the plant from both sides, occupies less space, keep the branches up from the soil surface and makes the harvesting more easy.

3.6. Sampling

From each treatment subplot randomly selected five tomato plants were tagged for sampling and data collection for all the given parameters was collected from those five representative plants.

3.7. Observations recorded

Following observations were recorded from the five tagged tomato plants per plot for representing the growth, yield and quality.

3.7.1. Growth Parameters

3.7.1.1 Plant height (cm) (30, 60, 90 DAT and at 1st harvest)

Height of 5 randomly tagged plants in a plot was recorded individually from the base above the soil surface to top point of the plant with the help of measuring scale and the average plant height was expressed in cm. The heights were noted at 30, 60, 90 DAT and at 1st harvest.

3.7.1.2 Number of leaves (30, 60, 90 DAT and at 1st harvest)

Total number of leaves of 5 randomly selected tagged plants was counted individually and the mean was taken.

3.7.1.3 Number of primary branches (30, 60, 90 DAT and at 1st harvest)

Total no. of branches were counted from 5 tagged plants individually and overall average of primary branch count was calculated.

3.7.1.4 Leaf chlorophyll index (30, 60, 90 DAT and at 1st harvest)

Chlorophyll content of leaves of 5 randomly selected tagged plants was observed from random leaves using SPAD meter. Chlorophyll index plants was noted at 30, 60, 90 DAT and at 1st harvest.

3.7.1.5 Diameter of stem (cm) (30, 60, 90 DAT and at 1st harvest)

Stem diameter of five randomly selected tagged plants was observed individually using vernier calipers and average diameter of stem per plant was calculated and expressed in cm. stem diameter was noted at 30, 60, 90 DAT and at 1st harvest.

3.7.1.6 Days to flower initiation

Total no. of days beginning from transplanting till the day when the first sign of flowering will appear on plants in each plot was observed and noted as days to flower initiation.

3.7.1.7 Days to 50% flowering

No. of days beginning from transplanting till day when flowers appear on 50% of the plants in a plot was observed and noted as days to 50% flowering.

3.7.1.8 Days to fruit initiation

No. of days starting from transplanting to the day when the first sign of fruit formation appeared on plants in each plot was observed and noted as days to fruit initiation.

3.7.1.9 Days to first picking

Number of days from transplanting to the day when the first picking of crop took place was observed and noted as days to first picking.

3.7.2. Yield parameters

3.7.2.1 Average fruit weight (g)

Weight from five randomly picked fruits from tagged plants was observed using a weighing balance and the average was calculated and noted as average fruit weight in grams.

3.7.2.2 Average polar fruit diameter (cm)

Polar diameter of five fruits from tagged plants was observed using a vernier calipers and the average was calculated and noted as average polar fruit diameter which was noted in cm.

3.7.2.3 Average equatorial fruit diameter (cm)

Equatorial diameter of 5 randomly picked fruits from tagged plants was observed using a vernier calipers and the average was calculated and noted as average equatorial fruit diameter which was noted in cm.

3.7.2.4 Number of locules

Five randomly picked fruits from tagged plants were cut and number of locules present in each fruit was manually counted and the calculated average of it was noted as number of locules.

3.7.2.5 Number of fruits per plant

Total no. of fruits in tagged plants was noted individually and their mean was taken as no. of fruits/plant.

3.7.2.6 Average yield per plant (kg)

Total yield from each tagged plant was taken individually using a weighing balance and the average of it was noted as average yield per plant which was expressed in kgs.

3.7.2.7 Total marketable yield (q/ha)

Total marketable yield in q/ha was calculated manually using the average yield per plant and noted as total marketable yield per hectare which was expressed in quintals.

3.7.3. Biochemical parameters

3.7.3.1 Total soluble solids (°Brix)

TSS is the concentration of dissolved solids in a liquid or juice, expressed as a percentage or °Brix. These solids are primarily composed of sugars, organic acids, and other soluble chemicals present in the sample. In order to assess the sweetness and flavor profile of fruits, vegetables, juices, and other related goods, TSS measurement is frequently employed in the agricultural and food industries. The simplest way to determine TSS is with a refractometer, which determines the refractive index of a sample. The concentration of dissolved solids in the sample influences the refractive index, which allows the estimation of TSS. The measurement is expressed in °Brix, which is the concentration of sucrose in an aqueous solution (1 ºBrix = 1 g sucrose / 100 g solution = 1%). This experiment was carried out using a digital refractometer. (Zoecklein *et al.*, 2013)

Procedure

- Fresh sample of ripe tomato fruit was taken and crushed using pestle-mortar.
- Crushed slurry was taken and squeezed to obtain the juice using muslin cloth.
- A drop of the liquid extract obtained was poured on the prism.
- The reading on the digital scale was recorded and expressed as °Brix.

3.7.3.2 Total soluble sugar (mg/g)

The total soluble sugar concentration is aggregate of all sugar types found in the fruit, such as sorbitol, sucrose, fructose and glucose (Quilot *et al*., 2004). In fleshy fruits, the quantity of soluble sugars is critical in determining fruit quality. It has a direct impact on the sweetness fruits and indirect impact on the qualities of processed products. The total soluble sugars in following experiment were estimated using the method given by Sadasuvam and Manickam, 1992 which is mentioned below:

Reagents

- 80% Ethanol
- Anthrone reagent (anthrone 200 mg was dissolved in 100ml ice cold 95% sulphuric acid) freshly prepared before use.

Procedure

- Homogenize 100mg of sample with 80% ethanol till the tissues fully digested, after homogenizing centrifuge the sample at 5000 rpm for 15 minutes and after that make the volume of extract up to 100 ml with distilled water.
- Pipette out 1ml of the extract in a test tube, add 6ml of anthrone reagent to it and keep it for 10 minutes in a boiling water bath. Then it was allowed to cool under running water.
- Keep it for a few minutes. After some time a blue color will develop.
- Measure the intensity of blue color at 620 nm with a spectrophotometer.

Calculations

$$\text{Total soluble sugar (mg)} = \frac{\text{OD of test}}{\text{OD of standard}} \times 100$$

3.7.3.3 Reducing sugar (Folin Wu method)

The reducing sugar content (RSC) of plant samples might vary depending on factors such as genotype, plant age, soil quality, geographical location, climate, cultivation techniques, and abiotic stressors (Arsenault *et al.*, 2010). Both reducing and non-reducing sugars are essential components of key metabolic pathways in plants, helping to synthesise secondary metabolites that improve the therapeutic properties of plants (Halford *et al.*, 2011). The reducing sugars in following experiment were estimated using Folin wu method and amount of non reducing sugars were obtained by subtracting reducing sugars from total soluble sugars, which is mentioned below:

Reagents

- **Phospho Molybdic Acid** Take a 1l beaker and add 200ml of 10% NaOH solution, 200ml of distilled water, 35g molybdic acid, 5g sodium tungstate mix them well and boil vigorously for 20-40 minutes. Let the solution cool and dilute it to 350ml. Add 125ml of orthophosphoric acid in it and dilute to make it 500ml.

- **Alkaline Copper solution** Take a beaker add 400ml water to it and dissolve 40g of Na_2CO_3 in it. Transfer this solution to a volumetric flask of 1l. Dissolve 7.5g of tartaric acid in this solution and then add 4.5 g $CuSO_4.5H_2O$, mix it and dilute to 1l. (use supernatant in case any sediments formed)

Procedure

- Take a test tube add 2ml of experimental broth into it and add 2ml of alkaline copper sulphate to it.
- Keep the test tube in boiling water bath till precipitate appears (at least 10 minutes).
- Let it cool under running water and add 2ml of phosphomolybdic acid to it and make up the volume to 25ml with distilled water.
- Read the absorbance of blue color developed at 420nm.

Calculations:

$$\text{Reducing sugar (mg)} = \frac{\text{OD of test}}{\text{OD of standard}} \times 100$$

3.7.3.4 Non-Reducing Sugar

- Total Non-Reducing Sugar(mg) = Total Soluble Sugar(mg) – Total Reducing Sugar(mg)

3.7.3.5 Total Phenol content (mg/g)

Total Phenolic Content (TPC) estimation is a method used to quantify the phenolic content of materials. Plant phenolic compounds have redox characteristics, which allow them to function effectively as antioxidants (Baba and Malik, 2015). These molecules have critical roles in plant defence mechanisms against ultraviolet (UV) rays, diseases, parasites, and predators, as well as contributing to plants' bright colors. Phenolic compounds are found in all plant organs and constitute an essential constituent of the human diet. Phenolic chemicals play an important role in human physiological defence responses, including anti-aging, anti-inflammatory, antioxidant, and anti-proliferative properties (Lin *et al.*, 2016). Total phenolic content in the current experiment was estimated using the method introduced by Mahadevan and Shridhar, 1982 which is mentioned below in detail:

Reagents

- 80% ethanol
- Folin-Ciocalteu reagent (FCR)
- 20% Na_2CO_3

Procedure

- 500mg of the sample was taken and crushed in 3ml of ethanol (80%), then centrifuged (10,000 rpm for 20 min).
- After centrifugation residue and supernatant were separated. Supernatant was saved and residue was washed again with 2ml of 80% ethanol and supernatant was saved. Both the supernatant were pooled and the volume was made up to 5ml by adding 80% ethanol.
- 1ml of above supernatant was taken in a test tube, and 1ml of Folin-Ciocalteu Reagent and 2ml of sodium carbonate were added into it.

- The absorbance was recorded at 650nm

Calculations

$$mg gallic acid/g = \frac{\text{O. D} \times \text{standard curve factor} \times \text{volume made up} \times \text{dilution}}{\text{Aliquant taken} \times \text{wt. of sample}}$$

3.7.3.6 Total soluble Protein content (mg/g)

Total soluble protein (TSP) in plants refers to the total amount of proteins that can be isolated and dissolved in a given buffer or solvent. This parameter is important in determining plant quality and serves as a great resource for understanding plant physiology. TSP is essential for a variety of plant functions, including nitrogen supply, growth regulation, immune response activation, and inflammation modulation. As a result, assessing TSP levels is critical for understanding both plant quality and physiological dynamics. Total soluble protein in the current experiment was estimated using the method introduced by Bradford, MM. 1976 which is mentioned below in detail.

Reagents

a) Sodium phosphate buffer (pH 7.4)

- **Solution A:** Dissolve 13.9g of 0.1M sodium dihydrogen phosphate (NaH_2PO_4) in distilled H_2O and make the volume up to 1l.

- **Solution B:** Dissolve 26.82g of 0.1M disodium hydrogen phosphate (Na_2HPO_4) in distilled H_2O and make the volume up to 1l.

For making sodium phosphate buffer mix the above solution A and B in the ratio of 19:81 and adjust the final pH using pH meter.

b) Dye

- 100 mg of G 250 Coomassie brilliant blue is dissolved in 50ml of ethanol (95%). concentrated ortho-phosphoric acid (100 ml) was further added into it and the final volume was made 200ml by adding distilled water.

- Dilute the concentrated dye with distilled water in ration of 1:4 before using

Procedure

- 100 mg of tomato fruit pulp was taken and crushed with mortar and pestle by adding 10ml of cold extraction till the fine slurry is made. During crushing mortar was kept in a ice container.

- Centrifuged the prepared sample at 15,000 rpm for 15 minutes and collect the supernatant.

- Take 0.2ml of crude protein extract (supernatant collected after centrifugation), 5ml diluted dye, 0.8 ml of distilled water and mix well. Allow it to develop the color for 5 minutes (not more than 30 minutes). The red color of dye will turn blue on binding to protein.

- Read the absorbance of it at 595nm with the help of spectrophotometer.

Calculations

To create the standard curve, 0.1–1.0 ml of bovine serum albumin (BSA) was used. By comparing the absorbance value on the y-axis to the concentration of sugar in solution on the x-axis, a standard curve was created. Using a standard curve and the absorbance value, the concentration of total soluble protein was determined.

3.7.3.7 Ascorbic acid content (%)

Ascorbic acid, often known as vitamin C, is a multifaceted chemical essential for plant growth, development, and stress resistance. Its role as an effective antioxidant is essential in protecting cells from damage caused by oxidative stress generated by reactive oxygen species (ROS) (Akram *et al*., 2017). Ascorbic acid is involved in a variety of biological activities, including photosynthesis, cell division, growth, senescence, and flowering. Its concentration in plant tissues varies based on plant species, tissue type, and environmental conditions. Ascorbic acid in tomato fruit in the current experiment was estimated using redox titration method which is mentioned below in detail.

Reagents

1. Iodine solution preparation (0.005 mol L^{-1}).

- Add 2 grams of KI and 1.3g iodine to a 100 m beaker.
- Dissolve the iodine by adding distilled water, put the iodine solution into a 1L volumetric flask, being careful to rinse out any remaining solution with distilled water.
- Add distilled water to the solution until it reaches the 1L mark.

2. Starch indicator solution (0.5%).

- Wt. 0.25g of soluble starch and add it into 50ml nearly boiling water.
- Stir to dissolve and cool it before using.

Procedure

Sample preparation

- Take 100 grams of the sample and crush it in mortar and pestle. Add 10ml distilled water several times while crushing the samples.
- Finally strain the crushed sample pulp with muslin cloth.
- The pulp is rinsed with 10 ml water portions, collecting all the filtrate of washing in volumetric flask.

- Finally make the filtered solution up to 100ml with distilled water.

Titration

- Pipette out 20ml of the sample prepared into a 250 ml conical flask and add 150ml of distilled water into it. Then 1ml of starch indicator solution is added to it.
- Titrate the sample against 0.005 mol L^{-1} iodine solution until the first permanent trace of blue-black color appears (due to starch-iodine complex).
- Repeat the titration with further samples until concordant results are obtained.

Calculation

Ascorbic acid (%) =

$$\frac{\text{Titre value} \times \text{dye factor} \times \text{volume make up}}{\text{Aliquot of extract taken for estimation} \times \text{volume of sample taken}} \times 100$$

3.7.3.8 Total carotenoids (mg/g)

Carotenoids are organic colours produced by several species, including plants, algae, bacteria, archaea, and fungi. They are responsible for the bright yellow, orange, and red colours found in fruits and vegetables including tomatoes, carrots, and pumpkins. Carotenoids have a variety of functions in plants, including protection against oxidative stress, promoting photosynthesis, and acting as precursors for the synthesis of plant hormones. In humans, carotenoids act as antioxidants, combating inflammation and strengthening the immune system (Maoka T, 2020). Total carotenoids in the current experiment were estimated using the method introduced by Jensen A. (1978) which is mentioned below in detail.

Reagents

- 85% acetone.

Procedure

- 1g sample was homogenized in 10 ml of 85% acetone.
- After homogenizing centrifuge the homogenized suspension at 6500 rpm for 10 minutes. Cool the centrifuged suspension. Discard the supernatant and save the residue.
- Add 3ml of 85% acetone in the residue and do repeated freezing and thawing until the residue becomes colorless.
- Measure its volume and make the final volume of extract up to 10 ml with 85% acetone.
- Read the optical density of the extract at 450nm using 85% acetone as blank.

Calculations

Amount of carotenoid in 100mg plant tissue =

$$\frac{4 \times \text{OD value} \times \text{total volume of sample}}{\text{weight of plant sample}}$$

3.7.3.9 Lycopene estimation (mg/kg fresh weight)

Lycopene, a carotenoid pigment found in a variety of foods, most notably tomatoes, serves as the principal dietary source. Lycopene is well-known for its strong antioxidant capabilities and is one of the most effective dietary carotenoids. It is associated with a variety of health benefits, such as improved heart health, sunburn protection, and cancer risk reduction, emphasizes its importance. Lycopene appears as an important ingredient with potential health benefits, abundant in a wide variety of foods, including tomatoes and tomato-based products (Story *et al.,* 2010). Lycopene content in the current experiment were estimated using the low hexane extraction method introduced by Fish *et al.,* 2002 which is mentioned below in detail.

Solvents

Acetone and hexane are HPLC grade from Fisher. The ethanol used is 200 proof absolute ethanol. Mix in a ratio of two parts hexane to one part acetone and one part ethanol.

Procedure

- Starting with well homogenized tomato juice (prepared under vacuum to minimize the introduction of air bubbles), use a 100 µL. micropipettor to take a sample. After drawing the sample into the pipetter, wipe any tomato juice from the outside of the glass bore with a kimwipe then inspect the pipetter to be sure no large air bubbles have been included. Dispense the sample into a 20 125 screw cap tube. Also prepare several blank samples with 100 µL water instead of tomato pulp.

- Add 8.0 ml of hexane:ethanol:acetone (2:1:1) using a repipetter. Cap and vortex the tube immediately then incubate out of bright light.

- After at least 10 minutes, or as long as several hours later, add 1.0 ml water to each sample and vortex again.

- Let samples stand 10 minutes to allow phases to separate and all air bubbles to disappear.

- Rinse the cuvette with the upper layer from one of the blank samples. Discard, then use a fresh blank to zero the spectrophotometer at 503 nm. Determine the A_{503} of the upper layers of the lycopene samples.

Calculations Lycopene levels in the hexane extract was calculated according to

Lycopene (mg/kg fresh wt.) =

$$\frac{\text{A503} \times \text{molecular wt. of lycopene} \times \text{volume of mixed solvent} \times \text{volume ratio of the upper layer}}{weight\ of\ fresh\ sample \times extinction\ coefficient\ for\ lycopene\ in\ hexane}$$

Molecular wt.of Lycopene = 537 g/mol

Volume of mixed solvent = 8 ml

Volume ratio of the upper layer = 0.55 ml

Weight of fresh sample = 0.10 g

Extinction coefficient for lycopene in hexane = 172mM^{-1}

3.7.4 Economics

3.6.5.1 Total cost of cultivation (₹/ha)

Total cost (₹/ha) for tomato cultivation was evaluated based on the input prices during the crop year (Appendix II). All input expenses, including manpower, capital, seed, fertilizer, and pesticides, are included in the total cost. Irrigation water, weed control techniques, and application fees were the variable portion of the overall cost.

3.6.5.2 Gross returns (₹)

The gross returns (₹/ha) were calculated on the basis of local wholesale market price of tomato in the experimental year 2022, which was ₹12 for Tomato no. 575 and ₹17 for Yellow Jubilee, whereas ₹10 for Tomato no. 575 and ₹15 for Yellow Jubilee in the experimental year 2023

Gross return = Yield of crop (kg) × Market price of the crop (₹/kg)

3.6.5.3 Net returns (₹)

The net returns were obtained by subtracting cost of cultivation from gross income.

$$\text{Net income } (₹\ ha^{-1}) = \text{Gross income } (₹\ ha^{-1}) - \text{Cost of cultivation } (₹\ ha^{-1}).$$

3.6.5.4 Benefit cost ratio (B:C)

The benefit-cost ratio (B:C) reflects the returns on investment per rupee. It was computed by dividing gross returns by the total cost of cultivation.

$$\text{Benefit cost ratio (B:C)} = \frac{\text{Net Return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

3.8. Statistical analysis

The following statistical analysis has been performed on the records that were obtained with respect for both qualitative and quantitative characteristics.

- **ANOVA (Panse and Sukhatme, 1985)**

As shown by Panse and Sukhatme (1985), the records based on the average of each plant chosen for surveillance were statistically examined to determine the overall variability of the material being studied for each character and for each population. The information received in respect of studied quantitative as well as qualitative traits has been undertaken for the following statistical analysis for factorial randomized block design with Duncan test using R software.

Mean: The mean for each character was calculated by the method given below:

$$\text{Grand mean } (\overline{X}) = \frac{\sum Xi}{N}$$

- **Range:** The range for each character was obtained by taking the minimum and maximum values for each trait within population.

Analysis of variance–

According to Panse and Sukhatheme's study from 1985, "analysis of variance" was applied to the data recorded from the set of findings for each parameter.

Source of variation	DF	SS	MSS	"F" Value	"F"table at 5%
Replication	(r-1)	RSS	RMS	RMS/EMS	
Treatment	(TV-1)	TSS	TMS	TMS/EM	
Treatment spray(T)	(T-1)	(T)SS	(T)MS	(T)MS/EMS	
Varieties(V)	(V-1)	(V)SS	(V)MS	(T×V)MS/EMS	
Interaction(N×M)	(T-1)(V-1)	(T×V)SS	(T×V)MS	(T×V)MS/EMS	
Error	(r-1)(TV-1)	ESS	EMS		
Total	**(rTV-1)**				

Calculation of the importance of the variation in treatment was done using Critical difference (CD) the provided formula (Panse and Sukatme, 1985).

i. CD for varieties (V)-

$$\sqrt{\frac{Er(EMS)\times 2}{r\times(N=15)}}\times t_{5\%}$$

Where,

T = treatment spray

T ='t' T value at error df

r = Number of replication

PLATE 1: NURSERY RAISING

YEAR 2022

Preparation of growing media

Seed sowing

Irrigation

Hardening of seedlings

YEAR 2

Filling of portrays

Irrigation

Germination

Hardening of seedlings

PLATE 2: Field Preparation and Transplanting

YEAR 2022 | **YEAR 2**

Field preparation

Pre emergence herbicide application

Pre emergence herbicide application

Pre transplanting irrigation

Transplanting

Transplanting

Post transplanting irrigation

Post transplanting irrigation

PLATE 3: Irrigation at different stages

YEAR 2022	YEAR 2

Post transplanting

Post transplanting

At vegetative growth stage

At vegetative growth stage

At reproductive growth stage

At reproductive growth stage

PLATE 4: Cultural Practices

YEAR 2022 | **YEAR 2**

Weeding

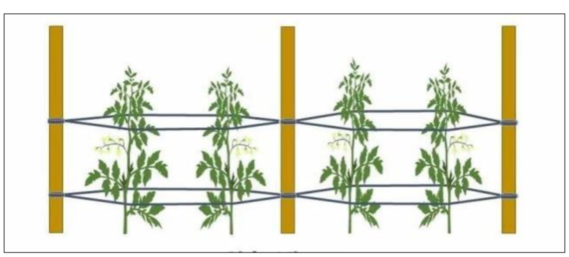
Weeding

Earthing up

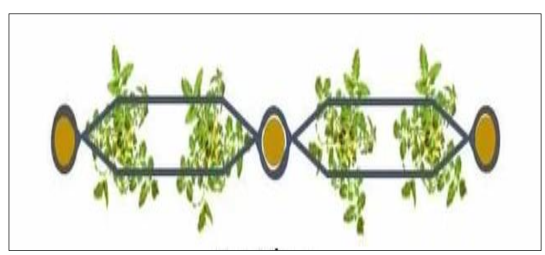
Earthing up

Staking

Staking



(a)



(b)

"Florida weave" Staking method: Side view (a), Top view (b)

PLATE 5: Insect Pest Management

YEAR 2022 | **YEAR 2**

Infestation at vegetative growth stage

Infestation at fruiting stage

Infestation at fruiting stage

Disposal of infested fruits

Insecticide applied

Insecticide applied

PLATE 6: Treatment Application

YEAR 2022 | **YEAR 2**

15 DAT

15 DAT

30 DAT

30 DAT

45 DAT

45 DAT

PLATE 7: Data Collection

YEAR 2022

Plant height

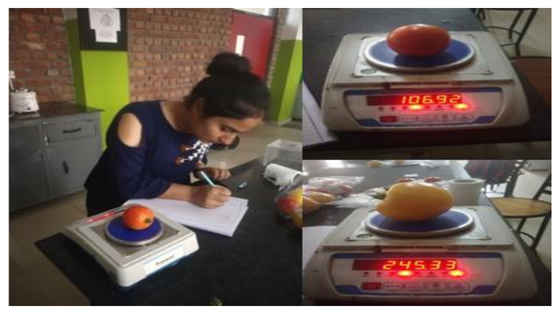
Leaf chlorophyll index

Stem diameter

Yield from each plot

YEAR 2

Number of fruits per plant



Fruit weight

No. of locules

Yield from each plot

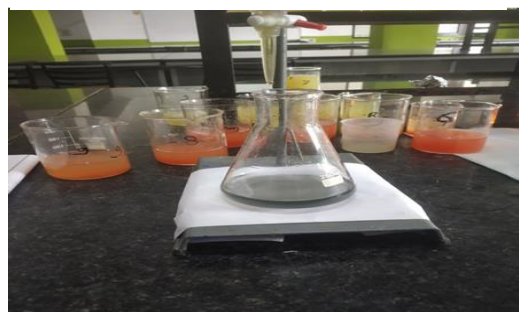
PLATE 8: Biochemical analysis

YEAR 2022 | **YEAR 2**

TSS

Total soluble sugar analysis

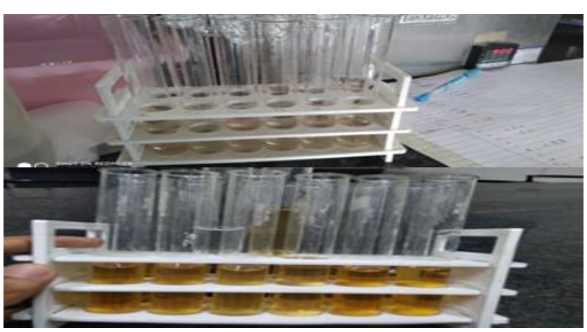
Protein estimation



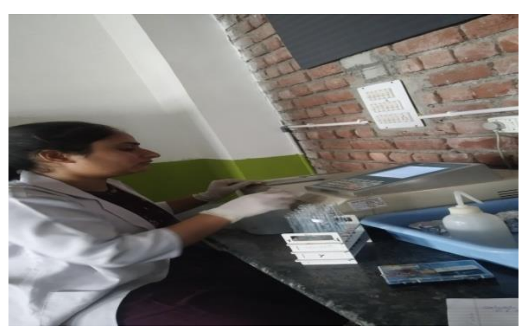
Ascorbic acid estimation

Spectrophotometric analysis for carotenoids

Lycopene estimation

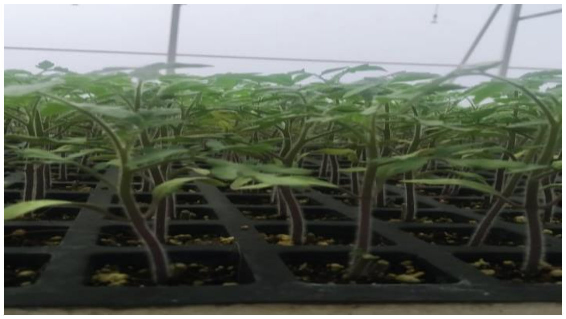


Lycopene estimation



Spectrophotometric analysis

PLATE 9: Different Growth Stages YEAR 2022



Seedlings

Transplanting

Primary branching

Secondary branching

Flowering

Fruiting

Harvesting stage

Harvesting stage

PLATE 10: Different Growth Stages Year 2

Seedlings

Transplanting

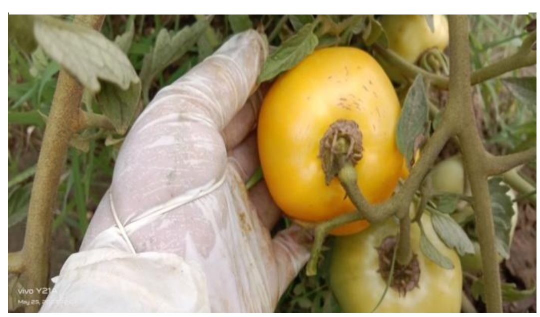
Primary branching

Secondary branching

Flowering

Fruiting

Harvesting stage



Harvesting stage

PLATE 11: Overview of Field

YEAR 2022

YEAR 2

PLATE 12: Treatment comparison

Control

Treatment 12

CHAPTER IV

RESULTS AND DISCUSSION

The findings of the field study titled **"Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)"** conducted during the years 2022 and 2023 at the Horticulture Research Farm, Lovely Professional University, are presented in this chapter. The observations pertaining to growth, yield and quality characters of tomato along with economic analysis recorded while conducting the experiment were statistically analyzed and have been interpreted in this chapter with aid of tables and figures as follows

4.1 Effect of foliar application of micronutrients and seaweed extract on the growth of tomato

Plant growth parameters refer to the various measurable attributes that describe the growth and development of a plant. They provide quantitative measures of varied plant growth aspects and development, enabling analysis of the contribution of applied treatments in overall plant growth. Application of seaweed extract (*Ascophyllum nodosum*) in combination with micronutrients (Zinc and Boron) showed significant positive results for both the studied varieties as compared to control.

4.1.1 Plant height (cm)

Height of a plant is a cruicial element of crop growth parameters, observation for which were taken at a time interval of 30 days (30, 60, 90 DAT and at 1st harvest). The results for plant height variation by the foliar application of seaweed extract and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.1, 4.2, 4.3 and 4.4. The data described in the table confirms that the application of ANSE and micronutrients in combination significantly transformed the plant height of both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 1-4

a) Plant height at 30 DAT (cm)

According to the results obtained for the treatments the maximum height for a plant at 30 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 43.17 cm, 54.26 cm and 48.72 cm for the year 2022, 2023 and pooled mean respectively, whereas the least height for plant at 30 DAT was observed in T_1 (control) for the year 2021-22 (22.94 cm), 2022-23 (28.83 cm) and the pooled mean (25.88 cm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher plant height at 30 DAT *i.e.* 2021-22 (34.99 cm), 2022-23 (43.97 cm) and pooled mean (39.48 cm), as compared to V_1 (Tomato no. 575) *i.e.* 34.05 cm, 42.78 cm and 38.41 cm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the plant height at 30 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 44.05 cm, 55.36 cm and 49.71 cm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) in the variety Tomato no. 575 (V_1) *i.e.* 42.29 cm, 53.15 cm and 47.72 cm for the year 2022, 2023 and the pooled mean respectively. Whereas least height for plant at 30 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 22.84 cm, 28.70 cm and 25.77cm for the year 2022, 2023 and the pooled mean followed by T_1V_2 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 23.04 cm, 28.96 cm and 26.00 cm for the year 2022, 2023 and the pooled mean respectively.

Table 4.1: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on plant height (cm) of tomato at 30 DAT

PLANT HEIGHT (cm) 30 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	V1
T1	22.84	23.04	**22.94**	28.70	28.96	**28.83**	25.77	26.00	**25.88**
T2	25.98	27.88	**26.93**	32.64	35.03	**33.84**	29.31	31.46	**30.38**
T3	28.08	29.86	**28.97**	35.29	37.52	**36.41**	31.69	33.70	**32.69**
T4	38.20	40.52	**39.36**	48.00	50.91	**49.46**	43.10	45.72	**44.41**
T5	40.26	41.31	**40.79**	50.59	51.92	**51.25**	45.43	46.61	**46.02**
T6	31.54	30.96	**31.25**	39.64	38.90	**39.27**	35.59	34.93	**35.26**
T7	33.23	31.13	**32.18**	41.75	39.11	**40.43**	37.48	35.12	**36.30**
T8	34.44	32.22	**33.33**	43.28	40.48	**41.88**	38.86	36.35	**37.61**
T9	34.25	37.90	**36.07**	43.04	47.61	**45.33**	38.64	42.75	**40.70**
T10	35.87	38.81	**37.34**	45.07	48.77	**46.92**	40.47	43.79	**42.13**
T11	41.56	42.22	**41.89**	52.23	53.06	**52.64**	46.90	47.64	**47.27**
T12	42.29	44.05	**43.17**	53.15	55.36	**54.26**	47.72	49.71	**48.72**
Mean V	**34.05**	**34.99**		**42.78**	**43.97**		**38.41**	**39.48**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.634	0.222	0.816	0.286	0.725	0.254
(V)	0.259	0.091	0.333	0.117	0.296	0.104
(T × V)	0.897	0.314	1.154	0.404	1.025	0.359

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

b) Plant height at 60 DAT (cm)

According to the results obtained for the treatments the maximum height for plants at 60 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 73.78 cm, 92.72 cm and 83.25 cm for the year 2022, 2023 and pooled mean respectively, whereas the least height for plant at 60 DAT was observed in T_1 (control) for the year 2021-22 (56.34 cm), 2022-23 (70.80 cm) and the pooled mean (63.57 cm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher plant height at 60 DAT *i.e.* 2021-22 (71.49 cm), 2022-23 (89.83 cm) and pooled mean (80.66 cm), as compared to V_1 (Tomato no. 575) *i.e.* 60.16 cm, 75.60 cm and 67.88 cm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the plant height at 60 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 80.90 cm, 101.67 cm and 91.29 cm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 79.85 cm, 100.34 cm and 90.10 cm for the year 2022, 2023 and the pooled mean respectively. Whereas least height for plant at 60 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 50.24 cm, 63.14 cm and 56.69 cm for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 53.95 cm, 67.80 cm and 60.87 cm for the year 2022, 2023 and the pooled mean respectively.

Table 4.2: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on plant height (cm) of tomato at 60 DAT

PLANT HEIGHT (cm) 60 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	50.24	62.43	**56.34**	63.14	78.45	**70.80**	56.69	70.44	**63.57**
T2	53.95	63.61	**59.02**	67.80	79.93	**74.17**	60.87	71.77	**66.60**
T3	54.43	68.62	**61.28**	68.40	86.22	**77.01**	61.42	77.42	**69.15**
T4	63.70	72.45	**68.07**	80.04	91.03	**85.54**	71.87	81.74	**76.80**
T5	63.61	76.47	**70.04**	79.93	96.09	**88.01**	71.77	86.27	**79.02**
T6	55.00	69.54	**62.27**	69.12	87.39	**78.26**	62.06	78.46	**70.26**
T7	58.90	68.41	**63.66**	74.02	85.98	**80.00**	66.46	77.19	**71.83**
T8	62.87	71.66	**67.27**	79.01	90.06	**84.53**	70.94	80.86	**75.90**
T9	63.42	72.48	**67.95**	79.69	91.08	**85.38**	71.55	81.78	**76.67**
T10	63.76	71.39	**67.58**	80.12	89.71	**84.92**	71.94	80.55	**76.25**
T11	65.41	79.85	**72.63**	82.19	100.34	**91.27**	73.80	90.10	**81.95**
T12	66.65	80.90	**73.78**	83.76	101.67	**92.72**	75.20	91.29	**83.25**
Mean V	**60.16**	**71.49**		**75.60**	**89.83**		**67.88**	**80.66**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.562	0.197	0.711	0.249	0.632	0.221
(V)	0.229	0.08	0.29	0.102	0.258	0.09
(T × V)	0.795	0.278	1.006	0.352	0.894	0.313

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

c) Plant height at 90 DAT (cm)

According to the results obtained for the treatments the maximum height for plant at 90 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 97.99 cm, 124.99 cm and 112.22 cm for the year 2022, 2023 and pooled mean respectively, whereas the least height for plant at 90 DAT was observed in T_1 (control) for the year 2021-22 (70.49 cm), 2022-23 (89.91 cm) and the pooled mean (80.72 cm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher plant height at 90 DAT *i.e.* 2021-22 (98.69 cm), 2022-23 (125.88 cm) and pooled mean (113.02 cm), as compared to V_1 (Tomato no. 575) *i.e.* 71.48 cm, 91.18 cm and 81.86 cm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the plant height at 90 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 108.44 cm, 138.32 cm and 124.19 cm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 106.78 cm, 136.20 cm and 122.29 cm for the year 2022, 2023 and the pooled mean respectively. Whereas least plant height at 90 DAT was found in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 53.80 cm, 68.62 cm and 61.61 cm for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 64.42 cm, 82.17 cm and 73.78 cm for the year 2022, 2023 and the pooled mean respectively.

Table 4.3: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on plant height (cm) of tomato at 90 DAT

PLANT HEIGHT (cm) 90 DAT									
	YEAR 2022			**YEAR 2023**			**POOLED**		
	V1	**V2**	**Mean T**	**V1**	**V2**	**Mean T**	**V1**	**V2**	**Mean T**
T1	53.80	87.17	**70.49**	68.62	111.19	**89.91**	61.61	99.83	**80.72**
T2	64.42	90.74	**77.58**	82.17	115.74	**98.96**	73.78	103.92	**88.85**
T3	65.57	93.58	**79.58**	83.64	119.37	**101.50**	75.09	107.18	**91.13**
T4	77.50	102.50	**90.00**	98.86	130.74	**114.80**	88.76	117.39	**103.08**
T5	78.63	104.54	**91.59**	100.29	133.34	**116.82**	90.05	119.73	**104.89**
T6	66.33	94.67	**80.50**	84.62	120.75	**102.68**	75.97	108.42	**92.20**
T7	68.67	96.43	**82.55**	87.59	123.01	**105.30**	78.64	110.44	**94.54**
T8	69.50	98.37	**83.93**	88.64	125.47	**107.06**	79.59	112.66	**96.13**
T9	71.99	99.50	**85.74**	91.82	126.91	**109.37**	82.45	113.95	**98.20**
T10	73.51	101.50	**87.51**	93.76	129.47	**111.61**	84.19	116.25	**100.22**
T11	80.32	106.78	**93.55**	102.45	136.20	**119.32**	91.99	122.29	**107.14**
T12	87.53	108.44	**97.99**	111.65	138.32	**124.99**	100.25	124.19	**112.22**
Mean V	**71.48**	**98.69**		**91.18**	**125.88**		**81.86**	**113.02**	
Factors	**CD**	**SEm±**		**CD**	**SEm±**		**CD**	**SEm±**	
(T)	0.593	0.208		0.812	0.284		0.703	0.246	
(V)	0.242	0.085		0.331	0.116		0.287	0.1	
(T × V)	0.839	0.294		1.148	0.402		0.994	0.348	

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

a) Plant height at 1st harvest(cm)

According to the results obtained for the treatments the utmost plant height at 1st harvestwas obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 102.85 cm, 128.56 cm and 115.70 cm for the year 2022, 2023 and pooled mean respectively, whereas the least plant height at 1st harvestwas observed in T_1 (control) for the year 2021-22 (78.72 cm), 2022-23 (98.59 cm) and the pooled mean (88.05 cm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher plant height at 1st harvest*i.e.* 2021-22 (103.84 cm), 2022-23 (129.80 cm) and pooled mean (116.82 cm), as compared to V_1 (Tomato no. 575) *i.e.* 76.14 cm, 95.20 cm and 85.67 cm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the plant height at 1st harvestwere obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 112.35 cm, 140.44 cm and 126.39 cm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 112.19 cm, 140.24 cm and 126.22 cm for the year 2022, 2023 and the pooled mean respectively. Whereas least height for plant at 1st harvestwas observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 59.52 cm, 74.79 cm and 67.15 cm for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 67.50 cm, 84.37 cm and 75.93 cm for the year 2022, 2023 and the pooled mean respectively.

The maximum plant height observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. Seaweed extracts are rich in bioactive compounds favouring better plant development. The presence of Auxins and cytokinins in seaweed extract might have affected the metabolism of plants, thereby inducing better growth. Higher concentration of seaweed extract was found to be more beneficial than the lesser concentration of seaweed extract. The results obtained were found in accordance with the results obtained by Ali *e.t al.*, 2018 in tomato when applied with Ascophllum nodosum extract at different concentrations similar results were also obtained by Ali *et al.*, 2016 and Sasikala *et al.*, 2016. Zinc and boron are essential micronutrients which are also involved in hormone synthesis and regulation in plants. These hormones, such as gibberellins and auxins, play a crucial role in promoting cell division and elongation, which directly influence the plant height. Sandilya *et al.*, 2023 also noted improved plant growth with the combined application of boron and zinc. Similar results for significant increase in plant height were also reported by Khatri *et al.*, 2022, Ahmed *et al.*, 2021 and Xu *et al.*, 2021. As for the varieties maximum plant height was observed in variety V_2 in all growth stages possible reason for which could be the varietal diversity and different growth habits of different varieties. Alike results were found by Roy and Munir, 2020 and Sanjida *et al.*, 2020 when different tomato lines were observed for their growth and yield potential.

The maximum plant height at all observation stages was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety yellow Jubilee.

Table 4.4: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on plant height (cm) of tomato at 1st harvest

PLANT HEIGHT (cm) AT 1st HARVEST									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	59.52	97.92	**78.72**	74.79	122.39	**98.59**	67.15	110.15	**88.65**
T2	67.50	95.31	**81.41**	84.37	119.14	**101.76**	75.93	107.23	**91.58**
T3	68.42	95.78	**82.10**	85.53	119.73	**102.63**	76.98	107.76	**92.37**
T4	82.72	106.56	**94.64**	103.40	133.20	**118.30**	93.06	119.88	**106.47**
T5	83.35	110.13	**96.74**	104.19	137.66	**120.92**	93.76	123.89	**108.83**
T6	69.69	98.06	**83.88**	87.11	122.58	**104.85**	78.40	110.32	**94.36**
T7	74.07	101.89	**87.98**	92.59	127.36	**109.98**	83.33	114.63	**98.98**
T8	73.42	103.87	**88.65**	91.77	129.83	**110.80**	82.60	116.85	**99.73**
T9	76.63	105.22	**90.93**	95.79	131.53	**113.66**	86.21	118.38	**102.29**
T10	80.20	106.79	**93.50**	100.25	133.49	**116.87**	90.23	120.14	**105.18**
T11	84.75	112.19	**98.47**	105.94	140.24	**123.09**	95.35	126.22	**110.78**
T12	93.35	112.35	**102.85**	116.68	140.44	**128.56**	105.01	126.39	**115.70**
Mean V	**76.14**	**103.84**		**95.20**	**129.80**		**85.67**	**116.82**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.539	0.189	0.667	0.233	0.589	0.206
(V)	0.22	0.077	0.272	0.095	0.241	0.084
(T × V)	0.762	0.267	0.943	0.33	0.833	0.292

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.2 Number of leaves

No. of leaves is a key element for crop growth as it affects the photosynthesis process which is important for overall plant growth. Observation for the same were taken at an interval 30, 60, 90 DAT and at 1st harvest. The results for number of leaves influenced by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.5, 4.6, 4.7 and 4.8. The results stated in the table confirms that the application of ANSE and micronutrients in combination positively impacted the no. of leaves in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 5-8.

a) Number of leaves at 30 DAT

According to the results obtained for the treatments the utmost no. of leaves at 30 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 63.33,, 81.27 and 72.30 for the year 2022, 2023 and pooled mean respectively, whereas the least leaf count at 30 DAT was observed in T_1 (control) for the year 2021-22 (34.58), 2022-23 (44.38) and the pooled mean (39.48).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of leaves at 30 DAT *i.e.* 2021-22 (52.97), 2022-23 (67.98) and pooled mean (60.48), as compared to V_1 (Tomato no. 575) *i.e.* 44.05, 56.53 and 50.29 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of leaves at 30 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 68.39, 87.77 and 78.08 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 65.58, 84.17 and 74.88 for the year 2022, 2023 and the pooled mean respectively. Whereas least no. of leaves at 30 DAT was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 2801, 35.95 and 31.98 for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) +

(Tomato no. 575)} *i.e.* 32.12, 41.23 and 36.67 for the year 2022, 2023 and the pooled mean respectively.

Table 4.5: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of leaves of tomato at 30 DAT

NUMBER OF LEAVES 30 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	28.014	41.158	**34.586**	35.953	52.817	**44.385**	31.983	46.987	**39.485**
T2	32.128	46.254	**39.191**	41.23	59.357	**50.293**	36.677	52.803	**44.74**
T3	35.221	41.277	**38.249**	45.197	52.967	**49.082**	40.207	47.123	**43.665**
T4	49.058	56.241	**52.65**	62.953	72.173	**67.563**	56.003	64.207	**60.105**
T5	51.504	56.204	**53.854**	66.103	72.13	**69.117**	58.803	64.167	**61.485**
T6	38.438	48.087	**43.263**	49.327	61.707	**55.517**	43.883	54.897	**49.39**
T7	46.115	48.382	**47.248**	59.18	62.087	**60.633**	52.65	55.233	**53.942**
T8	42.292	55.25	**48.771**	54.277	70.907	**62.592**	48.283	63.08	**55.682**
T9	48.158	53.392	**50.775**	61.797	68.52	**65.158**	54.98	60.957	**57.968**
T10	46.26	55.487	**50.873**	59.367	71.203	**65.285**	52.813	63.347	**58.08**
T11	53.223	65.589	**59.406**	68.307	84.177	**76.242**	60.763	74.883	**67.823**
T12	58.271	68.391	**63.331**	74.78	87.773	**81.277**	66.527	78.083	**72.305**
Mean V	**44.057**	**52.976**		**56.539**	**67.985**		**50.298**	**60.481**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.648	0.227	0.865	0.303	0.754	0.264
(V)	0.265	0.093	0.353	0.124	0.308	0.108
(T × V)	0.917	0.321	1.223	0.428	1.067	0.373

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

b) Number of leaves at 60 DAT

According to the results obtained for the treatments the maximum leaf count at 60 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 126.29, 162.07 and 144.18 for the year 2022, 2023 and pooled mean respectively, whereas the least number of leaves at 60 DAT was observed in T_1 (control) for the year 2021-22 (75.82), 2022-23 (97.31) and the pooled mean (86.57).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of leaves at 60 DAT *i.e.* 2021-22 (115.70), 2022-23 (148.48) and pooled mean (132.09), as compared to V_1 (Tomato no. 575) *i.e.* 89.09, 114.34 and 101.72 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of leaves at 60 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 140.59, 180.43 and 160.51 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 131.42, 168.66 and 150.04 for the year 2022, 2023 and the pooled mean respectively. Whereas least no. of leaves at 60 DAT was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 60.59, 77.76 and 69.18 for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 65.92, 84.60 and 75.26 for the year 2022, 2023 and the pooled mean respectively.

Table 4.6: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of leaves of tomato at 60 DAT

NUMBER OF LEAVES 60 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	60.599	91.059	**75.829**	77.767	116.863	**97.315**	69.183	103.963	**86.573**
T2	65.928	96.259	**81.093**	84.607	123.533	**104.07**	75.267	109.897	**92.582**
T3	71.388	104.109	**87.748**	91.613	133.603	**112.608**	81.5	118.853	**100.177**
T4	97.102	123.356	**110.229**	124.613	158.313	**141.463**	110.857	140.837	**125.847**
T5	100.14	130.373	**115.257**	128.513	167.317	**147.915**	114.327	148.843	**131.585**
T6	75.773	104.071	**89.922**	97.247	133.557	**115.402**	86.51	118.813	**102.662**
T7	91.688	111.988	**101.838**	117.667	143.723	**130.695**	104.68	127.853	**116.267**
T8	91.688	117.063	**104.376**	117.667	150.23	**133.948**	104.68	133.643	**119.162**
T9	96.117	116.488	**106.303**	123.35	149.5	**136.425**	109.737	132.993	**121.365**
T10	96.763	121.665	**109.214**	124.183	156.137	**140.16**	110.473	138.9	**124.687**
T11	110.013	131.426	**120.719**	141.183	168.667	**154.925**	125.597	150.043	**137.82**
T12	111.988	140.598	**126.293**	143.713	180.43	**162.072**	127.85	160.513	**144.182**
Mean V	**89.099**	**115.705**		**114.344**	**148.489**		**101.722**	**132.096**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.589	0.206	0.777	0.272	0.67	0.235
(V)	0.24	0.084	0.317	0.111	0.273	0.096
(T × V)	0.832	0.291	1.099	0.385	0.947	0.332

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

c) Number of leaves at 90 DAT

According to the results obtained for the treatments the utmost no. of leaves at 90 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 150.00, 192.51 and 171.25 for the year 2022, 2023 and pooled mean respectively, whereas the least number of leaves at 90 DAT was observed in T_1 (control) for the year 2021-22 (101.97), 2022-23 (130.86) and the pooled mean (116.42).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of leaves at 90 DAT *i.e.* 2021-22 (147.18), 2022-23 (188.89) and pooled mean (168.04), as compared to V_1 (Tomato no. 575) *i.e.* 106.01, 136.04 and 121.03 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of leaves at 90 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 172.55, 221.44 and 196.99 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 167.37, 214.79 and 191.08 for the year 2022, 2023 and the pooled mean respectively. Although least no. of leaves at 90 DAT was found in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 87.73, 112.58 and 100.16 for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 85.72, 110.00 and 97.86 for the year 2022, 2023 and the pooled mean respectively.

Table 4.7: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of leaves of tomato at 90 DAT

NUMBER OF LEAVES 90 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	87.73	116.218	**101.974**	112.587	149.143	**130.865**	100.16	132.68	**116.42**
T2	85.72	133.851	**109.786**	110.007	171.777	**140.892**	97.86	152.817	**125.338**
T3	90.714	124.338	**107.526**	116.42	159.57	**137.995**	103.567	141.957	**122.762**
T4	110.283	158.113	**134.198**	141.537	202.91	**172.223**	125.91	180.513	**153.212**
T5	116.116	166.392	**141.254**	149.013	213.533	**181.273**	132.563	189.963	**161.263**
T6	93.864	132.816	**113.34**	120.46	170.45	**145.455**	107.163	151.633	**129.398**
T7	106.128	144.536	**125.332**	136.193	185.49	**160.842**	121.163	165.013	**143.088**
T8	108.098	146.938	**127.518**	138.723	188.57	**163.647**	123.41	167.753	**145.582**
T9	108.368	148.867	**128.617**	139.07	191.05	**165.06**	123.723	169.957	**146.84**
T10	113.291	154.28	**133.786**	145.387	197.997	**171.692**	129.34	176.137	**152.738**
T11	124.371	167.374	**145.872**	159.613	214.797	**187.205**	141.993	191.087	**166.54**
T12	127.464	172.55	**150.007**	163.583	221.44	**192.512**	145.52	196.997	**171.258**
Mean V	**106.012**	**147.189**		**136.049**	**188.894**		**121.031**	**168.042**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.563	0.197	0.863	0.302	0.706	0.247
(V)	0.23	0.081	0.352	0.123	0.288	0.101
(T × V)	0.797	0.279	1.22	0.427	0.998	0.35

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

d) Number of leaves at 1st harvest

According to the results obtained for the treatments the utmost no. of leaves at 1st harvestwas obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 164.57, 211.19 and 187.88 for the year 2022, 2023 and pooled mean respectively, whereas the least no. of leaves at 1st harvestwas observed in T_1 (control) for the year 2021-22 (112.07), 2022-23 (143.81) and the pooled mean (127.94).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of leaves at 1st harvest*i.e.* 2021-22 (168.08), 2022-23 (215.70) and pooled mean (191.89), as compared to V_1 (Tomato no. 575) *i.e.* 110.99, 142.43 and 126.71 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of leaves at 1st harvestwere obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 195.64, 251.06 and 223.35 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 189.96, 243.77 and 216.87 for the year 2022, 2023 and the pooled mean respectively. Whereas least no. of leaves at 1st harvestwas observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 91.01, 116.79 and 103.90 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 92.01, 118.08 and 105.05 for the year 2022, 2023 and the pooled mean respectively.

The highest values for number of leaves were observed in T_{12} at all observed growth stages could be due to the shared effect of SES and micronutrients. Application of SES has been shown to enhance the number of leaves in tomato plants. Studies indicate that SES improves photosynthesis and chlorophyll content, which are crucial for leaf development. SES contains plant growth hormones such as Auxins and cytokinins, which encourages plant growth leading to increased leaf production. The results obtained were found in accordance with the findings obtained by Yao *et al.,* 2020 in tomato when applied with seaweed extract at different concentrations similar results were also obtained by Ali *et al.,* 2018 and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Zinc is crucial for various physiological functions in plants, including activation of enzymes and synthesis of protein whereas boron plays a vital role in cell wall formation and reproductive development. Their presence can enhance the comprehensive health of the plant, leading to better growth outcomes, including leaf proliferation and improve nutrient uptake and transport within the plant, contributing to increased leaf number. Kaur and Kaur, 2020 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in number of leaves were also reported by Ashraf *et al.,* 2020, Ahmed *et al.,* 2021 and Osman *et al.,* 2019. In terms of varieties, the largest number of leaves was recorded in variety V_2 at all growth stages, which could be attributed to varietal diversity and distinct growth behaviours. Naga Sivaiah *et al.,* 2013 and Sanjida *et al.,* 2020 discovered parallel results while evaluating various tomato cultivars for growth and yield potential.

The maximum no. of leaves at all observed growth stages was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.8: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of leaves of tomato at 1st harvest

NUMBER OF LEAVES AT 1st HARVEST									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	91.01	133.12	**112.07**	116.793	170.84	**143.817**	103.903	151.98	**127.942**
T2	92.01	153.07	**122.54**	118.087	196.44	**157.263**	105.05	174.757	**139.903**
T3	95.75	142.84	**119.30**	122.873	183.31	**153.092**	109.307	163.073	**136.19**
T4	114.15	181.80	**147.98**	146.5	233.303	**189.902**	130.327	207.547	**168.937**
T5	120.36	190.72	**155.54**	154.46	244.76	**199.61**	137.407	217.74	**177.573**
T6	99.00	152.26	**125.63**	127.057	195.397	**161.227**	113.027	173.83	**143.428**
T7	110.97	165.18	**138.08**	142.413	211.973	**177.193**	126.693	188.577	**157.635**
T8	114.02	167.42	**140.72**	146.327	214.85	**180.588**	130.173	191.137	**160.655**
T9	114.22	170.41	**142.31**	146.587	218.69	**182.638**	130.407	194.547	**162.477**
T10	117.40	174.59	**146.00**	150.667	224.063	**187.365**	134.033	199.33	**166.682**
T11	129.45	189.96	**159.70**	166.13	243.777	**204.953**	147.79	216.87	**182.33**
T12	133.51	195.64	**164.57**	171.333	251.063	**211.198**	152.423	223.35	**187.887**
Mean V	**110.99**	**168.08**		**142.436**	**215.706**		**126.712**	**191.895**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.586	0.205	0.831	0.291	0.669	0.234
(V)	0.239	0.084	0.339	0.119	0.273	0.096
(T × V)	0.829	0.29	1.175	0.412	0.946	0.331

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.3 Number of branches

No. of branches is a critical plant growth parameter that influences light capturing for photosynthesis, resource allocation and as an indicator of healthy and robust plant. Observation for the same were observed at an interval of 30 days (30, 60, 90 DAT and at 1st harvest). The results for number of branches determined by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.9, 4.10, 4.11 and 4.12. The results stated in the table confirm that the application of ANSE and micronutrients in combination showed a positive impact the no. of branches in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 9-12.

a) Number of branches at 30 DAT

According to the results obtained for the treatments the utmost no. of branches at 30 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 3.59, 4.86 and 4.23 for the year 2022, 2023 and pooled mean respectively, Although the least number of branches at 30 DAT was observed in T_1 (control) for the year 2021-22 (1.82), 2022-23 (2.47) and the pooled mean (2.15).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of branches at 30 DAT *i.e.* 2021-22 (2.87), 2022-23 (3.89) and pooled mean (3.38), as compared to V_1 (Tomato no. 575) *i.e.* 2.63, 3.56 and 3.09 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of branches at 30 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 3.67, 4.97 and 4.32 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 3.66, 4.96 and 4.31 for the year 2022, 2023 and the pooled mean respectively. Whereas least primary branch count at 30 DAT was found in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 1.56, 2.11 and

1.84 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 2.15, 2.91 and 2.53 for the year 2022, 2023 and the pooled mean respectively.

Table 4.9: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of branches of tomato at 30 DAT

NUMBER OF BRANCHES 30 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	1.56	2.09	**1.82**	2.11	2.83	**2.47**	1.84	2.46	**2.15**
T2	2.15	2.45	**2.33**	2.91	3.33	**3.16**	2.53	2.89	**2.74**
T3	2.38	2.20	**2.26**	3.23	2.99	**3.07**	2.80	2.59	**2.67**
T4	2.67	3.55	**3.11**	3.62	4.82	**4.22**	3.14	4.18	**3.66**
T5	3.10	3.24	**3.17**	4.21	4.40	**4.30**	3.65	3.81	**3.73**
T6	2.43	2.45	**2.44**	3.30	3.33	**3.31**	2.87	2.89	**2.88**
T7	2.67	2.61	**2.64**	3.61	3.53	**3.57**	3.14	3.07	**3.11**
T8	2.61	2.76	**2.68**	3.54	3.74	**3.64**	3.07	3.25	**3.16**
T9	2.62	2.86	**2.74**	3.56	3.88	**3.72**	3.09	3.37	**3.23**
T10	2.65	2.91	**2.78**	3.60	3.95	**3.77**	3.12	3.43	**3.28**
T11	3.11	3.66	**3.39**	4.22	4.96	**4.59**	3.67	4.31	**3.99**
T12	3.51	3.67	**3.59**	4.75	4.97	**4.86**	4.13	4.32	**4.23**
Mean V	**2.63**	**2.87**		**3.56**	**3.89**		**3.09**	**3.38**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.231	0.081	0.312	0.109	0.271	0.095
(V)	0.094	0.033	0.127	0.045	0.111	0.039
(T × V)	0.326	0.114	0.441	0.154	0.383	0.134

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

b) Number of branches at 60 DAT

According to the results obtained for the treatments the highest primary branch count at 60 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 8.43, 11.42 and 9.92 for the year 2022, 2023 and pooled mean respectively, whereas the least branch count at 60 DAT was observed in T_1 (control) for the year 2021-22 (4.33), 2022-23 (5.87) and the pooled mean (5.10).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of branches at 60 DAT *i.e.* 2021-22 (6.82), 2022-23 (9.24) and pooled mean (8.03), as compared to V_1 (Tomato no. 575) *i.e.* 6.26, 8.49 and 7.38 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of branches at 60 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 8.53, 11.56 and 10.04 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 8.48, 11.49 and 9.98 for the year 2022, 2023 and the pooled mean respectively. Whereas least primary branch count at 60 DAT was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 4.31, 5.84 and 5.07 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 5.28, 7.16 and 6.22 for the year 2022, 2023 and the pooled mean respectively.

Table 4.10: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of branches of tomato at 60 DAT

NUMBER OF BRANCHES 60 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	4.31	4.35	**4.33**	5.84	5.90	**5.87**	5.07	5.13	**5.10**
T2	5.28	5.37	**5.33**	7.16	7.28	**7.22**	6.22	6.33	**6.27**
T3	5.32	5.55	**5.44**	7.21	7.53	**7.37**	6.26	6.54	**6.4**
T4	6.61	8.50	**7.56**	8.96	11.52	**10.24**	7.79	10.01	**8.90**
T5	7.45	7.68	**7.57**	10.09	10.41	**10.25**	8.77	9.05	**8.91**
T6	5.34	6.34	**5.84**	7.23	8.59	**7.91**	6.29	7.46	**6.88**
T7	6.20	6.59	**6.39**	8.40	8.93	**8.66**	7.30	7.76	**7.53**
T8	6.31	6.60	**6.46**	8.56	8.95	**8.76**	7.44	7.78	**7.61**
T9	6.44	6.50	**6.47**	8.74	8.81	**8.77**	7.59	7.65	**7.62**
T10	6.17	7.34	**6.75**	8.36	9.94	**9.15**	7.26	8.64	**7.95**
T11	7.37	8.48	**7.92**	9.99	11.49	**10.74**	8.68	9.98	**9.33**
T12	8.33	8.53	**8.43**	11.29	11.56	**11.42**	9.80	10.04	**9.92**
Mean V	**6.26**	**6.82**		**8.49**	**9.24**		**7.38**	**8.03**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.279	0.098	0.378	0.132	0.327	0.115
(V)	0.114	0.04	0.154	0.054	0.134	0.047
(T × V)	0.394	0.138	0.534	0.187	0.463	0.162

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

c) Number of branches at 90 DAT

According to the results obtained for the treatments the maximum primary branches at 90 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 12.78, 16.62 and 14.70 for the year 2022, 2023 and pooled mean respectively, whereas the least branch count at 90 DAT was observed in T_1 (control) for the year 2021-22 (7.12), 2022-23 (9.26) and the pooled mean (8.19).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of branches at 90 DAT *i.e.* 2021-22 (10.22), 2022-23 (13.28) and pooled mean (11.75), as compared to V_1 (Tomato no. 575) *i.e.* 8.98, 11.67 and 10.32 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of branches at 90 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 13.70, 17.81 and 15.76 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 13.61, 17.69 and 15.65 for the year 2022, 2023 and the pooled mean respectively. Whereas least primary branch count was seen at 90 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 6.85, 8.91 and 7.88 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 7.21, 9.37 and 8.30 for the year 2022, 2023 and the pooled mean respectively.

Table 4.11: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of branches of tomato at 90 DAT

NUMBER OF BRANCHES 90 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	6.85	7.39	**7.12**	8.91	9.61	**9.26**	7.88	8.50	**8.19**
T2	7.21	8.24	**7.73**	9.37	10.72	**10.05**	8.30	9.48	**8.89**
T3	7.51	8.45	**7.98**	9.77	10.99	**10.38**	8.64	9.72	**9.18**
T4	9.21	10.30	**9.75**	11.97	13.39	**12.68**	10.58	11.84	**11.21**
T5	10.52	11.92	**11.22**	13.67	15.49	**14.58**	12.10	13.70	**12.90**
T6	7.54	8.67	**8.10**	9.80	11.27	**10.54**	8.67	9.97	**9.32**
T7	8.91	10.11	**9.51**	11.58	13.14	**12.36**	10.24	11.62	**10.93**
T8	9.08	10.13	**9.61**	11.80	13.17	**12.49**	10.44	11.65	**11.04**
T9	8.97	10.26	**9.62**	11.66	13.34	**12.50**	10.31	11.80	**11.05**
T10	8.96	10.38	**9.67**	11.65	13.5	**12.57**	10.3	11.94	**11.12**
T11	10.48	13.61	**12.09**	13.62	17.69	**15.72**	12.05	15.65	**13.91**
T12	11.95	13.70	**12.78**	15.54	17.81	**16.62**	13.75	15.76	**14.70**
Mean V	**8.98**	**10.22**		**11.67**	**13.28**		**10.32**	**11.75**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.358	0.125	0.466	0.163	0.411	0.144
(V)	0.146	0.051	0.19	0.067	0.168	0.059
(T × V)	0.506	0.177	0.659	0.231	0.581	0.203

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

d) Number of branches at 1st harvest

As per the results obtained for the treatments the maximum branch count at 1st harvestwas obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 13.84, 18.00 and 15.92 for the year 2022, 2023 and pooled mean respectively, although the least no. of branches at 1st harvestwas seen in T_1 (control) for the year 2021-22 (7.78), 2022-23 (10.11) and the pooled mean (8.95).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of branches at 1st harvest*i.e.* 2021-22 (11.03), 2022-23 (14.34) and pooled mean (12.68), as compared to V_1 (Tomato no. 575) *i.e.* 9.88, 12.84 and 11.36 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the number of branches at 1st harvestwere obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 14.31, 18.61 and 16.46 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 13.85, 18.01 and 15.93 for the year 2022, 2023 and the pooled mean respectively. Whereas least branch count at 1st harvestwas observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 7.22, 9.38 and 8.30 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 8.19, 10.64 and 9.42 for the year 2022, 2023 and the pooled mean respectively.

The maximum no. of branches observed in T_{12} at all observed growth stages could be due to the shared effect of SES and micronutrients. Application of SES has been shown to promote branching in tomato plants. The presence of natural growth hormones such as auxins and cytokinins in seaweed extracts stimulates lateral bud development, leading to increased branch formation. They also photosynthetic activity of plants, which contributes to overall plant vigor and can indirectly support branching by providing more energy for growth processes. The results obtained were found in accordance with the results obtained by Yao *et al.,* 2020 in tomato when applied with seaweed extract at different concentrations similar results were also obtained by Ali *et al* 2018 and Sasikala *et al.,* 2016. Zinc and boron are crucial for various physiological functions in plants, including activation of enzymes and synthesis of protein. Boron is essential for cell wall formation and the development of new tissues. Its application can improve nutrient transport within the plant, promoting better branching and growth. Adequate zinc and boron levels can enhance branching and overall plant structure. Kaur and Kaur, 2020 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in branch count were also reported by Ashraf *et al.*, 2020, Ahmed *et al.,* 2021 and Osman *et al.,* 2019. Variety V_2 had the highest number of branches across all growth phases, which could be attributable to varietal diversity and different growth behaviours. Naga Sivaiah *et al.,* 2013 and Roy and Monir 2020 discovered similar results when assessing various tomato cultivars for growth and production potential.

The greatest plant height at all observation stages was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.12: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of branches of tomato at 1st harvest

NUMBER OF BRANCHES AT 1st HARVEST									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	7.22	8.34	**7.78**	9.38	10.84	**10.11**	8.30	9.59	**8.95**
T2	8.19	8.93	**8.56**	10.64	11.61	**11.13**	9.42	10.27	**9.84**
T3	8.36	8.93	**8.65**	10.87	11.61	**11.24**	9.62	10.27	**9.94**
T4	9.88	13.87	**11.88**	12.84	18.04	**15.44**	11.36	15.95	**13.66**
T5	11.59	12.66	**12.13**	15.07	16.46	**15.77**	13.33	14.56	**13.95**
T6	8.21	9.10	**8.66**	10.67	11.83	**11.25**	9.44	10.46	**9.95**
T7	9.65	10.80	**10.23**	12.55	14.05	**13.30**	11.10	12.42	**11.76**
T8	9.80	10.87	**10.33**	12.74	14.13	**13.43**	11.27	12.50	**11.88**
T9	9.84	10.86	**10.35**	12.80	14.12	**13.46**	11.32	12.49	**11.91**
T10	9.87	10.9	**10.39**	12.83	14.17	**13.5**	11.35	12.54	**11.95**
T11	11.42	13.85	**12.64**	14.85	18.01	**16.43**	13.14	15.93	**14.53**
T12	13.38	14.31	**13.84**	17.39	18.61	**18.00**	15.38	16.46	**15.92**
Mean V	**9.88**	**11.03**		**12.84**	**14.34**		**11.36**	**12.68**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.397	0.139	0.517	0.181	0.456	0.16
(V)	0.162	0.057	0.211	0.074	0.186	0.065
Factor(T × V)	0.562	0.197	0.731	0.256	0.645	0.226

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.4 Leaf chlorophyll index

Chlorophyll index is a way to estimate the total chlorophyll content in plant leaves. Chlorophyll is a green pigment which absorbs the light energy from sun which is utilised in photosynthesis. The chlorophyll index of the leaves indicates plant's photosynthetic capacity. Observation for the same were taken at an interval of 30 days (30, 60, 90 DAT and at 1st harvest). The results for leaf chlorophyll index influenced by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.13, 4.14, 4.15 and 4.16. The data stated in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the leaf chlorophyll index in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 13-16.

a) Leaf chlorophyll index at 30 DAT

According to the results obtained for the treatments the maximum leaf chlorophyll index at 30 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 70.89, 71.08 and 70.89 for the year 2022, 2023 and pooled mean respectively, whereas the least leaf chlorophyll index at 30 DAT was observed in T1 (control) for the year 2021-22 (53.88), 2022-23 (53.77) and the pooled mean (53.83).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher leaf chlorophyll index at 30 DAT *i.e.* 2021-22 (66.96), 2022-23 (67.04) and pooled mean (67.00), as compared to V_1 (Tomato no. 575) *i.e.* 61.81, 61.87 and 61.84 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the leaf chlorophyll index at 30 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 74.63, 74.99 and 74.81 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 72.86, 72.89 and 72.88 for the year 2022, 2023 and the pooled mean respectively. Whereas least leaf chlorophyll index at 30 DAT was found in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 51.59, 51.34 and 51.46 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 54.49, 54.18 and 54.33 for the year 2022, 2023 and the pooled mean respectively.

Table 4.13: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on leaf chlorophyll index of tomato at 30 DAT

LEAF CHLOROPHYLL INDEX 30 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	51.59	56.18	**53.88**	51.34	56.20	**53.77**	51.46	56.19	**53.83**
T2	54.49	62.13	**58.31**	54.18	62.15	**58.16**	54.33	62.14	**58.24**
T3	59.92	63.60	**61.76**	59.94	63.95	**61.95**	59.93	63.77	**61.85**
T4	65.35	69.05	**67.20**	65.70	69.08	**67.39**	65.52	69.06	**67.29**
T5	65.85	69.76	**67.80**	65.87	69.78	**67.83**	65.86	69.77	**67.81**
T6	60.50	64.64	**62.57**	60.85	64.33	**62.59**	60.68	64.48	**62.58**
T7	61.00	66.14	**63.57**	61.02	66.16	**63.59**	61.01	66.15	**63.58**
T8	61.22	67.45	**64.34**	61.25	67.80	**64.52**	61.24	67.62	**64.43**
T9	63.44	68.23	**65.83**	63.79	68.25	**66.02**	63.61	68.24	**65.93**
T10	64.24	68.83	**66.54**	64.26	68.86	**66.56**	64.25	68.84	**66.55**
T11	67.02	72.86	**69.94**	67.05	72.89	**69.97**	67.03	72.88	**69.96**
T12	67.14	74.63	**70.89**	67.17	74.99	**71.08**	67.15	74.81	**70.98**
Mean V	**61.81**	**66.96**		**61.87**	**67.04**		**61.84**	**67.00**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.026	0.009	0.347	0.121	0.176	0.062
(V)	0.01	0.004	0.142	0.05	0.072	0.025
(T × V)	0.036	0.013	0.491	0.172	0.248	0.087

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

b) Leaf chlorophyll index at 60 DAT

According to the results obtained for the treatments the maximum leaf chlorophyll index at 60 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 79.22, 79.25 and 79.24 for the year 2022, 2023 and pooled mean respectively, whereas the least leaf chlorophyll index at 60 DAT was observed in T_1 (control) for the year 2021-22 (57.12), 2022-23 (57.14) and the pooled mean (57.13).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher leaf chlorophyll index at 60 DAT *i.e.* 2021-22 (71.72), 2022-23 (71.75) and pooled mean (71.73), as compared to V_1 (Tomato no. 575) *i.e.* 66.61, 66.64 and 66.63 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the leaf chlorophyll index at 60 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 79.73, 79.75 and 79.74 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 78.72, 78.75, 78.73 for the year 2022, 2023 and the pooled mean respectively. Whereas least leaf chlorophyll index at 60 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 54.60, 54.62 and 54.61 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 55.70, 55.72 and 55.71 for the year 2022, 2023 and the pooled mean respectively.

Table 4.14: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on leaf chlorophyll index of tomato at 60 DAT

LEAF CHLOROPHYLL INDEX 60 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	54.60	59.64	**57.12**	54.62	59.66	**57.14**	54.61	59.65	**57.13**
T2	55.70	65.01	**60.36**	55.72	65.03	**60.38**	55.71	65.02	**60.37**
T3	56.40	66.92	**61.66**	56.42	66.95	**61.68**	56.41	66.93	**61.67**
T4	72.13	75.57	**73.85**	72.15	75.59	**73.87**	72.14	75.58	**73.86**
T5	72.85	76.06	**74.46**	72.88	76.08	**74.48**	72.87	76.07	**74.47**
T6	63.13	68.97	**66.05**	63.15	69.00	**66.08**	63.14	68.98	**66.06**
T7	65.01	69.74	**67.38**	65.03	69.76	**67.40**	65.02	69.75	**67.39**
T8	65.85	72.64	**69.25**	65.87	72.67	**69.27**	65.86	72.66	**69.26**
T9	70.74	73.70	**72.22**	70.76	73.72	**72.24**	70.76	73.71	**72.23**
T10	71.15	75.18	**73.17**	71.18	75.21	**73.19**	71.17	75.20	**73.18**
T11	73.07	78.72	**75.29**	73.10	78.75	**75.32**	73.09	78.73	**75.30**
T12	77.51	79.73	**79.22**	77.53	79.75	**79.25**	77.52	79.74	**79.24**
Mean V	**66.61**	**71.72**		**66.64**	**71.75**		**66.63**	**71.73**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.041	0.014	0.037	0.013	0.096	0.034
(V)	0.017	0.006	0.015	0.005	0.039	0.014
(T × V)	0.058	0.02	0.053	0.019	0.136	0.047

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

c) Leaf chlorophyll index at 90 DAT

According to the results obtained for the treatments the maximum leaf chlorophyll index at 90 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 70.90 , 70.93 and 70.92 for the year 2022, 2023 and pooled mean respectively, whereas the least leaf chlorophyll index at 90 DAT was observed in T1 (control) for the year 2021-22 (49.16), 2022-23 (49.17) and the pooled mean (49.35).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher leaf chlorophyll index at 90 DAT *i.e.* 2021-22 (64.99), 2022-23 (65.02) and pooled mean (65.03), as compared to V_1 (Tomato no. 575) *i.e.* 54.38, 54.40 and 54.42 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the leaf chlorophyll index at 90 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 79.71, 79.73 and 79.72 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 70.71, 70.82 and 70.80 for the year 2022, 2023 and the pooled mean respectively. Whereas least leaf chlorophyll index at 90 DAT was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 46.82, 46.84 and 46.83 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 46.92, 46.94 and 46.93 for the year 2022, 2023 and the pooled mean respectively.

Table 4.15: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on leaf chlorophyll index of tomato at 90 DAT

LEAF CHLOROPHYLL INDEX 90 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	46.82	51.49	**49.16**	46.84	51.50	**49.17**	46.83	51.83	**49.33**
T2	46.92	52.97	**49.95**	46.94	52.99	**49.97**	46.93	52.98	**49.96**
T3	50.74	62.03	**56.39**	50.76	62.05	**56.41**	50.75	62.04	**56.40**
T4	56.83	67.24	**62.04**	56.85	67.27	**62.06**	56.84	67.26	**62.05**
T5	58.91	68.78	**63.85**	58.93	68.80	**63.87**	58.92	68.80	**63.86**
T6	50.87	62.98	**56.93**	50.89	63.01	**56.95**	50.88	62.99	**56.94**
T7	52.49	63.90	**58.20**	52.51	63.92	**58.22**	52.83	63.91	**58.37**
T8	54.39	65.85	**60.12**	54.41	65.87	**60.14**	54.73	65.86	**60.30**
T9	55.19	66.99	**61.09**	55.21	67.01	**61.11**	55.20	67.01	**61.11**
T10	55.67	67.19	**61.43**	55.68	67.22	**61.45**	55.34	67.21	**61.27**
T11	61.64	70.79	**66.21**	61.66	70.82	**66.24**	61.65	70.80	**66.23**
T12	62.10	79.71	**70.90**	62.12	79.73	**70.93**	62.11	79.72	**70.92**
Mean V	**54.38**	**64.99**		**54.40**	**65.02**		**54.42**	**65.03**	

Factors	**CD**	**SEm±**	**CD**	**SEm±**	**CD**	**SEm±**
(T)	0.044	0.015	0.086	0.03	0.272	0.095
(V)	0.018	0.006	0.035	0.012	0.111	0.039
(T × V)	0.062	0.022	0.121	0.042	0.385	0.135

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

d) Leaf chlorophyll index at 1st harvest

According to the results obtained for the treatments the maximum leaf chlorophyll index at 1st harvestwas obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 69.57, 70.93 and 69.66 for the year 2022, 2023 and pooled mean respectively, whereas the least leaf chlorophyll index at 1st harvestwas observed in T_1 (control) for the year 2021-22 (48.06), 2022-23 (49.17) and the pooled mean (48.15).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher leaf chlorophyll index at 1st harvest*i.e.* 2021-22 (63.74), 2022-23 (65.02) and pooled mean (63.77), as compared to V_1 (Tomato no. 575) *i.e.* 52.87, 54.40 and 52.95 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the leaf chlorophyll index at 1st harvest were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 78.71, 79.73 and 78.72 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 69.58, 70.82 and 69.64 for the year 2022, 2023 and the pooled mean respectively. Whereas least leaf chlorophyll index at 1st harvest was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 45.55, 46.84 and 45.55 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 45.90, 46.94 and 45.90 for the year 2022, 2023 and the pooled mean respectively.

The maximum leaf chlorophyll index observed in T_{12} at all observed growth stages could be due to the shared effect of SES and micronutrients. Application of SES has been shown to significantly enhance leaf chlorophyll index of tomato plants. SES contain naturally occurring hormones such as cytokinins and auxins, enhancing chlorophyll synthesis and improve leaf vitality. These hormonal effects contribute to better light absorption and photosynthesis, thereby increasing chlorophyll levels. The results obtained were found in accordance with the results obtained by Rajendran *et al.*, 2022 in tomato where seaweed extract when applied at different concentrations elevate the SPAD values by approximately 9.6% to 25.3% compared to control. Alike resultss were also obtained by Subramaniyan *et al.,* 2023 and Yao *et al.,* 2020. Zinc and boron are essential micronutrients. Zinc is essential for various physiological functions in plant, adequate zinc levels have been associated with improved leaf chlorophyll content, enhancing the overall photosynthetic capacity of tomato plants. Whereas, boron is crucial element for cell wall formation and nutrient transport within plants. Its presence can enhance the efficiency of photosynthesis by improving the structural integrity of chloroplasts, leading to increased chlorophyll synthesis. Kaur and Kaur, 2020 also reported improved plant growth as a result of combined effect of zinc and boron. Similar results for significant increase in leaf chlorophyll index were also noted by Ahmed *et al.,* 2021, Xu *et al.,* 2021 and Singh *et al.,* 2017. Variety V_2 had the maximum leaf chlorophyll index across all growth stages, which could be attributed to varietal diversity and varied growth patterns. When analysing the growth and production potential of numerous tomato cultivars, Gurmani *et al.,* 2012 and Naga Sivaiah *et al.,* 2013 discovered similar results.

The maximum leaf chlorophyll index at all the observation stages was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.16: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on leaf chlorophyll index of tomato at 1st harvest

LEAF CHLOROPHYLL INDEX AT 1st HARVEST									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	45.55	50.57	**48.06**	46.84	51.50	**49.17**	45.55	50.75	**48.15**
T2	45.90	51.97	**48.94**	46.94	52.99	**49.97**	45.90	51.98	**48.94**
T3	49.37	61.22	**55.30**	50.76	62.05	**56.41**	49.54	61.24	**55.39**
T4	55.40	65.78	**60.59**	56.85	67.27	**62.06**	55.57	65.79	**60.68**
T5	57.06	67.66	**62.36**	58.93	68.80	**63.87**	57.07	67.50	**62.29**
T6	48.56	61.53	**55.04**	50.89	63.01	**56.95**	48.74	61.37	**55.05**
T7	51.38	61.68	**56.53**	52.51	63.92	**58.22**	51.55	61.85	**56.70**
T8	53.17	64.45	**58.81**	54.41	65.87	**60.14**	53.18	64.29	**58.74**
T9	53.59	65.45	**59.52**	55.21	67.01	**61.11**	53.43	65.62	**59.53**
T10	54.43	66.29	**60.36**	55.68	67.22	**61.45**	54.61	66.47	**60.54**
T11	59.62	69.58	**64.60**	61.66	70.82	**66.24**	59.66	69.64	**64.65**
T12	60.42	78.71	**69.57**	62.12	79.73	**70.93**	60.60	78.72	**69.66**
Mean V	**52.87**	**63.74**		**54.40**	**65.02**		**52.95**	**63.77**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.057	0.020	0.420	0.147	0.216	0.076
(V)	0.023	0.008	0.171	0.060	0.088	0.031
(T × V)	0.080	0.028	0.594	0.208	0.306	0.107

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.5 Diameter of stem (mm)

Stem diameter have a significant relation with plant growth, it plays a key role in plant growth performance as it influences various aspects of plant growth like plant height, plant water status making it a valuable indicator in assessing plant performance. Observation for the same were taken at an interval of 30 days (30, 60, 90 DAT and at 1st harvest). The results for diameter of stem affected by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.17, 4.18, 4.19 and 4.20. The results defined in the table confirm that the application of ANSE and micronutrients in combination significantly influenced the diameter of stem in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 17-12.

a) Diameter of stem at 30 DAT (mm)

According to the results obtained for the treatments the maximum diameter of stem at 30 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 8.00 mm, 8.14 mm and 8.07 mm for the year 2022, 2023 and pooled mean respectively, whereas the least diameter of stem at 30 DAT was observed in T_1 (control) for the year 2021-22 (4.46 mm), 2022-23 (4.54 mm) and the pooled mean (4.50 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher diameter of stem at 30 DAT *i.e.* 2021-22 (6.52 mm), 2022-23 (6.64 mm) and pooled mean (6.58 mm), as compared to V_1 (Tomato no. 575) *i.e.* 6.09 mm, 6.20 mm and 6.14 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the diameter of stem at 30 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 8.32 mm, 8.46 mm and 8.40 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 8.09 mm, 8.23 mm and 8.16 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least diameter of stem at 30 DAT was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 4.35 mm, 4.43 mm and 4.39 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 4.52 mm, 4.60 mm and 4.56 mm for the year 2022, 2023 and the pooled mean respectively.

Table 4.17: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on diameter of stem (cm) of tomato at 30 DAT

DIAMETER OF STEM (mm) 30 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	4.35	4.56	**4.46**	4.43	4.65	**4.54**	4.39	4.60	**4.50**
T2	4.52	5.03	**4.78**	4.60	5.12	**4.86**	4.56	5.08	**4.82**
T3	4.91	5.37	**5.14**	5.00	5.47	**5.24**	4.95	5.42	**5.19**
T4	7.09	7.25	**7.17**	7.23	7.39	**7.31**	7.16	7.33	**7.24**
T5	7.34	7.39	**7.36**	7.47	7.51	**7.49**	7.41	7.45	**7.43**
T6	5.23	5.91	**5.57**	5.32	6.01	**5.66**	5.27	5.96	**5.61**
T7	5.52	6.31	**5.92**	5.62	6.42	**6.02**	5.57	6.36	**5.97**
T8	5.69	6.65	**6.17**	5.78	6.76	**6.27**	5.73	6.70	**6.22**
T9	6.05	6.85	**6.45**	6.16	6.96	**6.56**	6.10	6.90	**6.50**
T10	6.47	7.16	**6.82**	6.58	7.28	**6.93**	6.53	7.22	**6.87**
T11	7.6	8.09	**7.84**	7.72	8.23	**7.72**	7.66	8.16	**7.91**
T12	7.68	8.32	**8.00**	7.82	8.46	**8.14**	7.75	8.40	**8.07**
Mean V	**6.09**	**6.52**		**6.20**	**6.64**		**6.14**	**6.58**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.299	0.105	0.304	0.106	0.301	0.105
(V)	0.122	0.043	0.124	0.043	0.123	0.043
(T × V)	0.423	0.148	0.430	0.151	0.426	0.149

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

b) Diameter of stem at 60 DAT (mm)

According to the results obtained for the treatments the maximum diameter of stem at 60 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 13.83, 14.06 and 13.39 for the year 2022, 2023 and pooled mean respectively, whereas the least diameter of stem at 60 DAT was observed in T_1 (control) for the year 2021-22 (8.98), 2022-23 (9.15) and the pooled mean (9.06).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher diameter of stem at 60 DAT *i.e.* 2021-22 (12.24 mm), 2022-23 (12.46 mm) and pooled mean (12.35 mm), as compared to V_1 (Tomato no. 575) *i.e.* 11.39 mm, 11.75 mm and 11.57 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the diameter of stem at 60 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 14.38 mm, 14.63 mm and 14.50 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 13.98 mm, 14.22 mm and 14.10 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least diameter of stem at 60 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 8.76 mm, 8.92 and 8.84 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 9.11 mm, 9.29 mm and 9.20 mm for the year 2022, 2023 and the pooled mean respectively.

Table 4.18: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on diameter of stem (mm) of tomato at 60 DAT

DIAMETER OF STEM (mm) 60 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	8.76	9.20	**8.98**	8.92	9.37	**9.15**	8.84	9.29	**9.06**
T2	9.11	10.13	**9.62**	9.29	10.33	**9.81**	9.20	10.23	**9.71**
T3	9.89	10.82	**10.36**	10.08	11.03	**10.55**	9.98	10.93	**10.46**
T4	12.25	12.53	**12.39**	12.48	12.77	**12.63**	12.36	12.65	**12.51**
T5	12.69	12.76	**12.72**	12.90	12.98	**12.94**	12.79	12.87	**12.83**
T6	10.53	11.91	**11.22**	10.71	12.11	**11.41**	10.62	12.01	**11.32**
T7	11.13	12.71	**11.92**	11.32	12.92	**12.12**	11.23	12.82	**12.02**
T8	11.47	13.40	**12.43**	11.66	13.63	**12.64**	11.57	13.51	**12.54**
T9	12.20	13.80	**13.00**	12.41	14.04	**13.22**	12.30	13.92	**13.11**
T10	11.18	12.36	**11.77**	13.27	12.57	**12.92**	12.22	12.47	**12.35**
T11	13.12	13.98	**13.12**	13.35	14.22	**13.785**	13.24	14.1	**13.67**
T12	13.28	14.38	**13.83**	13.5	14.63	**14.065**	13.39	14.50	**13.39**
Mean V	**11.39**	**12.24**		**11.75**	**12.46**		**11.57**	**12.35**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.553	0.194	0.564	0.197	0.554	0.195
(V)	0.226	0.079	0.230	0.081	0.228	0.080
(T × V)	0.782	0.274	0.797	0.279	0.789	0.276

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

c) Diameter of stem at 90 DAT (mm)

According to the results obtained for the treatments the maximum diameter of stem at 90 DAT was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 19.46, 19.55 and 19.38 for the year 2022, 2023 and pooled mean respectively, whereas the least diameter of stem at 90 DAT was observed in T_1 (control) for the year 2021-22 (12.48 mm), 2022-23 (12.72 mm) and the pooled mean (12.60 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher diameter of stem at 90 DAT *i.e.* 2021-22 (17.02 mm), 2022-23 (17.31 mm) and pooled mean (17.16 mm), as compared to V_1 (Tomato no. 575) *i.e.* 16.05 mm, 16.33 mm and 16.19 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the diameter of stem at 90 DAT were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 19.99 mm, 20.33 mm and 20.16 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 19.43 mm, 19.76 mm and 19.60 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least diameter of stem at 90 DAT was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 12.17 mm, 12.40 mm and 12.29 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 12.66 mm, 12.90 mm and 12.78 mm for the year 2022, 2023 and the pooled mean respectively.

Table 4.19: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on diameter of stem (mm) of tomato at 90 DAT

DIAMETER OF STEM (mm) 90 DAT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	12.17	12.79	**12.48**	12.40	13.03	**12.72**	12.29	12.91	**12.60**
T2	12.66	14.09	**13.38**	12.90	14.35	**13.63**	12.78	14.22	**13.50**
T3	13.75	15.04	**14.40**	14.01	15.33	**14.67**	13.88	15.19	**14.53**
T4	17.03	17.42	**17.22**	17.35	17.75	**17.55**	17.19	17.59	**17.39**
T5	17.63	17.74	**17.69**	17.93	18.04	**17.99**	17.78	17.89	**17.83**
T6	14.64	16.55	**15.60**	14.89	16.84	**15.86**	14.77	16.70	**15.73**
T7	15.47	17.67	**16.57**	15.74	17.97	**16.85**	15.60	17.82	**16.71**
T8	15.94	18.63	**17.28**	16.21	18.94	**17.58**	16.07	18.78	**17.43**
T9	16.96	19.18	**18.07**	17.25	19.51	**18.38**	17.10	19.34	**18.22**
T10	18.13	17.18	**17.66**	18.44	17.47	**17.96**	18.29	17.33	**17.81**
T11	18.24	19.43	**18.83**	18.55	19.76	**19.15**	18.39	19.6	**18.99**
T12	18.46	19.99	**19.46**	18.77	20.33	**19.55**	18.61	20.16	**19.38**
Mean V	**16.05**	**17.02**		**16.33**	**17.31**		**16.19**	**17.16**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.770	0.270	0.783	0.274	0.776	0.272
(V)	0.314	0.110	0.320	0.112	0.317	0.111
(T × V)	1.089	0.381	1.108	0.388	1.097	0.384

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

d) Diameter of stem at 1st harvest (mm)

According to the results obtained for the treatments the maximum diameter of stem at 1st harvest was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) *i.e.* 19.78, 20.11 and 19.15 for the year 2022, 2023 and pooled mean respectively, whereas the least diameter of stem at 1st harvest was observed in T_1 (control) for the year 2021-22 (12.84 mm), 2022-23 (13.08 mm) and the pooled mean (12.96 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher diameter of stem at 1st harvest *i.e.* 2021-22 (17.50 mm), 2022-23 (16.92 mm) and pooled mean (17.21 mm), as compared to V_1 (Tomato no. 575) *i.e.* 16.51 mm, 15.79 mm and 16.15 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the diameter of stem at 1st harvest were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 20.57 mm, 20.91 mm and 20.74 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 19.99 mm, 20.33 mm and 20.16 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least diameter of stem at 1st harvest was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 12.52 mm, 12.76 mm and 12.64 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 13.03 mm, 13.28 mm and 13.15 mm for the year 2022, 2023 and the pooled mean respectively.

The maximum diameter of stem observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. Applying seaweed extract (SES) has been shown to significantly improve nutrient uptake and enhance photosynthetic efficiency, which are critical for stem development. Enhanced root growth associated with SES application also contributes to better nutrient absorption, further supporting stem growth. Seaweed extracts contain natural growth hormones found in plants such as cytokinins and auxins, which promote cell growth and multiplication in stems. This hormonal action leads to increased stem thickness and overall plant robustness. The results obtained were found in accordance with the results obtained by Hussain *et al.,* 2021 in tomato when applied with seaweed extract at different concentrations alike outcomes were also noted by Villa *et al* 2023 and Subramaniyan *et al.,* 2023. Zinc and boron are essential micronutrients. Adequate zinc levels can lead to improved stem structure and diameter by enhancing overall plant health and vigor. Boron plays a key role in formation of cell wall and and its structural integrity. Its application can improve the mechanical strength of stems, contributing to increased diameter and resilience against environmental stresses. Zinc deficiency is often linked to stunted growth, while proper zinc application promotes stronger stems. Dixit *et al.,* 2021 also reported improved diameter of stem with the conjugated approach of zinc and boron. Similar results for significant increase in diameter of stem were also illustrated by Mallick *et al* 2020 and Sasikala *et al.,* 2016. Variety V_2 had maximum diameter of stem across all growth phases, which could be attributable to varietal diversity and different growth patterns. Fakhrabad *et al.,* 2019 and Naga Sivaiah *et al*.,2013 discovered similar results while assessing the growth and production potential of various tomato varieties.

The maximum diameter of stem at all observation stages was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.20: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on diameter of stem (mm) of tomato at 1st harvest

DIAMETER OF STEM (mm) AT 1st HARVEST									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	12.52	13.15	**12.84**	12.76	13.41	**13.08**	12.64	13.28	**12.96**
T2	13.03	14.49	**13.76**	13.28	14.77	**14.02**	13.15	14.63	**13.89**
T3	14.14	15.48	**14.81**	14.41	15.77	**15.09**	14.27	15.62	**14.95**
T4	17.51	17.92	**17.72**	17.85	18.26	**18.06**	17.68	18.09	**17.89**
T5	18.14	18.25	**18.20**	18.45	18.56	**18.51**	18.30	18.41	**18.35**
T6	15.06	17.03	**16.05**	13.13	14.85	**13.99**	14.10	15.94	**15.02**
T7	15.92	18.18	**17.05**	13.88	15.85	**14.86**	14.90	17.01	**15.96**
T8	16.40	19.16	**17.78**	14.29	16.70	**15.50**	15.35	17.93	**16.64**
T9	17.45	19.73	**18.59**	15.21	17.20	**16.21**	16.33	18.47	**17.40**
T10	18.65	17.68	**18.17**	16.26	17.98	**17.12**	17.46	17.83	**17.64**
T11	18.77	19.99	**18.77**	19.09	20.33	**19.71**	18.92	20.16	**19.54**
T12	18.99	20.57	**19.78**	19.31	20.91	**20.11**	19.15	20.74	**19.15**
Mean V	**16.51**	**17.50**		**15.79**	**16.92**		**16.15**	**17.21**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.790	0.277	0.758	0.265	0.774	0.271
(V)	0.323	0.113	0.309	0.108	0.316	0.111
(T × V)	1.118	0.391	1.072	0.375	1.095	0.383

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.6 Days to flower initiation

Days taken for initiation of flowering is an important factor in plant growth metrics, it defines the time duration of plant's transitioning from vegetative to reproductive phase which can be influenced by environmental and nutritional availability. Observation for the same were taken at an interval of 30 days (30, 60, 90 DAT and at 1st harvest). The observations for days to flower initiation impacted by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are defined in Table 4.25. The observations given in the table confirms that the application of ANSE and micronutrients in combination positively influenced the days to flower initiation in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 25.

According to the results obtained for the treatments the minimum days to flower initiation was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 40.67 mm, 36.20 mm and 38.44 mm for the year 2022, 2023 and pooled mean respectively, whereas the maximum days to flower initiation were observed in T_1 (control) for the year 2021-22 (50.52 mm), 2022-23 (44.96 mm) and the pooled mean (47.74 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed least number of days to flower initiation at 30 DAT *i.e.* 2021-22 (41.92 mm), 2022-23 (37.31 mm) and pooled mean (39.62 mm), as compared to V_1 (Tomato no. 575) *i.e.* 49.18 mm, 43.77 mm and 46.47 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the maximum positive results for the days to flower initiation were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 37.40 mm, 33.28 mm and 35.34 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 38.56 mm, 34.32 mm and 36.44 mm for the year 2022, 2023 and the pooled mean respectively. Whereas highest days to flower initiation were observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 54.38 mm, 48.40 mm and 51.39 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 52.87 mm, 47.02 mm and 49.96 mm for the year 2022, 2023 and the pooled mean respectively.

The minimum amount of days taken for flowering observed in T_{12} at could be due to the shared effect of SES and micronutrients. Application of SES has been shown to significantly enhance the no. of days taken to flower initiation on tomato plants. ES not only boosts the overall health of the plant but also improves photosynthetic efficiency, which is crucial for energy production during the flowering phase. Increased chlorophyll content from SES leads to better light absorption and energy availability for flower development. The results obtained were found in accordance with the results obtained by Fakhrabad *et al.,* 2019 in tomato when applied with seaweed extract at different concentrations alike observas were also obtained by Villa *et al.,* 2023 and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Adequate zinc levels have been linked to improved flowering rates and overall reproductive health in plants. Boron plays a critical role in reproductive development. Their deficiency can delay flowering, while proper supplementation promotes timely flower initiation Ahmed *et al.,* 2021 also reported improved plant growth with the conjugative effects of zinc and boron. Similar results for significant decrease in number of days to flower initiation were also revealed by Sanjida *et al.,* 2020, Ahmed *et al.,* 2021 and Osman *et al.,* 2019. Among varieties variety V_2 had the least number of days to flower initiation, which could be attributable to varietal heterogeneity and unique growth patterns. Fakhrabad *et al.,* 2019, and Naga Sivaiah *et al.,* 2013 discovered familiar results when assessing the growth potential of various tomato varieties.

The least no. of days taken to flower initiation was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.21: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on flowering of tomato

DAYS TO FLOWER INITIATION									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	54.38	46.66	**50.52**	48.40	41.53	**44.96**	51.39	44.09	**47.74**
T2	52.87	45.65	**49.26**	47.06	40.62	**43.84**	49.96	43.14	**46.55**
T3	52.90	44.56	**48.73**	47.08	39.66	**43.37**	49.99	42.10	**46.05**
T4	47.20	39.99	**43.60**	42.01	35.59	**38.80**	44.60	37.79	**41.20**
T5	45.60	38.94	**42.27**	40.58	34.65	**37.61**	43.09	36.80	**39.94**
T6	52.30	43.96	**48.13**	46.55	39.12	**42.84**	49.42	41.54	**45.48**
T7	50.77	42.88	**46.83**	45.18	38.17	**41.68**	47.97	40.52	**44.25**
T8	49.14	42.54	**45.84**	43.73	37.86	**40.79**	46.43	40.20	**43.32**
T9	48.71	41.51	**45.11**	43.35	36.94	**40.15**	46.04	39.22	**42.63**
T10	47.70	40.45	**44.08**	42.46	36.00	**39.23**	45.08	38.23	**41.65**
T11	44.60	38.56	**41.58**	39.70	34.32	**37.01**	42.14	36.44	**39.29**
T12	43.95	37.40	**40.67**	39.11	33.28	**36.20**	41.53	35.34	**38.44**
Mean V	**49.18**	**41.92**		**43.77**	**37.31**		**46.47**	**39.62**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.564	0.198	0.501	0.176	0.533	0.187
(V)	0.23	0.081	0.205	0.072	0.218	0.076
(T × V)	0.798	0.28	0.709	0.248	0.754	0.264

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.7 Days to 50% flowering

The no. of days taken to reach 50% flowering serves as a crucial part of plant growth reflecting plants overall development and flowering efficacy. It is a valuable insight as it could be a result of environmental conditions or different treatments. Observation for the same were taken at 30, 60, 90 DAT and at 1st harvest. The results for days to 50% flowering determined by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.26. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the days to 50% flowering in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 26.

According to the results obtained for the treatments the least no. of days to 50% flowering were obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 46.44, 41.33 and 43.88 for the year 2022, 2023 and pooled mean respectively, whereas the utmost no. of days taken to 50% flowering were observed in T_1 (control) for the year 2021-22 (56.93), 2022-23 (50.67) and the pooled mean (53.80).

Among both the studied varieties V_2 (Yellow Jubilee) showed minimum number of days to 50% flowering *i.e.* 2021-22 (47.67), 2022-23 (42.43) and pooled mean (45.05), as compared to V_1 (Tomato no. 575) *i.e.* 55.83, 49.68 and 52.75 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for days to 50% flowering were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 42.96, 38.24 and 40.60 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 43.62, 38.83 and 41.22 for the year 2022, 2023 and the pooled mean respectively. Although highest no. of days to 50% flowering was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 60.95, 54.25 and 57.60 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @

0.2%) + (Tomato no. 575) *i.e.* 59.93, 53.34 and 56.64 for the year 2022, 2023 and the pooled mean respectively.

The least no. of days to 50% flowering observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Inclusion of SES has been shown to significantly enhance the number of days to 50% flowering on tomato plants. SES not only boosts the overall health of the plant but also improves photosynthetic efficiency, which is crucial for energy production during the flowering phase. Increased chlorophyll content from SES leads to better light absorption and energy availability for flower development which creates optimal environment for reduction in number of days to reach 50% flowering. The results obtained were found in accordance with the results obtained by Hussain *et al.*, 2021 in tomato when applied with seaweed extract at different concentrations alike observings were also obtained by Villa *et al.*, 2023 and Subramaniyan *et al.*, 2023. Zinc and boron are essential micronutrients. Adequate zinc levels have been linked to improved flowering rates and overall reproductive health in plants. Boron plays a critical role in reproductive development. Their deficiency can delay flowering, while proper supplementation promotes timely flower initiation and reduce the number of days to reach maximum flowering potential. Ahmed *et al.*, 2021 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant decline in number of days to 50% flowering were also doccumented by Saha *et al.*, 2023, Ahmed *et al.*, 2021 and Khatri *et al.*, 2022. Among varieties variety V_2 had the least number of days to 50% flowering, which could be attributable to varietal heterogeneity and unique growth patterns. Fakhrabad *et al.*, 2019, and Roy and Munir, 2020 discovered similar results when assessing the growth potential of various tomato varieties.

The least no. of days taken to 50% flowering was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.22: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on flowering of tomato

DAYS TO 50% FLOWERING									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	60.95	52.91	**56.93**	54.25	47.09	**50.67**	57.60	49.99	**53.80**
T2	59.93	51.74	**55.83**	53.34	46.05	**49.69**	56.64	48.89	**52.77**
T3	60.16	50.61	**55.38**	53.54	45.05	**49.29**	56.85	47.82	**52.34**
T4	54.10	45.91	**50.00**	48.15	40.86	**44.50**	51.12	43.38	**47.25**
T5	52.84	44.74	**48.79**	47.03	39.82	**43.42**	49.93	42.27	**46.10**
T6	58.82	49.46	**54.14**	52.35	44.02	**48.19**	55.59	46.74	**51.17**
T7	57.62	49.08	**53.35**	51.28	43.68	**47.48**	54.46	46.39	**50.42**
T8	56.00	48.03	**52.01**	49.84	42.74	**46.29**	52.92	45.38	**49.15**
T9	55.08	47.06	**51.07**	49.02	41.88	**45.45**	52.05	44.47	**48.26**
T10	53.54	45.92	**49.73**	47.65	40.87	**44.26**	50.60	43.40	**47.00**
T11	50.95	43.62	**47.29**	45.35	38.83	**42.09**	48.15	41.22	**44.69**
T12	49.91	42.96	**46.44**	44.42	38.24	**41.33**	47.16	40.60	**43.88**
Mean V	**55.83**	**47.67**		**49.68**	**42.43**		**52.75**	**45.05**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.504	0.177	0.449	0.157	0.479	0.168
(V)	0.206	0.072	0.183	0.064	0.195	0.068
(T × V)	0.713	0.25	0.635	0.222	0.677	0.237

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.8 Days to fruit initiation

Days taken to fruit initiation play a very crucial role as a plant growth parameter as it have a direct impact on timely and successful fruit production which ultimately affects the yield and profitability. Observation for the same were noted at 30, 60, 90 DAT and at 1st harvest. The results for days to fruit initiation influenced by the foliar spray of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are defined in Table 4.27. The observation given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the days to fruit initiation in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 27.

According to the results obtained for the treatments the least number of days to fruit initiation were obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 53.52, 47.63 and 50.57 for the year 2022, 2023 and pooled mean respectively, whereas the utmost number of days to fruit initiation were observed in T_1 (control) for the year 2021-22 (62.13), 2022-23 (55.29) and the pooled mean (58.55).

Among both the studied varieties V_2 (Yellow Jubilee) showed least number of days to fruit initiation *i.e.* 2021-22 (53.94), 2022-23 (48.00) and pooled mean (51.01), as compared to V_1 (Tomato no. 575) *i.e.* 62.22, 55.38 and 58.86 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the days to fruit initiation were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 50.24, 44.71, 47.48 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 50.48, 44.93 and 47.70 for the year 2022, 2023 and the pooled mean respectively. Whereas utmost number of days to fruit initiation was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 65.65, 58.43 and 62.04 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 69.25, 61.64 and 65.45 for the year 2022, 2023 and the pooled mean respectively.

The minimum number of days to fruit initiation observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the number of days to fruit initiation on tomato plants. Studies indicate that SES enhances nutrient uptake and improves photosynthetic efficiency, both critical for energy allocation during the flowering and fruiting phases. Improved chlorophyll levels from SES also contribute to better light absorption, facilitating earlier fruit development. The results obtained were found in accordance with the results obtained by Dookie *et al.,* 2021 in tomato when applied with seaweed extract at different concentrations alike observations were also obtained by Ahmed *et al* 2023a and Villa *et al.,* 2023. Zinc and boron are essential micronutrients. Boron plays a key role in reproductive development by enhancing pollen viability and promoting successful fertilization. Its application has been linked to improved flower initiation and fruit set, contributing to earlier fruiting times. Adequate zinc levels are associated with improved flowering rates and faster fruit initiation which that zinc application can lead to a reduction in the time taken for plants to initiate fruiting. Khatri *et al.,* 2022 also reported improved plant growth with the conjugative approach of zinc and boron. Similar results for significant decrease in number of days to fruit initiation were also reported by Ahmed *et al* 2021 and Dixit *et al.,* 2021. Regarding the varieties. Variety V_2 exhibited the least number of days to fruit initiation, which could be attributed to varietal variability and distinct growth patterns. Naga Sivaiah *et al.,* 2013 and Fakhrabad *et al.,* 2019, found similar results while evaluating the fruiting potential of different tomato varieties.

The least no. of days taken to fruit initiation was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.23: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on fruit initiation of tomato

DAYS TO FRUIT INITIATION									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	65.65	58.61	**62.13**	58.43	52.16	**55.29**	62.04	55.05	**58.55**
T2	69.25	54.64	**61.95**	61.64	48.63	**55.13**	65.45	51.64	**58.54**
T3	69.36	54.19	**61.77**	61.73	48.23	**54.98**	65.54	51.21	**58.37**
T4	58.70	51.93	**55.32**	52.24	46.22	**49.23**	55.14	49.07	**52.11**
T5	58.72	51.55	**55.13**	52.26	45.88	**49.07**	55.83	48.88	**52.35**
T6	65.77	55.60	**60.68**	58.53	49.48	**54.01**	62.15	52.87	**57.51**
T7	62.87	57.55	**60.21**	55.96	51.22	**53.59**	59.75	54.71	**57.23**
T8	62.76	56.94	**59.85**	55.86	50.68	**53.27**	59.65	53.81	**56.73**
T9	59.51	53.60	**56.55**	52.96	47.70	**50.33**	56.23	50.65	**53.44**
T10	60.42	51.93	**56.18**	53.77	46.22	**50.00**	57.10	49.07	**53.09**
T11	57.12	50.48	**53.68**	50.84	44.93	**47.78**	53.98	47.70	**50.73**
T12	56.55	50.24	**53.52**	50.33	44.71	**47.63**	53.44	47.48	**50.57**
Mean V	**62.22**	**53.94**		**55.38**	**48.00**		**58.86**	**51.01**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.047	0.016	0.028	0.01	0.329	0.115
(V)	0.019	0.007	0.012	0.004	0.134	0.047
(T × V)	0.067	0.023	0.04	0.014	0.465	0.163

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% **+** B @ 0.2%, **T7**-Zn @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% **+** *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.1.9 Days to first picking

Days taken to first picking is a notable plant growth parameter which influences harvest timings, economic outcomes which leads to successful fruit production. Observation for the same were noted at 30, 60, 90 DAT and at 1st harvest. The results for days to first picking governed by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are described in Table 4.28. The resulys given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the days to first picking in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 28.

According to the results obtained for the treatments the least number of days to first picking obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 84.68, 77.06 and 80.87 for the year 2022, 2023 and pooled mean respectively, whereas the utmost number of days to first picking were observed in T_1 (control) for the year 2021-22 (97.86), 2022-23 (89.05) and the pooled mean (93.45).

Among both the studied varieties V_2 (Yellow Jubilee) showed minimum number of days to first picking *i.e.* 2021-22 (83.65), 2022-23 (76.12) and pooled mean (79.89), as compared to V_1 (Tomato no. 575) *i.e.* 98.89, 89.99 and 94.44 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the days to first picking at were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 75.90, 69.07 and 72.49 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 77.01, 70.08 and 73.55 for the year 2022, 2023 and the pooled mean respectively. Although utmost number of days to first picking were observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 104.83, 95.40 and 100.11 for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 103.42, 94.11 and 98.77 for the year 2022, 2023 and the pooled mean respectively.

The least no. of days taken to reach 1st picking observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the number of days to first picking on tomato plants. Studies indicate that SES has been shown to reduce the days to first picking in tomato plants. The hormonal compounds in seaweed extracts, particularly cytokinins and auxins, promote earlier flower initiation and fruit set. This leads to a quicker transition from flowering to fruiting, thereby shortening the time to first picking. The results obtained were found in accordance with the results obtained by Yao *et al.,* 2020 in tomato when applied with seaweed extract at different concentrations parallel outcomes were also obtained by Di Mola *et al.,* 2023b and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Boron plays a critical role in reproductive development by enhancing pollen viability and promoting successful fertilization. Its application has been linked to improved fruit set and quicker maturation, contributing to a reduction in the days to first picking. Zinc is essential for various processes, including activation of enzymes and synthesis of proteins. Adequate zinc levels have been associated with improved flowering rates and faster fruit initiation, ultimately leading to earlier harvests. Meena *et al.,* 2015 also reported improved plant growth with the combined approach of zinc and boron. Similar results for significant decrease in number of days to first picking were also reported by Ashraf *et al.,* 2020, Ahmed *et al.,* 2023b and Khatri *et al.,* 2022. Variety V_2 exhibited the lowest number of days to first picking, which could be related to varietal diversity and different growth habits. Javanmardi and Sattar, 2016 and Sanjida *et al*. (2020) found similar results when assessing various tomato cultivars for growth and yield potential.

The least number of days to first picking was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.24: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on days to first picking of tomato

DAYS TO FIRST PICKING									
	YEAR 2022			**YEAR 2023**			**POOLED**		
	V1	**V2**	**Mean T**	**V1**	**V2**	**Mean T**	**V1**	**V2**	**Mean T**
T1	104.83	90.88	**97.86**	95.40	82.70	**89.05**	100.11	86.79	**93.45**
T2	103.42	90.77	**97.10**	94.11	82.60	**88.36**	98.77	86.69	**92.73**
T3	102.18	90.10	**96.14**	92.99	81.99	**87.49**	97.59	86.04	**91.81**
T4	95.47	79.23	**87.35**	86.88	72.10	**79.49**	91.17	75.66	**83.42**
T5	95.14	78.08	**86.61**	86.58	71.05	**78.82**	90.86	74.56	**82.71**
T6	101.53	89.09	**95.31**	92.39	81.07	**86.73**	96.96	85.08	**91.02**
T7	101.18	86.37	**93.77**	92.07	78.60	**85.33**	96.62	82.48	**89.55**
T8	100.16	83.97	**92.06**	91.15	76.41	**83.78**	95.65	80.19	**87.92**
T9	97.82	82.39	**90.10**	89.01	74.97	**81.99**	93.41	78.68	**86.05**
T10	96.48	80.04	**88.26**	87.79	72.84	**80.32**	92.14	76.44	**84.29**
T11	95.03	77.01	**86.02**	86.47	70.08	**78.28**	90.75	73.55	**82.15**
T12	93.46	75.90	**84.68**	85.05	69.07	**77.06**	89.25	72.49	**80.87**
Mean V	**98.89**	**83.65**		**89.99**	**76.12**		**94.44**	**79.89**	

Factors	**CD**	**SEm±**	**CD**	**SEm±**	**CD**	**SEm±**
(T)	0.099	0.035	0.059	0.021	0.088	0.031
(V)	0.04	0.014	0.024	0.008	0.036	0.013
(T × V)	0.14	0.049	0.083	0.029	0.125	0.044

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2 Effect of foliar application of micronutrients and seaweed extract on the yield of tomato

Plant yield parameters are referred as specific measurements crucial for assessing the productivity and output of plant. They provide guidance in agricultural practices for optimizing crop management strategies and provide quantitative measures of various yield aspects, enabling analysis of the contribution of applied treatments in overall plant productivity. Application of seaweed extract (*Ascophyllum nodosum*) in combination with micronutrients (Zinc and Boron) showed significant positive results for both the studied varieties as compared to control.

4.2.1 Average fruit diameter (cm)

Fruit diameter is a critical plant yield parameter which directly impacts the total yield and productivity of fruiting plants. Larger fruit diameter is generally associated with higher yield as it reflects plant's ability to produce larger and better marketable fruits. The results for polar and equitorial fruit diameter influenced by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.29. The data shown in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the polar as well as equitorial fruit diameter in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 29 and 30.

a) Average equatorial fruit diameter (mm)

According to the results obtained for the treatments the maximum average polar fruit diameter was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 63.67 mm, 71.31 mm and 67.49 mm for the year 2022, 2023 and pooled mean respectively, whereas the least average polar fruit diameter was observed in T_1 (control) for the year 2021-22 (49.93 mm), 2022-23 (55.93 mm) and the pooled mean (52.93 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher average polar fruit diameter *i.e.* 2021-22 (58.18 mm), 2022-23 (65.16 mm) and pooled mean (61.67 mm), as compared to V_1 (Tomato no. 575) *i.e.* 52.89 mm, 59.24 mm and 56.06 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the average polar fruit diameter were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 67.74 mm, 75.88 mm and 71.81 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 64.99 mm, 72.79 mm and 68.89 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least average polar fruit diameter was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 49.86 mm, 55.85 mm and 52.86 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 50.00 mm, 56.00 mm and 53.00 mm for the year 2022, 2023 and the pooled mean respectively.

b) Average polar fruit diameter (cm)

According to the results obtained for the treatments the maximum average equitorial fruit diameter was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 62.54 mm, 70.04 mm and 66.29 mm for the year 2022, 2023 and pooled mean respectively, whereas the least average equitorial fruit diameter was observed in T_1 (control) for the year 2021-22 (46.37 mm), 2022-23 (51.93 mm) and the pooled mean (49.15 mm).

Among both the studied varieties V_2 (Yellow Jubilee) showed lesser average equitorial fruit diameter *i.e.* 2021-22 (52.84 mm), 2022-23 (59.19 mm) and pooled mean (56.02 mm), as compared to V_1 (Tomato no. 575) *i.e.* 54.65 mm, 61.20 mm and 57.92 mm for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for average equitorial fruit diameter were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 65.10 mm, 72.91 mm and 69.01 mm for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 64.15 mm, 71.85

mm and 68.00 mm for the year 2022, 2023 and the pooled mean respectively. Whereas least average equitorial fruit diameter was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 43.75 mm, 49.00 mm, 46.37 mm for the year 2022, 2023 and the pooled mean followed by T_2V_1 (Zn @ 0.2%) + (Tomato no. 575) *i.e.* 46.78 mm, 52.40 mm and 49.59 mm for the year 2022, 2023 and the pooled mean respectively.

The maximum fruit diameter observed in T_{12} could be due to the shared effect of SES and micronutrients. Application of SES has been shown to significantly increase the fruit diameter in tomato plants. The hormonal components found in seaweed extracts, particularly cytokinins and auxins, promote cell division and expansion, leading to larger fruit size. The results obtained were found in accordance with the results obtained by Villa *et al.,* 2023 in tomato when applied with seaweed extract at different concentrations similar results were also obtained by Ali *et al* 2019 and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Zinc is essential for various processes, including activation of enzymes and synthesis of proteins. Adequate zinc levels have been associated with improved fruit size and quality. Research shows that zinc application can lead to an increase in fruit diameter by enhancing overall plant health and vigor. Boron potrays a crucial role in formation of cell wall and reproductive development. Its application has been linked to improved fruit set and size. Boron enhances the structural integrity of the fruit, contributing to increased diameter. Dixit *et al.,* 2021also reported improved plant growth with the combined approach of zinc and boron. Similar results for significant increase in fruit diameter were also reported by Kaur and Kaur, 2020, Ali *et al.,* 2015 and Osman *et al.,* 2019. Variety V_2 had the largest fruit diameter, possibly due to differences in development patterns between varieties. Naga Sivaiah *et al*. (2013) and Roy and Munir, 2020 discovered similar results when evaluating the growth and productvity potential of multiple tomato varieties.

The maximum diameter for fruits was seen in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.25: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on fruit diameter (mm) of tomato

POLAR DIAMETER (mm)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	49.86	50.68	**49.93**	55.85	56.76	**55.93**	52.86	53.72	**52.93**
T2	50.00	53.79	**52.24**	56.00	60.25	**58.50**	53.00	57.02	**55.37**
T3	51.10	54.59	**52.84**	57.23	61.14	**59.18**	54.16	57.86	**56.01**
T4	53.68	59.06	**56.37**	60.12	66.14	**63.13**	56.90	62.60	**59.75**
T5	54.03	61.80	**57.92**	60.52	69.21	**64.87**	57.28	65.50	**61.39**
T6	51.91	56.59	**54.25**	58.14	63.39	**60.76**	55.03	59.99	**57.51**
T7	52.03	56.61	**54.32**	58.28	63.41	**60.84**	55.16	60.01	**57.59**
T8	52.13	57.22	**54.68**	58.39	64.08	**61.24**	55.26	60.65	**57.96**
T9	52.91	57.61	**55.26**	59.26	64.52	**61.89**	56.08	61.07	**58.58**
T10	52.80	58.18	**55.49**	59.13	65.16	**62.15**	55.96	61.67	**58.82**
T11	53.93	64.99	**59.46**	60.40	72.79	**66.60**	57.17	68.89	**63.03**
T12	59.59	67.74	**63.67**	66.74	75.88	**71.31**	63.17	71.81	**67.49**
Mean V	**52.89**	**58.18**		**59.24**	**65.16**		**56.06**	**61.67**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.379	0.133	0.429	0.150	0.396	0.139
(V)	0.155	0.054	0.175	0.061	0.162	0.057
(T × V)	0.536	0.188	0.607	0.212	0.559	0.196

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

Table 4.26: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on fruit diameter (mm) of tomato

EQUITORIAL DIAMETER (mm)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	43.75	48.98	**46.37**	49.00	54.86	**51.93**	46.37	51.92	**49.15**
T2	46.78	49.70	**48.24**	52.40	55.66	**54.03**	49.59	52.68	**51.14**
T3	50.16	48.91	**49.54**	56.18	54.79	**55.48**	53.17	51.85	**52.51**
T4	55.74	53.63	**54.68**	62.43	60.06	**61.25**	59.08	56.84	**57.96**
T5	57.24	55.89	**56.57**	64.11	62.60	**63.36**	60.68	59.24	**59.96**
T6	53.79	49.10	**51.45**	60.24	55.00	**57.62**	57.01	52.05	**54.53**
T7	55.09	49.60	**52.35**	61.71	55.55	**58.63**	58.40	52.57	**55.49**
T8	55.18	51.11	**53.15**	61.81	57.25	**59.53**	58.50	54.18	**56.34**
T9	55.95	52.97	**54.46**	62.66	59.33	**61.00**	59.31	56.15	**57.73**
T10	55.99	53.12	**54.56**	62.71	59.50	**61.10**	59.35	56.31	**57.83**
T11	57.96	64.15	**61.06**	64.92	71.85	**68.38**	61.44	68.00	**64.72**
T12	59.97	65.10	**62.54**	67.17	72.92	**70.04**	63.57	69.01	**66.29**
Mean V	**54.65**	**52.84**		**61.20**	**59.19**		**57.92**	**56.02**	

Factors	YEAR 2022 CD	YEAR 2022 SEm±	YEAR 2023 CD	YEAR 2023 SEm±	POOLED CD	POOLED SEm±
(T)	0.346	0.121	0.388	0.136	0.373	0.131
(V)	0.141	0.049	0.159	0.056	0.152	0.053
(T × V)	0.489	0.171	0.549	0.192	0.528	0.185

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.2 Number of locules per fruit

No. of locules play a significant role as a plant yield parameter which is important for determining productivity of tomato. Number of locules is closely related to yield potential of the crop as number of locules influence fruit width and weight affecting fruit size which in turns affect yield. The results for number of locules per fruit affected by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.31. The observations given in the table confirms that the application of ANSE and micronutrients in combination positively impacted the number of locules per fruit in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 31.

According to the results obtained for the treatments the maximum no. of locules were obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 6.27, 6.77 and 5.23 for the year 2022, 2023 and pooled mean respectively, whereas the least number of locules were observed in T_3 (B @ 0.2%) for the year 2021-22 (3.74), 2022-23 (3.57) and the pooled mean (3.70).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher number of locules per fruit *i.e.* 2021-22 (5.58), 2022-23 (5.72) and pooled mean (5.23), as compared to V_1 (Tomato no. 575) *i.e.* 3.40, 3.32 and 3.30 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the number of locules per fruit were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 8.81, 8.82 and 7.04 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + ANSE @ 0.2% (T_7) in the variety Yellow Jubilee (V_2) *i.e.* 6.80, 7.46 and 6.96 for the year 2022, 2023 and the pooled mean respectively. Whereas least no. of locules per fruit was seen in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 2.72, 3.24 and 2.98 for the year 2022, 2023 and the pooled mean followed by T_5V_1 {(ANSE @ 0.4%) + (Tomato no.

575)} *i.e.* 3.39, 3.24 and 3.15 for the year 2022, 2023 and the pooled mean respectively.

The maximum number of locules observed in T_{12} could be due to the shared impact of SES and micronutrients. The use of seaweed extract (SES) has been proven to considerably improve number of locules in tomato fruit. Seaweed extracts contain hormonal components, mainly cytokinins and auxins, which promote cell division and expansion, resulting in larger fruit size and more number of locules. The results obtained were found in accordance with the results obtained by Hussain *et al.,* 2021 in tomato when applied with seaweed extract at different concentrations alike outcomes were also obtained by Villa *et al* 2023 and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Zinc is required for several physiological functions, such as enzyme activation and protein synthesis. Adequate zinc levels have been linked to increased fruit size and quality. According to research, zinc application can enhance fruit diameter by improving general plant health and vigour, resulting in higher number of locules in larger fruits. Boron plays a critical function in construction of cell wall and reproductive development. Its use has been linked to increased fruit yield and size. Boron improves the structural integrity of the fruit, resulting in increased diameter and number of locules. Khatri *et al.,* 2022 also reported improved plant growth with the combined approach of zinc and boron. Similar results for significant increase in number of locules were also reported by Saha *et al.,* 2023, Mallick *et al.,* 2020 and Osman *et al.,* 2019. Variety V_2 had the largest number of locules, possibly due to differences in development patterns between varieties. Javanmardi and Sattar, 2016 and Meena *et al.,* 2015 discovered similar results when evaluating the growth and production potential of multiple tomato varieties.

The higher number of locules were observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.27: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of locules of tomato

NUMBER OF LOCULES									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	2.72	4.42	**3.91**	3.24	5.78	**4.59**	2.98	5.27	**4.25**
T2	3.40	5.78	**4.59**	3.40	4.76	**3.74**	3.23	5.70	**4.34**
T3	3.40	4.09	**3.74**	3.40	3.74	**3.57**	3.15	4.25	**3.70**
T4	3.40	4.76	**4.08**	3.74	4.76	**4.25**	3.57	4.59	**4.08**
T5	3.39	5.78	**4.59**	3.24	5.78	**4.25**	3.15	5.87	**4.51**
T6	3.40	4.76	**4.08**	3.40	5.10	**4.25**	3.40	5.27	**4.34**
T7	3.40	6.80	**4.08**	3.40	7.46	**5.43**	3.06	6.96	**5.05**
T8	3.40	4.76	**5.10**	3.74	4.76	**4.25**	3.40	5.70	**4.55**
T9	3.74	6.80	**5.27**	3.74	5.78	**4.76**	3.66	6.38	**5.02**
T10	3.40	4.76	**3.74**	3.40	4.76	**4.08**	3.23	4.76	**4.00**
T11	3.40	5.44	**4.42**	3.40	7.13	**5.27**	3.32	6.38	**4.85**
T12	3.74	8.81	**6.27**	3.26	8.82	**6.77**	3.49	7.04	**5.23**
Mean V	**3.40**	**5.58**		**3.32**	**5.72**		**3.30**	**5.68**	

Factors	YEAR 2022 CD	YEAR 2022 SEm±	YEAR 2023 CD	YEAR 2023 SEm±	POOLED CD	POOLED SEm±
(T)	1.189	0.416	1.253	0.439	0.439	0.153
(V)	0.486	0.17	0.512	0.179	0.179	0.063
(T × V)	1.682	0.589	1.772	0.621	0.619	0.217

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.3 Number of fruits per plant

No. of fruits per plant holds a significant importance as a plant yield parameter as it is crucial for determining overall productivity of plant. Higher number of fruits per plants indicates increase in yield. The results for number of fruits per plant influenced by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.32. The data given in the table confirms that the application of ANSE and micronutrients in combination certainly influenced the fruit count in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 32.

According to the results obtained for the treatments the utmost number of fruits per plant were obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 20.14, 30.21 and 25.17 for the year 2022, 2023 and pooled mean respectively, whereas the least no. of fruits per plant fruit was observed in T_1 (control) for the year 2021-22 (14.59), 2022-23 (21.88) and the pooled mean (18.24).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher no of fruits per plant fruit 2021-22 (17.76), 2022-23 (26.65) and pooled mean (22.20), as compared to V_1 (Tomato no. 575) *i.e.* 16.89, 25.34 and 21.12 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the no. of fruits per plant fruit were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 20.82, 31.23 and 26.02 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 19.87, 29.80 and 24.83 for the year 2022, 2023 and the pooled mean respectively. Whereas least fruit count was found in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 14.56, 21.84 and 18.20 for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 14.88, 22.32 and 18.60 for the year 2022, 2023 and the pooled mean respectively.

The utmost no. of fruits per plant noted in T_{12} at all the growth stages could be due to the shared effect of seaweed extract and micronutrients. Application of (SES) has been linked to a significant increase in the number of fruits per plant. Studies indicate that SES enhances overall plant health, leading to improved flowering and fruit set. Seaweed extracts enhanced chlorophyll content from SES contributes to better light absorption, facilitating higher fruit production. The results obtained were found in accordance with the results obtained by Hussain *et al.,* 2021 in tomato when applied with seaweed extract at different concentrations parallel outcomes were also reported by Dookie *et al.,* 2022 and Zodape *et al.,* 2011. Zinc and boron are essential micronutrients. Zinc is important various physiological activities in plants, including activation of enzymes and synthesis of protein which has been associated with raise fruit set and numbers of fruits per plant whereas boron critical factor in reproductive development by enhancing pollen viability and promoting successful fertilization. Its application has been linked to improved flower initiation and fruit set, contributing to an increased number of fruits. Ahmed *et al.,* 2023b also reported improved plant growth with the combined approach of zinc and boron. Similar results for significant increase in no. of fruits were also suggested by Saha *et al.,* 2023, Khatri *et al.,* 2021 and Gopal and Sarangtham, 2021. In terms of variety, V_2 produced the most fruits per plant, which could be ascribed to varietal diversity and unique growth patterns. Javanmardi and Sattar, 2016 and Patil *et al.,* 2010 discovered similar results when assessing various tomato varieties for yield potential.

The utmost fruit count was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.28: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on number of fruits per plant of tomato

NUMBER OF FRUITS PER PLANT									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	14.56	14.62	**14.59**	21.84	21.93	**21.88**	18.20	18.27	**18.24**
T2	14.88	15.63	**15.26**	22.32	23.45	**22.89**	18.60	19.54	**19.07**
T3	14.99	15.84	**15.41**	22.48	23.76	**23.12**	18.73	19.80	**19.27**
T4	17.89	19.35	**18.62**	26.84	29.03	**27.93**	22.36	24.19	**23.28**
T5	18.12	19.76	**18.94**	27.18	29.64	**28.41**	22.65	24.70	**23.68**
T6	15.04	16.64	**15.84**	22.56	24.96	**23.76**	18.80	20.80	**19.80**
T7	15.80	16.73	**16.27**	23.70	25.10	**24.40**	19.75	20.91	**20.33**
T8	17.08	17.36	**17.22**	25.61	26.04	**25.83**	21.34	21.70	**21.52**
T9	17.67	17.88	**17.78**	26.51	26.82	**26.66**	22.09	22.35	**22.22**
T10	17.88	18.73	**18.30**	26.82	28.09	**27.46**	22.35	23.41	**22.88**
T11	19.28	19.87	**19.57**	28.92	29.80	**29.36**	24.10	24.83	**24.47**
T12	19.46	20.82	**20.14**	29.19	31.23	**30.21**	24.32	26.02	**25.17**
Mean V	**16.89**	**17.76**		**25.34**	**26.65**		**21.12**	**22.20**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.093	0.033	0.143	0.05	0.119	0.042
(V)	0.038	0.013	0.058	0.02	0.049	0.017
(T × V)	0.132	0.046	0.202	0.071	0.169	0.059

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.4 Average fruit weight (g)

Average weight of fruit is a key plant yielding parameter which helps in measuring the yield of a fruiting plant. It provides the information about the individual weight of the fruits produced, which directly associated with overall yield. The results for average fruit weight governed by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.33. The data given in the table confirms that the application of ANSE in combination significantly influenced the average fruit weight fruit in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 33.

According to the results obtained for the treatments the maximum average fruit weight was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 99.00 g, 184.06 g and 141.53 g for the year 2022, 2023 and pooled mean respectively, although least average fruit weight was reported in T_1 (control) for the year 2021-22 (82.81 g), 2022-23 (87.88 g) and the pooled mean (85.35 g).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher average fruit weight *i.e.* 2021-22 (94.02 g), 2022-23 (153.80 g) and pooled mean (123.92 g), as compared to V_1 (Tomato no. 575) *i.e.* 91.42 g, 106.4 g and 98.89 g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the average fruit weight were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 100.21 g, 238.00 g and 167.89 g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 99.80 g, 219.97 g and 156.41 g for the year 2022, 2023 and the pooled mean respectively. Whereas least average fruit weight was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 80.85 g, 76.08 g and 78.47 g for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 82.64 g, 92.63 g and 92.89 g for the year 2022, 2023 and the pooled mean respectively.

The maximum average fruit weight observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. Application of SES has shown significant increase the fruit weight in tomato plants. The hormonal components found in seaweed extracts, particularly cytokinins and auxins, promote cell division and expansion, leading to larger fruit size. The results obtained were found in accordance with the results obtained by Subramaniyan *et al.,* 2023 in tomato when applied with seaweed extract at different concentrations parallel outcomes were reported by Ahmed *et al* 2023a and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Zinc is required for several physiological functions, such as enzyme activation and protein synthesis. Adequate zinc levels have been linked to increased fruit size and quality. According to research, zinc treatment can improve fruit weight by improving overall plant health and vigour. Boron is a key factor in cell wall construction and reproductive development. Its use has been associated to better fruit set and average fruit weight. Boron improves the structural integrity of the fruit, resulting in greater fruit weight. Dixit *et al.,* 2021also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in number of fruits per plant were also reported by Ali *et al.,* 2015, Sultana *et al.,* 2016 and Singh *et al.,* 2017. Variety V_2 recorded maximum average fruit weight, possibly due to differences in development patterns between varieties. Gurmani *et al.,* 2021 and Roy and Munir, 2020 discovered similar results when evaluating the yield potential of multiple tomato varieties.

The utmost no. of fruits was noted in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.29: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on average fruit weight of tomato

AVERAGE FRUIT WEIGHT (g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	80.85	84.77	**82.81**	76.08	99.68	**87.88**	78.47	92.23	**85.35**
T2	82.64	92.85	**87.74**	92.63	103.86	**98.24**	92.89	93.34	**93.12**
T3	82.83	93.15	**87.99**	95.52	121.29	**108.41**	91.74	107.55	**99.65**
T4	95.86	97.96	**96.91**	95.88	183.73	**139.80**	102.58	133.30	**117.94**
T5	96.76	98.17	**97.47**	121.75	179.07	**150.41**	110.78	138.33	**124.56**
T6	84.87	94.98	**89.93**	96.03	131.16	**113.60**	92.56	112.53	**102.55**
T7	87.97	93.82	**90.90**	103.05	137.54	**120.29**	92.84	115.19	**104.02**
T8	89.09	93.90	**91.50**	111.58	139.92	**125.75**	108.96	113.05	**111.01**
T9	92.85	94.77	**93.81**	120.04	132.21	**126.12**	104.88	118.34	**111.61**
T10	93.89	97.88	**95.89**	107.19	170.76	**138.97**	90.38	139.35	**114.87**
T11	97.60	99.80	**98.70**	115.13	219.97	**167.55**	104.95	156.41	**130.68**
T12	97.78	100.21	**99.00**	130.12	238.00	**184.06**	115.16	167.89	**141.53**
Mean V	**91.42**	**94.02**		**106.4**	**153.8**		**98.89**	**123.92**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.322	0.113	4.338	1.519	2.21	0.774
(V)	0.131	0.046	1.771	0.62	0.902	0.316
(T × V)	0.455	0.159	6.134	2.148	3.126	1.094

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.5 Yield per plant (kg)

Yield per plant is a parameter which plays a crucial role determining overall crop productivity. It directly influences the overall yield of the crop and is essential for assessing its success. The results for yield affected by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.34. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the yield per plant fruit in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 34.

According to the findings observed for the treatments the utmost yield per plant was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 1.97 kg, 2.76 kg and 2.37 kg for the year 2022, 2023 and pooled mean respectively, whereas the least yield per plant was observed in T_1 (control) for the year 2021-22 (1.19 kg), 2022-23 (1.67 kg) and the pooled mean (1.43 kg).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher yield per plant *i.e.* 2021-22 (1.62 kg), 2022-23 (2.27 kg) and pooled mean (1.94 kg), as compared to V_1 (Tomato no. 575) *i.e.* 1.57 kg, 2.20 kg and 1.89 kg for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the yield per plant fruit were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 2.06 kg, 2.89 kg and 2.47 kg for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 1.96 kg, 2.74 kg and 2.35 kg for the year 2022, 2023 and the pooled mean respectively. Whereas least yield per plant was seen in combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 1.16 kg, 1.63 kg and 1.40 kg for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 1.22 kg, 1.72 kg and 1.47 kg for the year 2022, 2023 and the pooled mean respectively.

The maximum yield per plant observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. The application of SES is associated with a considerable increase in plant production. According to studies, SES improves overall plant health, which leads to better flowering and fruit set. The increased chlorophyll concentration from SES contributes to greater light absorption, allowing increased fruit production. The results obtained were found in accordance with the results obtained by Yao *et al.,* 2020 in tomato when applied with seaweed extract at different concentrations parallel outcomes were also noted by Sîrbu *et al.,* 2022 and Zodape *et al.,* 2011. Zinc and boron are critical micronutrients. Zinc is required for a variety of physiological functions in plants, including protein synthesis and activation of various enzymes, which have been linked to increased fruit set and higher yield per plant, whereas boron is critical for reproductive development by increasing pollen viability and promoting successful fertilisation. Its application has been associated to better flower initiation and fruit set, resulting in a higher yield per plant. Dixit *et al.,* 2021 also reported improved yield with the combined approach of zinc and boron. Similar results for significant increase in yield per plant were also reported by Mallick *et al.,* 2020, Khatri *et al.,* 2021 and Ashraf *et al.,* 2020. In terms of variety, V_2 produced the maximum yield per plant, which could be a result of varietal diversity and unique growth patterns. Fakhrabad *et al.,* 2019, Gurmani *et al.,* 2016 and Patil *et al.,* 2010 discovered similar results when assessing various tomato varieties for yield potential.

The utmost yield plant^{-1} was noted in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.30: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on yield per plant of tomato

YIELD PER PLANT (kg)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	1.16	1.27	**1.19**	1.63	1.79	**1.67**	1.40	1.53	**1.43**
T2	1.22	1.37	**1.32**	1.72	1.91	**1.85**	1.47	1.64	**1.59**
T3	1.30	1.38	**1.34**	1.82	1.93	**1.87**	1.56	1.66	**1.61**
T4	1.69	1.87	**1.78**	2.37	2.62	**2.50**	2.03	2.25	**2.14**
T5	1.73	1.92	**1.82**	2.43	2.69	**2.56**	2.08	2.30	**2.19**
T6	1.40	1.41	**1.41**	1.95	1.98	**1.97**	1.67	1.69	**1.68**
T7	1.45	1.46	**1.46**	2.04	2.05	**2.04**	1.75	1.76	**1.75**
T8	1.53	1.58	**1.56**	2.14	2.22	**2.18**	1.83	1.90	**1.87**
T9	1.62	1.67	**1.65**	2.27	2.35	**2.31**	1.95	2.01	**1.98**
T10	1.66	1.81	**1.73**	2.32	2.54	**2.43**	1.99	2.17	**2.08**
T11	1.86	1.96	**1.91**	2.60	2.74	**2.67**	2.23	2.35	**2.29**
T12	1.88	2.06	**1.97**	2.63	2.89	**2.76**	2.26	2.47	**2.37**
Mean V	**1.57**	**1.62**		**2.20**	**2.27**		**1.89**	**1.94**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.012	0.004	0.017	0.006	0.014	0.005
(V)	0.005	0.002	0.007	0.002	0.006	0.002
(T × V)	0.017	0.006	0.023	0.008	0.02	0.007

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.6 Total marketable yield (q/ha)

Total marketable yield is referred as the produce that meets the sales and consumption standards of a crop. It includes the fruits that are suitable for market purpose on the bases of size, shape and color; it excludes the diseased or defected fruits. The results for total marketable yield determined by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.35. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the total marketable yield in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 35.

According to the findings obtained for the treatments the highest total marketable yield was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 729.65 q/ha, 1022.25 q/ha and 877.80 q/ha for the year 2022, 2023 and pooled mean respectively, whereas the least total marketable yield was observed in T_1 (control) for the year 2021-22 (440.75 q/ha), 2022-23 (618.53 q/ha) and the pooled mean (529.64 q/ha).

Among both the studied varieties V_2 (Yellow Jubilee) showed highest total marketable yield *i.e.* 2021-22 (600.02 q/ha), 2022-23 (840.76 q/ha) and pooled mean (718.54 q/ha), as compared to V_1 (Tomato no. 575) *i.e.* 581.48 q/ha, 814.84 q/ha and 700.02 q/ha for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the total marketable yield were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 762.98 q/ha, 1070.40 q/ha and 914.84 q/ha for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Yellow Jubilee (V_2) *i.e.* 725.94 q/ha, 1014.84 q/ha and 870.39 q/ha for the year 2022, 2023 and the pooled mean respectively. Whereas least total marketable yield was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 429.63 q/ha, 603.72 q/ha and 518.53 q/ha for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 451.85 q/ha, 637.05 q/ha and 544.46 q/ha for the year 2022, 2023 and the pooled mean respectively.

The maximum total marketable yield observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. The application of SES has been associated to a considerable increase in plant production. According to studies, SES improves overall plant health, which resulted into better flowering, fruit seting and rised marketable yield with lesser diseased or unmarketable fruits. The increased chlorophyll concentration from SES contributes to greater light absorption, allowing increased fruit production. The results obtained were found in accordance with the results obtained by Khatri *et al.,* 2022 in tomato when applied with seaweed extract at different concentrations parallel effects were also noted by Murtic *et al.,* 2018 and Yao *et al.,* 2020. Zinc and boron are critical micronutrients. Zinc is required for a variety of functions in plants, including activation of various enzymes and synthesis of protein, which have been linked to increased fruit set and higher marketable yield, whereas boron is critical for reproductive development by increasing pollen viability and promoting successful fertilisation. Its application has been associated to better flower initiation, fruit set, resulting in a higher total marketable yield. Gopal and Sarangtham, 2021 also reported improved yield with the integrated approach of zinc and boron. Similar results for significant increase in yield per plant were also reported by Sultana *et al.,* 2016 and Ashraf *et al.,* 2020. In terms of variety, V_2 produced the maximum yield per plant, which could be a result of varietal diversity and unique growth patterns. Fakhrabad *et al.,* 2019, Gurmani *et al.,* 2016 and Patil *et al.,* 2010 discovered similar results when assessing various tomato varieties for yield potential.

The maximum total marketable yield was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.31: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on yield per hectare of tomato

YIELD PER HECTARE (q/ha)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	429.63	470.38	**440.75**	603.72	662.98	**618.53**	518.53	566.68	**529.64**
T2	451.85	507.42	**488.90**	637.05	707.43	**685.20**	544.46	607.42	**588.90**
T3	481.48	511.12	**496.31**	674.09	714.83	**692.61**	577.79	614.83	**596.31**
T4	625.93	692.61	**659.28**	877.80	970.40	**925.95**	751.87	833.36	**792.61**
T5	640.74	711.13	**674.09**	900.02	996.32	**948.17**	770.39	851.87	**811.13**
T6	518.52	522.24	**522.24**	722.24	733.35	**729.65**	618.53	625.94	**622.24**
T7	537.04	540.75	**540.75**	755.56	759.28	**755.58**	648.17	651.87	**648.17**
T8	566.67	585.20	**577.79**	792.61	822.24	**807.43**	677.80	703.72	**692.61**
T9	600.00	618.53	**611.13**	840.76	870.39	**855.58**	722.24	744.46	**733.35**
T10	614.81	670.39	**640.76**	859.28	940.77	**900.02**	737.06	803.72	**770.39**
T11	688.89	725.94	**707.43**	962.99	1014.84	**988.91**	825.95	870.39	**848.17**
T12	696.30	762.98	**729.65**	974.10	1070.40	**1022.25**	837.06	914.84	**877.80**
Mean V	**581.48**	**600.02**		**814.84**	**840.76**		**700.02**	**718.54**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	4.417	1.547	6.21	2.175	2.989	1.047
(V)	1.803	0.631	2.535	0.888	1.22	0.427
(T × V)	6.246	2.187	8.782	3.075	4.227	1.48

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.2.7 Harvest duration (days)

Harvest duration is refers to the period during which the crop was harvested after reaching maturity. It can be influenced by environmental conditions, varietal character and growing conditions. The results for harvest duration influenced by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.35. The data noted in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the harvest duration in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 35.

According to the results obtained for the treatments the maximum harvest duration was observed in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 21.87, 24.21 and 23.04 for the year 2022, 2023 and pooled mean respectively, although the least harvest was observed in T_1 (control) for the year 2021-22 (16.74), 2022-23 (18.98) and the pooled mean (17.86).

Among both the studied varieties V_2 (Yellow Jubilee) showed maximum harvest duration *i.e.* 2021-22 (19.49), 2022-23 (21.82) and pooled mean (20.65), as compared to V_1 (Tomato no. 575) *i.e.* 19.47, 21.73 and 20.61 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the harvest duration were obtained for variety Yellow Jubilee (V_1) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 21.95, 24.28 and 23.11 for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) in the variety Yellow Jubilee (V_2) *i.e.* 21.95, 24.28 and 23.11 for the year 2022, 2023 and the pooled mean respectively. Whereas least harvest duration was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 16.68, 18.91 and 17.80 for the year 2022, 2023 and the pooled mean followed by T_1V_2 {(Control) + (Yellow Jubilee)} *i.e.* 16.79, 18.93 and 17.92 for the year 2022, 2023 and the pooled mean respectively.

The maximum harvest duration observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES is associated with increase in the harvesting duration of tomato fruits. This is primarily due to the hormonal effects of SES, which promote earlier flowering and fruit set, allowing for a more extended period of fruit availability. Studies indicate that SES can lead to a more staggered fruit ripening process, thereby prolonging the harvesting window facilitating not only earlier fruit maturation but also sustained fruit production over a longer period. The results obtained were found in accordance with the results obtained by Sirbu *et al.*, 2022 in tomato when applied with seaweed extract at different concentrations parallel results were also obtained by Villa *et al.,* 2023 and Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients, adequate levels of zinc and boron have been associated with improved flowering rates and fruit retention, which can extend the harvesting duration by ensuring that fruits remain viable for picking over a longer time frame Dixit *et al.,* 2021 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in harvest duration were also proclaimed by Mallick *et al.,* 2020, Ahmed *et al.,* 2021 and Gopal and Sarangtham, 2021. In terms of varieties, variety V_2 had the longest harvest duration among both the studied varieties, which could be ascribed to varietal diversity and different growth patterns. Naga Sivaiah *et al*. (2013), Roy and Monir, 2020 and Sanjida *et al*. (2020) found similar results when assessing various tomato cultivars for growth and yield potential.

The prolonged harvest duration was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.32: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on harvest duration of tomato

HARVEST DURATION									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	16.68	16.79	**16.74**	18.91	19.04	**18.98**	17.80	17.92	**17.86**
T2	17.91	17.35	**17.63**	20.24	18.93	**19.59**	19.08	18.14	**18.61**
T3	17.89	17.91	**17.90**	20.20	20.22	**20.21**	19.04	19.07	**19.06**
T4	21.22	20.42	**20.82**	23.64	22.47	**23.05**	22.43	21.45	**21.94**
T5	20.65	21.26	**20.96**	23.13	23.68	**23.41**	21.89	22.47	**22.18**
T6	18.44	18.85	**18.65**	20.92	21.08	**21.00**	19.67	19.97	**19.82**
T7	19.20	18.94	**19.07**	21.71	21.07	**21.39**	20.46	20.01	**20.23**
T8	18.85	19.18	**19.01**	20.94	21.21	**21.08**	19.90	20.19	**20.05**
T9	19.84	19.90	**19.87**	22.19	22.09	**22.14**	21.01	21.00	**21.01**
T10	19.84	20.33	**20.08**	22.12	23.00	**22.56**	20.98	21.66	**21.32**
T11	21.19	21.13	**21.16**	23.60	23.83	**23.72**	22.40	22.48	**22.44**
T12	21.95	21.79	**21.87**	24.28	24.13	**24.21**	23.11	22.96	**23.04**
Mean V	**19.47**	**19.49**		**21.82**	**21.73**		**20.65**	**20.61**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.278	0.097	0.316	0.111	0.249	0.087
(V)	0.113	0.04	0.182	0.045	0.153	0.036
(T × V)	0.392	0.137	0.447	0.157	0.353	0.124

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3 Effect of foliar application of micronutrients and seaweed extract on biochemical characters of tomato

Boichemical parameters play a crucial role in plant growth and development by reflecting the physiological processes occur within plant parts. It defines plant's ability to adapt in different environments, stress response and nutrient utilization which determines overall plant health and quality of produce. Exposure of plant to different chemicals and nutritional interventions can alter various biochemical characters in plants. Application of seaweed extract (*Ascophyllum nodosum*) in combination with micronutrients (Zinc and Boron) showed significant positive results for both the studied varieties as compared to control.

4.3.1 Total soluble solids (TSS) (°Brix)

Total soluble solids serve as an important biochemical character in assessing the quality of crop produce mostly fruits and vegetables. Monitoring TSS is important for determining the suitable harvest stage for better post harvest storage and handling. The results for total soluble solids affected by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.37. The data given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the total soluble solids in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 37.

According to the results obtained for the treatments the utmost amount of total soluble solids was acquired in T_7 (Zn @ 0.2% + ANSE @ 0.2%) *i.e.* 5.32, 5.35 and 5.34 for the year 2022, 2023 and pooled mean respectively, whereas the least amount of total soluble solids fruit was observed in T_2 (Zn @ 0.2%) for the year 2021-22 (4.37), 2022-23 (4.36) and the pooled mean (4.38).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher total soluble solids *i.e.* 2021-22 (5.26), 2022-23 (5.29) and pooled mean (5.28), as compared to V_1 (Tomato no. 575) *i.e.* 4.38, 4.40 and 4.39 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the total soluble solids were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + ANSE @ 0.2% (T_7) *i.e.* 6.03, 6.06 and 6.05 for the year 2022, 2023 and pooled mean followed by the application of (T_{10}) in the variety Yellow Jubilee (V_2) *i.e.* 5.93, 5.96 and 5.94 for the year 2022, 2023 and the pooled mean respectively. Whereas least TSS was observed in the combination T_8V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} *i.e.* 4.12, 4.14 and 4.13 for the year 2022, 2023 and the pooled mean followed by T_2V_2 {(Zn @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)} *i.e.* 4.22, 4.24 and 4.23 for the year 2022, 2023 and the pooled mean respectively.

Highest TSS was observed in T_7 could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the TSS of tomato. The application of SES improves overall fruit quality, including TSS, due to its rich content of natural growth hormones such as cytokinins and auxins enhancing photosynthetic efficiency and nutrient uptake crucial for the synthesis of carbohydrates, which stimulate metabolic processes involved in sugar accumulation in fruits The results obtained were found in accordance with the results obtained by Subramaniyan *et al.*, 2023 in tomato when applied with seaweed extract at different concentrations parallel outcomes were also described by Ahmed *et al.,* 2021 and Di Mola *et al.,* 2023a. Zinc is an essential micronutrient that plays a vital role in various physiological processes, including enzyme activation which has been associated with increased fruit quality, including higher TSS. Zinc application enhances the metabolic pathways involved in sugar accumulation, further boosting TSS levels in tomatoes. Prasad *et al.,* 2021 also noted improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in TSS were also stated by Ahmed *et al.,* 2021 and Sathya *et al.,* 2010. In terms of varieties, the maximum TSS was recorded in variety V_2 as different varieties exhibit marked difference in TSS content e.g. processing varieties show higher TSS as compared to fresh market Varieties. Gurmani *et al.,* 2012 as well as Sanjida *et al.,* 2020 discovered similar results while evaluating various tomato cultivars for growth and production potential.

The maximum TSS was seen in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.33: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on total soluble solids (TSS) (°Brix)

TSS (°Brix)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	4.32	4.52	**4.42**	4.34	4.54	**4.44**	4.33	4.54	**4.43**
T2	4.52	4.22	**4.37**	4.54	4.24	**4.39**	4.53	4.23	**4.38**
T3	4.72	4.62	**4.67**	4.75	4.65	**4.70**	4.73	4.63	**4.68**
T4	4.22	5.43	**4.83**	4.24	5.46	**4.85**	4.23	5.44	**4.84**
T5	3.62	5.43	**4.53**	3.64	5.46	**4.55**	3.63	5.44	**4.53**
T6	4.72	5.23	**4.98**	4.75	5.25	**5.00**	4.74	5.24	**4.99**
T7	4.62	6.03	**5.32**	4.65	6.06	**5.35**	4.64	6.05	**5.34**
T8	4.12	5.33	**4.73**	4.14	5.36	**4.75**	4.13	5.34	**4.74**
T9	4.22	5.63	**4.92**	4.24	5.66	**4.95**	4.23	5.64	**4.94**
T10	4.42	5.93	**5.18**	4.44	5.96	**5.20**	4.44	5.94	**5.19**
T11	4.62	5.03	**4.83**	4.65	5.05	**4.85**	4.63	5.04	**4.84**
T12	4.42	5.73	**5.08**	4.44	5.76	**5.10**	4.44	5.75	**5.09**
Mean V	**4.38**	**5.26**		**4.40**	**5.29**		**4.39**	**5.28**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.008	0.003	0.022	0.008	0.011	0.004
(V)	0.003	0.001	0.009	0.003	0.005	0.002
(T × V)	0.11	0.004	0.031	0.011	0.016	0.006

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.2 Total soluble sugars (mg/g)

Total soluble sugars serve as an important biochemical character significantly influencing fruit quality, sweetness and processing efficiency. Increased sugar content can enhance sweetness of fresh tomatoes and improve the yield and quality which are critical factors for consumer preference, marketability. The results for total soluble sugar determined by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are shown in Table 4.38. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the total soluble sugars in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 38.

According to the results obtained for the treatments the maximum amount of total soluble sugarss was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 2.134 mg/g, 3.260 mg/g and 2.678 mg/g for the year 2022, 2023 and pooled mean respectively, whereas the least total soluble sugars were observed in T_2 (Zn @ 0.2%) for the year 2021-22 (1.638 mg/g), 2022-23 (1.587 mg/g) and the pooled mean (1.682 mg/g).

Among both the studied varieties V_1 (Tomato no. 575) showed higher total soluble sugars *i.e.* 2021-22 (1.907 mg/g), 2022-23 (3.059 mg/g) and pooled mean (2.518 mg/g), as compared to V_2 (Yellow Jubilee) *i.e.* 1.823, 1.828 and 1.859 for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the total soluble sugars were obtained for variety Tomato no. 575 (V_1) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 2.256 mg/g, 4.393 mg/g and 3.323 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + ANSE @ 0.2% (T_7) in the variety Tomato no. 575 (V_1) *i.e.* 2.256 mg/g, 3.890 mg/g and 3.117 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least amount of total soluble solids fruit was observed in the combination T_2V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} *i.e.* 1.57 mg/g, 0.980 mg/g and 1.310 mg/g for the year 2022, 2023 and the pooled mean followed by T_3V_2 {(B @ 0.2%) + (Yellow Jubilee)} *i.e.* 1.618 mg/g, 1.650 mg/g and 1.663 mg/g for the year 2022, 2023 and the pooled mean respectively.

The utmost total soluble sugar content was observed in T_{12} could be due to the shared effect of SES and micronutrients. Incorporation of SES has been shown to significantly enhance total soluble sugar content in tomato fruits. total soluble sugar content The results obtained were found in accordance with the results obtained by Rajendran *et al.,* 2022 in tomato when applied with seaweed extract at different concentrations parallel outcomes were also defined by Sasikala *et al.,* 2016. Zinc and boron are essential micronutrients. Adequate zinc and boron levels have been associated with increased total soluble sugars in tomatoes. Research indicates that zinc application can enhance the metabolic pathways involved in sugar accumulation, further boosting total soluble sugar levels. Prasad *et al.,* 2021 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in total soluble sugar were also outlined by Singh *et al.,* 2017 and Xu *et al.,* 2021. In terms of varieties, the highest total soluble sugar was recorded in variety V_1 among both the studied varieties, which could be attributed to varietal diversity and distinct growth behaviours. Genetic traits play a fundamental role in determining soluble sugar content. Specific genes, such as those encoding cell wall invertase (LIN5), have been identified as key regulators of sugar accumulation in tomato fruits. Gurmani *et al.,* 2012 as well as Sanjida *et al.,* 2020 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The utmost values for total soluble sugar was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.34: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on total soluble sugars (mg/g) of tomato

TOTAL SOLUBLE SUGARS (mg/g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	1.940	1.676	**1.808**	2.857	1.323	**2.090**	2.433	1.527	**1.980**
T2	1.698	1.578	**1.638**	1.717	0.980	**1.587**	1.713	1.310	**1.682**
T3	1.810	1.618	**1.714**	1.523	1.650	**1.615**	1.700	1.663	**1.738**
T4	1.645	2.004	**1.825**	3.150	1.513	**2.065**	2.453	1.797	**1.882**
T5	1.859	1.889	**1.874**	3.353	1.460	**2.407**	2.640	1.710	**2.175**
T6	1.860	1.844	**1.852**	3.483	1.650	**2.567**	2.710	1.780	**2.245**
T7	2.256	1.682	**1.969**	3.890	2.437	**3.163**	3.117	2.087	**2.602**
T8	1.705	1.584	**1.644**	3.360	3.023	**3.192**	2.567	2.337	**2.452**
T9	1.817	2.230	**2.023**	3.640	2.110	**2.875**	2.760	2.210	**2.485**
T10	2.170	1.868	**2.019**	1.323	1.817	**1.670**	1.827	1.650	**1.755**
T11	1.867	1.896	**1.881**	4.020	2.447	**3.233**	2.977	2.207	**2.592**
T12	2.256	2.012	**2.134**	4.393	2.127	**3.260**	3.323	2.033	**2.678**
Mean V	**1.907**	**1.823**		**3.059**	**1.828**		**2.518**	**1.859**	

Factors	**CD**	**SEm±**	**CD**	**SEm±**	**CD**	**SEm±**
(T)	0.123	0.043	0.108	0.038	0.076	0.027
(V)	0.050	0.018	0.044	0.015	0.031	0.011
(T × V)	0.173	0.061	0.152	0.053	0.108	0.038

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.3 Total reducing sugar (mg/g)

Total reducing sugars are carbohydrates which due to the presence of a free aldehyde or ketone group can also act as reducing agents. They serve as an important biochemical character and have a significant role in food chemistry, enhancing flavours and colors through Maillard reaction influencing fruit quality, sweetness and processing efficiency. The results for total soluble sugar determined by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.39. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the total reducing sugars in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 39.

According to the results obtained for the treatments the maximum amount of reducing sugars was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 1.156 mg/g, 1.799 mg/g and 1.450 mg/g for the year 2022, 2023 and pooled mean respectively, whereas the least reducing sugars were observed in T_3 (B @ 0.2%) for the year 2021-22 (0.651 mg/g), 2022-23 (0.642 mg/g) and the pooled mean (0.658 mg/g).

Among both the studied varieties V_1 (Tomato no. 575) showed higher amount of reducing sugars *i.e.* 2021-22 (1.041 mg/g), 2022-23 (1.122 mg/g) and pooled mean (1.081 mg/g), as compared to V_2 (Yellow Jubilee) *i.e.* 0.922 mg/g, 1.120 mg/g and 1.021 mg/g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for reducing sugars were obtained for variety Tomato no. 575 (V_1) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 1.287 mg/g, 1.896 mg/g and 1.519 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) in the variety Tomato no. 575 (V_1) *i.e.* 1.232 mg/g, 1.702 mg/g and 1.381 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least reducing sugar content was seen in the combination T_3V_2 {(B @ 0.2%) + (Yellow Jubilee)} *i.e.* 0.623 mg/g, 0.459 mg/g and 0.569 mg/g for the year 2022, 2023 and the pooled mean followed by T_8V_1 {(Zn @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)} *i.e.* 0.648 mg/g, 0.778 mg/g and 0.733 mg/g for the year 2022, 2023 and the pooled mean respectively.

The utmost total reducing sugar content was found in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the total reducing sugars in tomato fruits. The natural growth hormones present in seaweed extracts, such as cytokinins and auxins, stimulate metabolic processes that are crucial for sugar accumulation in fruits. This resulted in an increase in total reducing sugars, contributing to better flavor and overall fruit quality. The results obtained were found in accordance with the results obtained by Rajendran *et al.,* 2022 in tomato when applied with seaweed extract at different concentrations parallel observations were also obtained by Mallick *et al.,* 2021 and Subramaniyan *et al.,* 2022. Zinc and boron are essential micronutrients. Adequate zinc and boron levels have been associated with increased total reducing sugars in tomatoes. Various studies indicates that zinc application can enhance the metabolic pathways involved in sugar accumulation, further boosting total reducing sugar levels. Sandilya *et al.,* 2023 also reported improved reducing sugar content with the intigrated approach of zinc and boron. Similar results for significant increase in total reducing sugar were also mentioned by Singh *et al.,* 2017 and Xu *et al.,* 2021. In terms of varieties, the maximum reducing sugar was found in variety V_1 among both the studied varieties, which could be attributed to varietal diversity and distinct growth behaviours. Genetic traits play a fundamental role in determining reducing sugar content. Specific genes, such as those encoding cell wall invertase (LIN5), have been identified as key regulators of sugar accumulation in tomato fruits. Gurmani *et al.,* 2012 and Roy and Monir, 2020 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The rise in reducing sugars in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.35: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on reducing sugar (mg/g) of tomato

REDUCING SUGAR (mg/g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	1.065	0.715	**0.890**	1.118	0.907	**1.013**	1.091	0.811	**0.951**
T2	1.099	1.020	**1.059**	0.991	0.495	**0.666**	0.989	0.757	**1.016**
T3	0.678	0.623	**0.651**	0.873	0.459	**0.642**	0.748	0.569	**0.658**
T4	0.986	1.218	**1.112**	1.457	0.893	**0.976**	1.278	1.065	**1.027**
T5	1.185	0.832	**1.008**	1.264	1.324	**1.294**	1.224	1.078	**1.151**
T6	1.107	0.743	**0.925**	1.232	1.540	**1.386**	1.17	1.142	**1.156**
T7	1.143	1.060	**1.102**	1.110	1.215	**1.163**	1.126	1.138	**1.132**
T8	0.648	0.705	**0.677**	0.778	1.011	**0.895**	0.733	1.11	**0.921**
T9	1.232	0.865	**1.048**	0.877	0.876	**0.876**	0.951	1.081	**1.018**
T10	1.143	0.865	**1.028**	0.818	1.514	**1.166**	1.005	0.938	**0.972**
T11	1.232	1.060	**1.102**	1.702	1.045	**1.374**	1.381	1.139	**1.139**
T12	1.287	1.026	**1.156**	1.896	1.500	**1.699**	1.519	1.183	**1.351**
Mean V	**1.041**	**0.922**		**1.122**	**1.120**		**1.081**	**1.021**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.005	0.002	0.009	0.003	0.005	0.002
(V)	0.002	0.001	0.004	0.001	0.002	0.001
(T × V)	0.007	0.002	0.013	0.004	0.008	0.003

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.4 Non reducing sugar (mg/g)

Non reducing sugars, primarily sucrose plays a significant role as a biochemical character in tomatoes, contributing to various aspects of fruit quality, plant metabolism and health benefits. It acts as signalling molecule that regulates various physiological processes in plants including fruit set, growth and ripening. They are also associated with health benefits by enhancing bioavailability of of other beneficial compounds present in tomato such as vitamins and antioxidants. The results for total soluble sugar determined by the foliar spray of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.40. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the non reducing sugars in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 40.

According to the results obtained for the treatments the maximum non reducing sugar was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 1.086 mg/g, 1.987 mg/g and 1.479 mg/g for the year 2022, 2023 and pooled mean respectively, whereas the least non reducing sugar was observed in T_2 (Zn @ 0.2%) for the year 2021-22 (0.579 mg/g), 2022-23 (0.671 mg/g) and the pooled mean (0.692 mg/g).

Among both the studied varieties V_1 (Tomato no. 575) showed higher non amount of reducing sugars *i.e.* 2021-22 (0.901 mg/g), 2022-23 (1.937 mg/g) and pooled mean (1.402 mg/g), as compared to V_2 (Yellow Jubilee) *i.e.* 0.866 mg/g, 0.708 mg/g and 0.805 mg/g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the non reducing sugars were obtained for variety Tomato no. 575 (V_1) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 1.236 mg/g, 3.346 mg/g and 2.142 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + ANSE @ 0.2% (T_7) in the variety Tomato no. 575 (V_1) *i.e.* 1.187 mg/g, 2.781 mg/g and 1.947 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least amount of non reducing sugars were seen in the combination T_2V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} *i.e.* 0.558 mg/g, 0.484 mg/g and 0.521 mg/g for the year 2022, 2023 and the pooled mean followed by T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 0.599 mg/g, 0.650 mg/g and 0.691 mg/g for the year 2022, 2023 and the pooled mean respectively.

The utmost non reducing sugar content was observed in T_{12} at all observed growth stages could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the non reducing sugars in tomato fruits. The natural growth hormones present in seaweed extracts, such as cytokinins and auxins, stimulate metabolic processes that are crucial for sugar accumulation in fruits. This leads to an increase in non reducing sugars, contributing to better flavor and overall fruit quality. The results obtained were found in accordance with the results obtained by Rajendran *et al.,* 2022 in tomato when applied with seaweed extract at different concentrations parallel results were also obtained by Subramaniyan *et al.,* 2022. Zinc and boron are essential micronutrients. Adequate zinc and boron levels have been associated with increased non reducing sugars in tomatoes. Various studies indicates that zinc application can enhance the metabolic pathways involved in sugar accumulation, further boosting non reducing sugar levels. Sandilya *et al.,* 2023 also reported improved reducing sugar content with the collaborative approach of zinc and boron. Similar results for significant increase in plant height were also reported by Singh *et al.,* 2017 and Xu *et al.,* 2021. In terms of varieties, the utmost non reducing sugar was recorded in variety V_1 among both the studied varieties, which could be attributed to varietal diversity and distinct growth behaviours. Genetic traits play a fundamental role in determining non reducing sugar content. Specific genes, such as those encoding cell wall invertase (LIN5), have been identified as key regulators of sugar accumulation in tomato fruits. Gurmani *et al.,* 2012 and Roy and Monir, 2020 discovered similar results while evaluating various tomato cultivars for biochemical characteristics.

The maximum reducing sugar was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.36: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on non reducing sugar (mg/g) of tomato

NON REDUCING SUGAR (mg/100g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	0.961	0.875	**0.918**	1.738	0.514	**1.076**	1.307	0.687	**0.997**
T2	0.599	0.558	**0.579**	0.650	0.484	**0.671**	0.691	0.521	**0.692**
T3	0.940	1.113	**1.064**	0.723	1.190	**0.920**	0.919	1.065	**0.730**
T4	0.767	0.658	**0.713**	1.689	0.619	**1.087**	1.144	0.693	**0.833**
T5	1.057	0.675	**0.866**	2.089	0.138	**1.114**	1.382	0.597	**0.990**
T6	1.101	0.753	**0.927**	2.254	0.109	**1.182**	1.503	0.605	**1.054**
T7	1.187	0.622	**0.867**	2.781	1.220	**2.000**	1.947	0.920	**1.434**
T8	0.879	1.056	**0.968**	2.544	1.511	**2.028**	1.800	1.195	**1.478**
T9	0.943	0.791	**0.867**	2.763	1.235	**1.999**	1.777	1.089	**1.433**
T10	1.147	1.024	**0.971**	0.543	0.206	**0.375**	0.784	0.677	**0.992**
T11	0.836	0.723	**0.780**	2.125	0.745	**1.435**	1.424	0.790	**1.107**
T12	1.236	0.938	**1.086**	3.346	0.628	**1.987**	2.142	0.815	**1.479**
Mean V	**0.901**	**0.866**		**1.937**	**0.708**		**1.402**	**0.805**	

Factors	YEAR 2022 CD	YEAR 2022 SEm±	YEAR 2023 CD	YEAR 2023 SEm±	POOLED CD	POOLED SEm±
(T)	0.123	0.043	0.108	0.038	0.076	0.026
(V)	0.085	0.018	0.044	0.015	0.031	0.011
(T × V)	0.174	0.061	0.152	0.053	0.107	0.037

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.5 Total Phenol content (mg/g)

Total phenol content in tomatoes serve critical role as biochemical character, it affects the antioxidant activity, disease resistance, flavour enhancement and health benefits (regular consumption of phenol rich foods reduce the risks of cardiovascular disease, inflammation and certain cancers). The results for total soluble sugar determined by the foliar spray of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.41. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the phenol content in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 41.

According to the results obtained for the treatments the maximum phenol content was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 30.41 mg/g, 32.28 mg/g and 30.51 mg/g for the year 2022, 2023 and pooled mean respectively, whereas the least phenol content was observed in T_1 (control) for the year 2021-22 (11.83 mg/g), 2022-23 (18.07 mg/g) and the pooled mean (16.22 mg/g).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher phenol content *i.e* 2021-22 (25.16 mg/g), 2022-23 (23.32 mg/g) and pooled mean (23.74 mg/g), as compared to V_1 (Tomato no. 575) *i.e.* 23.20 mg/g, 22.68 mg/g and 22.94 mg/g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the phenol content were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 31.93 mg/g, 32.42 mg/g and 31.68 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) in the variety Tomato no. 575 (V_1) *i.e.* 29.95 mg/g, 32.14 mg/g and 29.34 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least amount of phenol content was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 11.37 mg/g, 16.37 mg/g and 14.33 mg/g for the year 2022, 2023 and the pooled mean followed by T_1V_2 {(Control) + (Yellow Jubilee)} *i.e.* 12.29 mg/g, 21.04 mg/g and 18.11 mg/g for the year 2022, 2023 and the pooled mean respectively.

The maximum phenol content observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance the total phenol content in tomato fruits. Studies indicate that SES enhances overall plant health and stress resistance, which can lead to increased phenol synthesis. The application of seaweed extracts improves nutrient uptake and photosynthesis, facilitating the accumulation of secondary metabolites like phenol. The results obtained were found in accordance with the results obtained by Ranjendran *et al.,* 2022 in tomato when applied with seaweed extract at different concentrations alike results were also noted by Saha *et al.,* 2023 and Cozzolino *et al.,* 2021. Zinc and boron are essential micronutrients. They are vital for reproductive development and can influence the synthesis of secondary metabolites, including phenolics and adequate incorporation of zinc and boron has been linked to improved fruit quality and higher antioxidant levels, contributing to an increase in total phenol content. Salam *et al*, 2011 also suggested improved plant growth with the integrated application of zinc and boron. Similar results for significant increase in phenol content were also reported by Abo Hameed *et al.*, 2014, and Singh *et al.,* 2017. In terms of varieties, the highest phenol content was recorded in variety V_2, which could be attributed to varietal diversity and distinct growth behaviours as different tomato varieties exhibit substantial differences in their total phenol content.. Gurmani *et al.,* 2012 as well as Sanjida *et al.,* 2020 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The utmost phenol content was found in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.37: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on total phenol content (mg/g) of tomato

TOTAL PHENOL CONTENT (mg/g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	11.37	12.29	**11.83**	16.37	21.04	**18.07**	14.33	18.11	**16.22**
T2	18.33	20.18	**19.25**	27.54	29.23	**28.38**	22.94	24.70	**23.82**
T3	26.01	23.88	**24.94**	21.37	22.84	**21.60**	22.19	22.46	**22.32**
T4	25.59	28.17	**26.88**	21.93	28.92	**24.42**	22.76	28.54	**25.65**
T5	26.14	28.77	**27.45**	30.71	21.90	**26.31**	28.42	25.34	**26.88**
T6	21.61	24.09	**22.85**	26.79	23.23	**25.51**	23.70	23.66	**23.68**
T7	28.34	31.76	**30.05**	26.55	23.54	**25.04**	22.44	27.65	**25.05**
T8	27.08	28.55	**28.32**	28.71	22.98	**24.34**	27.89	24.77	**26.33**
T9	28.54	29.87	**28.74**	26.79	23.30	**24.04**	27.87	22.59	**25.23**
T10	14.67	16.15	**15.41**	25.46	20.63	**22.04**	19.07	19.39	**19.73**
T11	22.84	25.14	**23.99**	23.77	20.86	**22.32**	23.31	23.00	**23.16**
T12	29.95	31.93	**30.41**	32.14	32.42	**32.28**	29.34	31.68	**30.51**
Mean V	**23.20**	**25.16**		**22.68**	**23.32**		**22.94**	**23.74**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	1.157	0.405	0.158	0.055	0.6	0.21
(V)	0.472	0.165	0.064	0.023	0.245	0.086
(T × V)	1.637	0.573	0.223	0.078	0.848	0.297

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.6 Total soluble protein content (mg/g)

Total soluble protein content significantly impacts the nutritional value of tomatoes, influencing both health benefits and culinary qualities. Total soluble protein content varies with the cultivar variability. The results for total soluble sugar determined with the foliar spray of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.42. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the total soluble protein content in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 42.

According to the results obtained for the treatments the maximum soluble protein content was obtained in T_9 (B @ 0.2% + ANSE t @ 0.2%) *i.e.* 6.51 mg/g, 10.78 mg/g and 8.65 mg/g for the year 2022, 2023 and pooled mean respectively, whereas the least soluble protein content was observed in T_2 (Zn @ 0.2%) for the year 2021-22 (3.80 mg/g), 2022-23 (4.51 mg/g) and the pooled mean (4.56 mg/g).

Among both the studied varieties V_1 (Tomato no. 575) showed higher soluble protein content *i.e.* 2021-22 (5.36 mg/g), 2022-23 (7.45 mg/g) and pooled mean (6.40 mg/g), as compared to V_2 (Yellow Jubilee) *i.e.* 4.28 mg/g, 5.94 mg/g and 5.11 mg/g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive result for the soluble protein content were obtained for variety Tomato no. 575 (V_1) with the application of B @ 0.2% + ANSE t @ 0.2% (T_9) *i.e.* 7.14 mg/g, 15.80 mg/g and 11.03 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + ANSE @ 0.4% (T8) in the variety Yellow Jubilee (V_2) *i.e.* 6.89 mg/g, 8.39 mg/g and 7.35 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least soluble protein content was observed in the combination T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} *i.e.* 3.16 mg/g, 3.20 mg/g and 4.52 mg/g for the year 2022, 2023 and the pooled mean followed by T_2V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} *i.e.* 4.45 mg/g, 5.36 mg/g and 4.63 mg/g for the year 2022, 2023 and the pooled mean respectively.

The maximum soluble protein content observed in T_{12} could be due to the shared effect of SES and micronutrients. Application of SES has been shown to significantly enhance the protein content in tomato plants. The application of SES provides essential nutrients and bioactive compounds that stimulate protein synthesis. This increase can be defined as the presence of natural plant growth hormones like cytokinins and auxins, which promote metabolic activities related to protein production. The results obtained were found in accordance with the results obtained by Di Mola *et al.,* 2023b in tomato when applied with seaweed extract at different concentrations similar parallel outcomes were also denoted by Rajendran *et al* 2022 and Murtic *et al.,* 2018. Boron is an essential micronutrient that plays a vital role in various physiological processes, including the formation of cell wall and reproductive development. Its application has been linked to improved nutrient transport within the plant, which supports higher protein synthesis. Xu *et al.,* 2021 also noted improved plant growth with the integrated application of zinc and boron. Similar results for significant increase in soluble protein content was also reported by Abo Hameed *et al.,* 2014, and Gurmani *et al.,* 2012. In terms of varieties, the utmost soluble protein content was recorded in variety V_2, which could be attributed to varietal diversity and distinct growth behaviours. Different tomato varieties exhibit considerable differences in total soluble protein content. For instance, studies have shown that certain cultivars can have significantly higher protein levels due to their genetic makeup. Varieties developed for specific traits often display enhanced protein content compared to traditional cultivars. Gurmani *et al.,* 2012 and Sathya *et al.,* 2010 discovered alike results while evaluating various tomato cultivars for growth and yield potential.

The maximum soluble protein content was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.38: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on total soluble protein content (mg/g) of tomato

TOTAL SOLUBLE PROTEIN (mg/g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	4.22	4.53	**4.38**	7.76	5.99	**6.88**	6.99	5.26	**6.13**
T2	3.16	4.45	**3.80**	3.20	5.36	**4.51**	4.52	4.63	**4.56**
T3	5.72	6.19	**5.96**	5.31	7.87	**6.59**	5.51	7.03	**6.27**
T4	5.93	4.36	**5.13**	5.93	6.90	**6.42**	7.04	3.28	**5.16**
T5	6.11	4.33	**5.22**	5.82	8.27	**7.05**	5.97	6.30	**6.14**
T6	6.53	6.42	**6.47**	6.28	4.63	**5.45**	6.40	5.65	**5.46**
T7	6.80	4.54	**5.67**	6.68	8.10	**7.39**	6.74	5.32	**6.03**
T8	4.46	6.89	**5.64**	6.28	8.39	**7.33**	4.92	7.35	**6.14**
T9	7.14	6.77	**6.51**	15.80	5.76	**10.78**	11.03	6.27	**8.65**
T10	6.68	4.74	**5.71**	8.39	8.36	**8.33**	5.74	6.39	**6.07**
T11	4.33	5.39	**4.86**	7.19	4.05	**5.19**	6.02	4.19	**5.11**
T12	6.25	5.20	**6.17**	6.50	6.33	**6.42**	6.82	5.76	**6.29**
Mean V	**5.36**	**4.28**		**7.45**	**5.94**		**6.40**	**5.11**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.397	0.139	0.447	0.156	0.292	0.102
(V)	0.162	0.057	0.182	0.064	0.119	0.042
(T × V)	0.562	0.197	0.632	0.221	0.413	0.145

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.7 Ascorbic acid content (mg/100g)

Ascorbic acid is an essential biochemical character in tomatoes that provides antioxidant protection and enhances nutritional value. Genetic factors of cultivar, environmental conditions and soil fertility can significantly impact the ascorbic acid levels. The results for total soluble sugar determined by the foliar application of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.43. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the ascorbic acid content in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 43.

According to the results obtained for the treatments the minimum amount ascorbic acid content was obtained in T_{12} (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 10.59 mg/100g, 12.26 mg/100g and 11.42 mg/100g for the year 2022, 2023 and pooled mean respectively, although the utmost ascorbic acid content was observed in T_8 (Zn @ 0.2% + ANSE @ 0.4%) for the year 2021-22 (11.61 mg/100g), 2022-23 (13.07 mg/100g) and the pooled mean (12.34 mg/100g).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher ascorbic acid content *i.e.* 2021-22 (11.32 %), 2022-23 (13.04 mg/100g) and pooled mean (12.18 mg/100g), as compared to V_1 (Tomato no. 575) *i.e.* 10.95 mg/100g, 12.68 mg/100g and 11.81 mg/100g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results with a minimum value for the ascorbic acid content were obtained for variety Tomato no. 575 (V_1) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) *i.e.* 10.57 mg/100g, 12.25 mg/100g and 11.41 mg/100g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) in the variety Yellow Jubilee (V_2) *i.e.* 10.61 mg/100g, 12.26 mg/100g and 11.44 mg/100g for the year 2022, 2023 and the pooled mean respectively. Although highest amount of ascorbic acid was noted in the combination T_8V_2 {(Zn @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} *i.e.* 12.60 mg/100g, 13.89 mg/100g and 13.24 mg/100g for the year 2022, 2023 and the pooled mean followed by T_2V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} *i.e.* 12.53 mg/100g, 13.82 mg/100g and 13.17 mg/100g for the year 2022, 2023 and the pooled mean respectively.

The minimum ascorbic acid content observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Ascorbic acid content in tomato varies with different growth stages it reaches maximum levels at pink stage and then declines gradually with ripening. Seaweed extract (SES) typically enhances the nutritional profile of tomato fruits, including ascorbic acid (vitamin C) levels. However, specific studies indicate that while SES can improve overall fruit quality, the effects on ascorbic acid content based on the concentration used and the timing of application. the application of SES lead to potential reductions in ascorbic acid due to improved plant health and fruit quality with even ripening. The results obtained were found in accordance with the results obtained by Murtic *et al.,* 2018 in tomato when applied with seaweed extract at different concentrations alike outcomes were noted by Subhramaniyan *et al.,* 2023 and Di Mola *et al.,* 2023a. Boron is crucial for various physiological activities, including cell wall formation and reproductive development. Its application can influence the synthesis of ascorbic acid, by proper fruit development leading to even ripening. Boron can enhance metabolic pathways related to fruit quality, but its concentration must be carefully managed to avoid negative effects. Sandilya *et al.,* 2023 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant rise in ascorbic acid content were also reported by Saha *et al.,* 2023, Ahmed *et al.,* 2021 and Pasad *et al.,* 2021. In terms of varieties, the minimum amount of ascorbic acid content was noted in variety V_1. Varietal differences significantly influence the ascorbic acid content in tomatoes, which can vary due to genetic factors, environmental conditions. Gurmani *et al.,* 2012, Javanmardi and Sattar, 2016 and Sathya *et al.,* 2010 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The least amount of ascorbic acid content was noted in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.39: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on ascorbic acid content (mg/100g) of tomato

ASCORBIC ACID CONTENT (mg/100g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	10.81	11.21	**11.01**	12.97	12.73	**12.85**	11.89	11.97	**11.93**
T2	10.73	12.53	**11.55**	12.34	13.82	**13.04**	11.63	13.17	**12.29**
T3	11.91	10.69	**11.30**	13.16	12.83	**12.99**	12.53	11.76	**12.15**
T4	10.75	11.06	**10.91**	12.52	12.72	**12.62**	11.63	11.89	**11.76**
T5	10.78	11.61	**11.19**	12.61	13.38	**13.00**	11.70	12.50	**12.10**
T6	10.79	10.67	**10.73**	12.46	13.08	**12.77**	11.60	11.85	**11.72**
T7	10.87	11.27	**11.07**	13.11	12.72	**12.92**	11.99	12.00	**11.99**
T8	10.63	12.60	**11.61**	12.48	13.89	**13.07**	11.50	13.24	**12.34**
T9	11.97	10.74	**11.36**	13.23	12.75	**12.99**	12.60	11.75	**12.17**
T10	10.81	11.12	**10.97**	12.51	12.72	**12.61**	11.66	11.92	**11.79**
T11	10.84	11.67	**11.26**	12.54	13.51	**13.02**	11.69	12.59	**12.14**
T12	10.57	10.61	**10.59**	12.25	12.26	**12.26**	11.41	11.44	**11.42**
Mean V	**10.95**	**11.32**		**12.68**	**13.04**		**11.81**	**12.18**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.139	0.049	0.452	0.226	0.320	0.112
(V)	0.057	0.02	0.263	0.092	0.131	0.046
(T × V)	0.197	0.069	0.911	0.319	0.452	0.158

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.8 Carotenoid content (mg/g)

Carotenoid content in tomatoes plays a crucial role in enhancing their nutritional value and providing health benefits through antioxidant. Carotenoids responsible for vibrant yellow and red color in tomatoes which enhance their visual appeal and marketability. Different tomato cultivars exhibit significant variability in carotenoid content. The results for total soluble sugar determined by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.44. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the carotenoid content in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 44.

According to the results obtained for the treatments the maximum carotenoid content was obtained in T11 (Zn @ 0.2% + B @ 0.2% + *ANSE* @ 0.2%) *i.e.* 0.074 mg/g, 0.092 and 0.086 for the year 2022, 2023 and pooled mean respectively, whereas the least carotenoid content was observed in T_1 (control) for the year 2021-22 (0.045 mg/g), 2022-23 (0.027 mg/g) and the pooled mean (0.038 mg/g).

Among both the studied varieties V_2 (Yellow Jubilee) showed higher carotenoid content *i.e.* 2021-22 (0.062 mg/g), 2022-23 (0.047 mg/g) and pooled mean (0.049 mg/g), as compared to V_1 (Tomato no. 575) *i.e.* 0.047 mg/g, 0.036 mg/g and 0.050 mg/g for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the carotenoid content were obtained for variety Yellow Jubilee (V_2) with the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2% (T_{11}) *i.e.* 0.074 mg/g, 0.092 mg/g and 0.086 mg/g for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + ANSE @ 0.4% (T_8) in the variety Yellow Jubilee (V_2) *i.e.* 0.063 mg/g, 0.070 mg/g and 0.061 mg/g for the year 2022, 2023 and the pooled mean respectively. Whereas least amount of carotenoid content was observed in the combination T_1V_1 {(Control) + (Tomato no. 575)} *i.e.* 0.041 mg/g, 0.017 mg/g and 0.035 mg/g for the year 2022, 2023 and the pooled mean followed by T_3V_1 {(B @ 0.2%) + (Tomato no. 575)} *i.e.* 0.041 mg/g, 0.022 mg/g and 0.040 mg/g for the year 2022, 2023 and the pooled mean respectively.

The maximum carotenoid content observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance carotenoid levels in tomato fruits. The bioactive compounds and growth hormones present in seaweed extracts stimulate the biosynthesis of carotenoids, including beta-carotene. Study indicates that the application of SES can lead to higher concentrations of carotenoid content, which is crucial for fruit color and nutritional value.. The results obtained were found in accordance with the results obtained by Sîrbu *et al.,* 2022 in tomato when applied with SES at different concentrations. Zinc and boron are essential micronutrients. They influence various physiological processes, including enzyme activation. Application with adequate level of zinc and boron have been associated with improved fruit quality and higher carotenoid content. Current study suggests that zinc application can enhance the metabolic pathways involved in carotenoid synthesis, further increasing their levels in tomato fruits. Saha *et al*, 2023 also reported improved plant growth with the integrated approach of zinc and boron. Similar results for significant increase in carotenoid content were also reported by Xu *et al.,* 2021. In terms of varieties, the highest carotenoid content was recorded in variety V_2, which could be attributed to varietal diversity and distinct growth behaviours. The genetic makeuo of tomato varieties plays a crucial role in finding the levels of color pigments *i.e.* the presence of specific gene associated with carotene biosynthesis leads to increased carotenoind content. Roy and Monir, 2020, Javanmardi and Sattar and Sanjida *et al.,* 2020 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The utmost carotenoid content was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.40: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on carotenoid content (mg/g) of tomato

CAROTENOID CONTENT (mg/g)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	0.041	0.049	**0.045**	0.017	0.030	**0.027**	0.035	0.047	**0.038**
T2	0.048	0.058	**0.053**	0.041	0.040	**0.040**	0.052	0.054	**0.053**
T3	0.041	0.052	**0.047**	0.022	0.043	**0.030**	0.040	0.043	**0.045**
T4	0.041	0.056	**0.049**	0.016	0.036	**0.026**	0.039	0.032	**0.036**
T5	0.044	0.063	**0.053**	0.018	0.067	**0.040**	0.055	0.038	**0.047**
T6	0.048	0.070	**0.059**	0.032	0.053	**0.042**	0.050	0.045	**0.048**
T7	0.051	0.070	**0.060**	0.060	0.056	**0.058**	0.051	0.055	**0.053**
T8	0.052	0.063	**0.057**	0.042	0.070	**0.056**	0.041	0.061	**0.051**
T9	0.046	0.062	**0.054**	0.052	0.038	**0.045**	0.042	0.057	**0.050**
T10	0.050	0.063	**0.056**	0.012	0.060	**0.036**	0.051	0.043	**0.047**
T11	0.061	0.074	**0.066**	0.054	0.092	**0.078**	0.041	0.086	**0.064**
T12	0.041	0.061	**0.058**	0.044	0.062	**0.053**	0.050	0.052	**0.051**
Mean V	**0.047**	**0.062**		**0.036**	**0.047**		**0.047**	**0.049**	

Factors	CD	SEm±	CD	SEm±	CD	SEm±
(T)	0.004	0.001	0.003	0.001	0.003	0.001
(V)	0.001	0.001	0.001	0.000	0.001	0.000
(T × V)	0.005	0.002	0.004	0.002	0.004	0.001

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.3.9 Lycopene content (mg/kg fresh weight)

Lycopene is a key secondary metabolite in tomatoes, known for its numerous health benefits and contributions to fruit quality. It is a powerful antioxidant helps neutralizing free radicals in body resulting risks of certain cancers and heart disease. Its concentration is critical indicator of tomato quality, affecting consumer preference. Different tomato cultivars exhibit significant variability in Lycopene content, determined by genetics, growing conditions and ripening stages. The results for total soluble sugar gained by the foliar spraying of SES and micronutrients alone and in combination with each other on two varieties (Tomato no. 575 and Yellow Jubilee) are presented in Table 4.45 and. The observations given in the table confirms that the application of ANSE and micronutrients in combination significantly influenced the lycopene content in both the varieties irrespective of their growth stages. ANOVA tables for the same are given as Appendix 45.

According to the results obtained for the treatments the maximum lycopene content was obtained in T_9 (B @ 0.2% + *ANSE* @ 0.4%) *i.e.* 1.201 mg/kg, 1.199 mg/kg and 1.136 mg/kg for the year 2022, 2023 and pooled mean respectively, whereas the least lycopene content was observed in T_1 (control) for the year 2021-22 (0.486 mg/kg), 2022-23 (0.500 mg/kg) and the pooled mean (0.536 mg/kg).

Among both the studied varieties V_1 (Tomato no. 575) showed higher lycopene content *i.e.* 2021-22 (0.849 mg/kg), 2022-23 (1.225 mg/kg) and pooled mean (1.037 mg/kg), as compared to V_2 (Yellow Jubilee) *i.e.* 0.653 mg/kg, 0.622 mg/kg and 0.637 mg/kg for the year 2022, 2023 and pooled mean respectively.

As per the treatment combinations the highest positive results for the lycopene content were obtained for variety Tomato no. 575 (V_1) with the application of B @ 0.2% + ANSE @ 0.4% (T_9) *i.e.* 1.584 mg/kg, 1.715 mg/kg and 1.426 mg/kg for the year 2022, 2023 and pooled mean followed by the application of Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4% (T_{12}) in the variety Tomato no. 575 (V_1) *i.e.* 1.405 mg/kg, 1.512 mg/kg and 1.304 mg/kg for the year 2022, 2023 and the pooled mean respectively. Whereas least amount of lycopene content was observed in the combination T_1V_2 {(Control) + (Yellow Jubilee)} *i.e.* 0.453 mg/kg, 0.442 mg/kg and 0.528 mg/kg for the year 2022, 2023 and the pooled mean followed by T_4V_1 {(ANSE @ 0.2%) + (Tomato no. 575)} *i.e.* 0.456 mg/kg, 0.536 mg/kg and 0.544 mg/kg for the year 2022, 2023 and the pooled mean respectively.

The maximum lycopene content observed in T_{12} could be due to the shared effect of seaweed extract and micronutrients. Application of SES has been shown to significantly enhance carotenoid levels in tomato fruits. The bioactive compounds and growth hormones present in seaweed extracts stimulate the biosynthesis of carotenoids, including beta-carotene and lycopene. Study indicates that the application of SES can lead to higher levels of carotenoid *i.e.* Lycopene content, which is crucial for fruit color and nutritional value. The results obtained were found parallel with the outcomes provided by Murtic *et al.,* 2018 and Subramaniyan *et al.*, 2023 in tomato when applied with seaweed extract at different concentrations. Zinc and boron are essential micronutrients. They influence various physiological processes, including enzyme activation. Application with adequate level of zinc and boron have been associated with improved fruit quality and higher carotenoids including beta-carotene and lycopene. Current study suggests that zinc application can enhance the metabolic pathways involved in carotenoid synthesis, further increasing their levels in tomato fruits. Prasad *et al*, 2021 also reported improved plant growth with the integrated approach of zinc and boron. Alike findings for significant increase in lycopene content were also reported by Ahmed *et al.,* 2021 and Xu *et al.*, 2021. In terms of varieties, the maximum lycopene content was recorded in variety V_2, which could be attributed to varietal diversity and distinct growth behaviors. The genetic makeup of tomato varieties plays a crucial role in determining the levels of color pigments *i.e.* the presence of specific gene associated with carotene biosynthesis leads to increased lycopene content. Roy and Monir, 2020, Javanmardi and Sattar and Sathya *et al.,* 2010 discovered similar results while evaluating various tomato cultivars for growth and yield potential.

The highest amount for lycopene content was observed in the combination $T_{12}V_2$ which could be possibly due to the successful combined effect of seaweed extract and micronutrients with the varietal effect of variety Yellow Jubilee.

Table 4.41: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on lycopene content (mg/kg) of tomato

LYCOPENE CONTENT (mg/kg)									
	YEAR 2022			YEAR 2023			POOLED		
	V1	V2	Mean T	V1	V2	Mean T	V1	V2	Mean T
T1	0.516	0.453	**0.486**	0.656	0.442	**0.500**	0.644	0.528	**0.566**
T2	0.691	0.472	**0.581**	1.392	0.664	**1.028**	0.954	0.648	**0.801**
T3	0.594	0.638	**0.616**	1.011	0.554	**0.783**	0.802	0.596	**0.699**
T4	0.456	0.658	**0.553**	0.536	0.702	**0.679**	0.544	0.616	**0.563**
T5	0.555	0.645	**0.600**	1.478	0.638	**1.058**	1.100	0.639	**0.869**
T6	0.517	0.632	**0.575**	1.803	0.703	**1.253**	0.673	0.587	**0.630**
T7	0.498	0.645	**0.571**	0.832	0.557	**0.684**	0.694	0.591	**0.642**
T8	1.315	0.702	**1.009**	0.840	0.658	**0.749**	1.225	0.659	**0.942**
T9	1.584	0.817	**1.201**	1.715	0.683	**1.199**	1.426	0.845	**1.136**
T10	1.341	0.996	**1.169**	1.511	0.695	**1.103**	1.212	0.738	**0.975**
T11	0.722	0.638	**0.680**	1.134	0.615	**0.875**	1.115	0.570	**0.843**
T12	1.405	0.533	**0.969**	1.512	0.775	**1.173**	1.304	0.818	**1.111**
Mean V	**0.849**	**0.653**		**1.225**	**0.622**		**1.037**	**0.637**	

Factors	CD (2022)	SEm± (2022)	CD (2023)	SEm± (2023)	CD (Pooled)	SEm± (Pooled)
(T)	0.064	0.022	0.104	0.037	0.061	0.021
(V)	0.026	0.009	0.043	0.015	0.025	0.009
(T × V)	0.091	0.032	0.148	0.052	0.086	0.030

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

4.4 Effect of foliar application of micronutrients and seaweed extract on economics of tomato

Calculating the economics of crop production under different treatment combinations is essential for assessing the financial viability and efficiency of agricultural practices. Understanding the cost-benefit ratio of the treatments is crucial to determine if the additional inputs result in a profitable return. By calculating the economics, farmers can identify the most cost-effective strategies that not only maximize yield and quality but also optimize resource use, ensuring sustainable crop production. Evaluating the economic performance of different treatments allows for better decision-making, balancing both the physiological benefits to the crop and the financial outcomes for the farmer. The results for economics of the tomato crop determined by the foliar spraying of SES and micronutrients in combination on two varieties (Tomato no. 575 and Yellow Jubilee) are given in Table 4.46. The data presented in the table confirms that the application of ANSE and micronutrients in combination on two different varieties influenced the total cost of cultivation (₹/ha), gross returns (₹/ha), net returns (₹/ha) and B:C ratio of the crop. Cost of cultivation tables for the same is given as Appendix 45-68

4.4.1 Total cost of cultivation (₹/ha)

The data observed for cost of cultivation confirms that the application of seaweed extract and micronutrients in combination with two different varieties of tomato influenced the total cost of cultivation per combination. The least values total cost of cultivation found in T_1V_1 {(Control) + (Tomato no. 575)} i.e., ₹395265/ha, while the maximum total cost of cultivation found $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} *i.e.*, ₹413775/ha.

4.4.2 Gross monetary returns (₹/ha)

The data observed for gross monetary returns (₹/ha) with the selling price for V_1 (Tomato no. 575) as ₹15 for year 2021-2022 and ₹10 for year 2022-2023, and for variety V_2 (Yellow Jubilee) as ₹ 17 for year 2021-2022 and ₹12 for year 2022-2023 confirms that the application of SES and micronutrients in combination with two different varieties of tomato influenced the gross monetary returns (₹/ha) for each treatment combination. The maximum gross monetary returns were found in $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} i.e., ₹1297066, ₹1284480 and ₹1290773 for the year 2022, 2023 and the pooled mean respectively, while the minimum gross monetary returns were found T_1V_1 {(Control) + (Tomato no. 575)} .i.e., 2021-22 (₹644445), 2022-23 (₹603720) and pooled mean (₹624082.50).

4.4.3 Net monetary returns (₹/ha)

The data observed for net returns (₹/ha), confirms that the application of SES and micronutrients in combination with two different varieties of tomato influenced the net monetary returns (₹/ha) for each combination. The maximum net monetary returns were found in $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} i.e., ₹883291, ₹870705 and ₹876998 for the year 2022, 2023 and the pooled mean respectively, while the minimum net monetary returns were found T_1V_1 {(Control) + (Tomato no. 575)} .i.e., 2021-22 (₹249180), 2022-23 (₹208455) and pooled mean (₹228817.50).

4.4.4 Benefit cost ratio (B:C)

The data observed for benefit cost ratio (B:C), confirms that the application of SES and micronutrients in combination with two different varieties of tomato influenced the benefit cost ratio for each combination. The maximum benefit cost ratio was found in $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} i.e. 2.13, 2.10 and 2.12 for the year 2022, 2023 and the pooled mean respectively, while the minimum gross monetary returns were found T_1V_1 {(Control) + (Tomato no. 575)} .i.e., 2021-22 (0.63), 2022-23(0.53) and pooled mean(0.58).

Treatment T_{12} in combination with variety V_2 showed highest cost of cultivation which could be due to the increased seed price of V_2 as compare to V_1, and varied input cost than other applied treatments. Similar trends were obtained for gross and net return due to the improved yield market quality of the produce with treatment combination T_{12} and higher market price of the V_2 in comparison with V_1 for both consecutive years. B:C ratio was observed to be increased in the treatment combination $T_{12}V_2$ which could be possibly due to the higher net returns as compared to the other treatment combinations. Familiar findings were also obtained by Prasad and Saravanan (2014), Patil *et al*, 2010, Panjikar *et al.*, 2023, Patil *et al*. (2008) and Yao *et al.*, 2020

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Table 4.42: Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on economics of tomato

TREATMENTS	ECONOMICS											
	COST OF CULTIVATION			GROSS MONETARY RETURN			NET MONETARY RETURN			BENEFIR COST RATIO		
	YEAR 2022	YEAR 2023	POOLED	YEAR 2022	YEAR 2023	POOLED	YEAR 2022	YEAR 2023	POOLED	YEAR 2022	YEAR 2023	POOLED
T1V1	395265.00	395265.00	395265.00	644445.00	603720.00	624082.50	249180.00	208455.00	228817.50	0.63	0.53	0.58
T1V2	409365.00	409365.00	409365.00	799646.00	795576.00	797611.00	390281.00	386211.00	388246.00	0.95	0.94	0.95
T2V1	396175.00	396175.00	396175.00	677775.00	637050.00	657412.50	281600.00	240875.00	261237.50	0.71	0.61	0.66
T2V2	410275.00	410275.00	410275.00	862614.00	848916.00	855765.00	452339.00	438641.00	445490.00	1.10	1.07	1.09
T3V1	395965.00	395965.00	395965.00	722220.00	674090.00	698155.00	326255.00	278125.00	302190.00	0.82	0.70	0.76
T3V2	410065.00	410065.00	410065.00	868904.00	857796.00	863350.00	458839.00	447731.00	453285.00	1.12	1.09	1.11
T4V1	396665.00	396665.00	396665.00	938895.00	877800.00	908347.50	542230.00	481135.00	511682.50	1.37	1.21	1.29
T4V2	410765.00	410765.00	410765.00	1177437.00	1164480.00	1170958.50	766672.00	753715.00	760193.50	1.87	1.83	1.85
T5V1	398065.00	398065.00	398065.00	961110.00	900020.00	930565.00	563045.00	501955.00	532500.00	1.41	1.26	1.34
T5V2	412165.00	412165.00	412165.00	1208921.00	1195584.00	1202252.50	796756.00	783419.00	790087.50	1.93	1.90	1.92
T6V1	396875.00	396875.00	396875.00	777780.00	722240.00	750010.00	380905.00	325365.00	353135.00	0.96	0.82	0.89
T6V2	410975.00	410975.00	410975.00	887808.00	880020.00	883914.00	476833.00	469045.00	472939.00	1.16	1.14	1.15
T7V1	397575.00	397575.00	397575.00	805560.00	755560.00	780560.00	407985.00	357985.00	382985.00	1.03	0.90	0.96
T7V2	411675.00	411675.00	411675.00	919275.00	911136.00	915205.50	507600.00	499461.00	503530.50	1.23	1.21	1.22
T8V1	398975.00	398975.00	398975.00	850005.00	792610.00	821307.50	451030.00	393635.00	422332.50	1.13	0.99	1.06
T8V2	413075.00	413075.00	413075.00	994840.00	986688.00	990764.00	581765.00	573613.00	577689.00	1.41	1.39	1.40
T9V1	397365.00	397365.00	397365.00	900000.00	840760.00	870380.00	502635.00	443395.00	473015.00	1.26	1.12	1.19
T9V2	411465.00	411465.00	411465.00	1051501.00	1044468.00	1047984.50	640036.00	633003.00	636519.50	1.56	1.54	1.55
T10V1	398765.00	398765.00	398765.00	922215.00	859280.00	890747.50	523450.00	460515.00	491982.50	1.31	1.15	1.23
T10V2	412865.00	412865.00	412865.00	1139663.00	1128924.00	1134293.50	726798.00	716059.00	721428.50	1.76	1.73	1.75
T11V1	398275.00	398275.00	398275.00	1033335.00	962990.00	998162.50	635060.00	564715.00	599887.50	1.59	1.42	1.51
T11V2	412375.00	412375.00	412375.00	1234098.00	1217808.00	1225953.00	821723.00	805433.00	813578.00	1.99	1.95	1.97
T12V1	399675.00	399675.00	399675.00	1044450.00	974100.00	1009275.00	644775.00	574425.00	609600.00	1.61	1.44	1.53
T12V2	413775.00	413775.00	413775.00	1297066.00	1284480.00	1290773.00	883291.00	870705.00	876998.00	2.13	2.10	2.12

T1-Control, **T2**-Zn @ 0.2%, **T3**-B @ 0.2%, **T4**-*Ascophyllum nodosum* extract @ 0.2%, **T5**-*Ascophyllum nodosum* extract @ 0.4%, **T6**-Zn @ 0.2% + B @ 0.2%, **T7**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T8**-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T9**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T10**-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **T11**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, **T12**-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, **V1**- Tomato no.575, **V2**- Yellow Jubilee

CHAPTER V

SUMMARY AND CONCLUSION

The current study entitled with "**Effect of foliar application of micronutrients (B and Zn) and seaweed extract (*Ascophyllum nodosum*) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* L.)**" was coordinated during the years 2021-22 and 2022-23 at the horticulture research farm of Lovely Professional University comprising two factors, factor A, *i.e.,* 12 treatment combinations of *Ascophyllum nodosum* extract (0.2% and 0.4%), Zinc (0.2%) and Boron (0.2%) applied at 15, 30 and 45 days after transplanting as a foliar spray and factor B, *i.e.,* two hybrid varieties of tomato *viz.,* Tomato no. 575 (red) and Yellow Jubilee (yellow). The study aims to provide insights into the effectiveness of these treatment combinations in improving tomato cultivation, thereby offering a foundation for future agricultural practices and economic evaluations. The research was undertaken with the below mentioned objectives.

- To analyze the effects of foliar application of boron, zinc and seaweed extract on growth and yield parameters of tomato.
- To examine the effects of foliar application of boron, zinc and seaweed extract on biochemical parameters of tomato.
- To workout the economics of tomato cultivation with foliar application of boron, zinc and seaweed extract.

5.1. Effects of foliar application of boron, zinc and seaweed extract on growth and yield parameters of tomato

- Plant height (cm) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum height of plant at 30, 60, and 90 DAT ,as well as at 1st harvest, was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum plant height at 30, 60, and 90

DAT and at 1st harvest recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)}for both the consecutive years 2021-22 and 2022-23.

- Number of leaves showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum number of leaves at 30, 60, and 90 DAT (Days After Transplanting), as well as at 1st harvest, was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum number of leaves at 30, 60, and 90 DAT and at 1st harvest was documented in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Number of branches showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum no. of branches at 30, 60, and 90 DAT, as well as at 1st harvest, was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum number of branches at 30, 60, and 90 DAT and at 1st harvest was listed in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Leaf chlorophyll index showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. A rise in leaf chlorophyll index at 30, 60, and 90 DAT, as well as at 1st harvest, was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum leaf chlorophyll index at 30, 60, and 90 DAT and at 1st harvest was documented in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Diameter of stem (mm) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages.

The maximum diameter of stem at 30, 60, and 90 DAT, as well as at 1st harvest, was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum diameter of stem at 30, 60, and 90 DAT and at 1st harvest was noted in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Days to flower initiation showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The least no. of days for the initiation of flowering was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the maximum number of days to flower initiation was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Days to 50% flowering exhibited significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The minimum no. of days to 50% flowering was found in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the utmost no. of days for 50% flowering was noted in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Days to fruit initiation showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The least no. of days to fruit initiation were obtained in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the maximum number of days to fruit initiation was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Days to first picking showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The minimum number of days to first picking was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the maximum number of days to first picking was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Polar fruit diameter (mm) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost polar fruit diameter was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum polar fruit diameter was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Equatorial fruit diameter (mm) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost equatorial fruit diameter was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, although least equatorial fruit diameter was noted in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Number of locules per fruit showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum no. of locules per fruit was documented in the combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum number of locules per fruit was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- No. of fruits per plant exhibited significant beneficial results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum number of fruits per plant was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum number of fruits per plant was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Average fruit weight (g) exhibited significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The increased average fruit weight was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum average weight of fruit was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Yield per plant (kg) exhibited remarkable results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost yield per plant was noted in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum yield per plant was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Total marketable yield (q/ha) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum total marketable yield was obtained in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while least marketable yield was observed in combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23. An approximate 76% increase in yield was obtained in $T_{12}V_2$ as compared to control.

- Harvest duration (days) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum harvest duration was observed in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the minimum harvest duration was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

5.2. Effects of foliar application of boron, zinc and seaweed extract on biochemical parameters of tomato.

- Total soluble solids (TSS) (°Brix) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum TSS content was noted in the treatment combination T_7V_2 {(Zn @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)}, although the minimum TSS content was recorded in the treatment combination T_2V_2 {(Zn @ 0.2%) + (Yellow Jubilee)} for both the consecutive years, 2021-22 and 2022-23.

- Total soluble sugars (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The highest total soluble sugar content was observed in the combination $T_{12}V_1$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)}, although least total soluble sugars were recorded in the treatment combination T_2V_2 (Control + Yellow Jubilee) for both the consecutive years, 2021-22 and 2022-23.

- Total reducing sugar (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. Highest reducing sugars was observed in the treatment combination $T_{12}V_1$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)}, while the minimum reducing sugars was recorded in the treatment combination T_3V_2 {(Control) + (Tomato no. 575)} for both the consecutive years, 2021-22 and 2022-23.

- Non reducing sugar (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. Highest non reducing sugars was observed in the treatment combination $T_{12}V_1$, while the least non reducing sugars was recorded in the treatment combination T_2V_2 {(B @ 0.2%) + (Yellow Jubilee)} for both the consecutive years, 2021-22 and 2022-23.

- Total phenol (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum phenol content was noted in the combination $T_{12}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, although the minimum phenol content was noted in the treatment combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years, 2021-22 and 2022-23.

- Total soluble protein content (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The maximum soluble protein content was obtained in the treatment combination T_9V_1 {(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)}, while the least possible amount soluble protein content was recorded in the treatment combination T_2V_1 {(Zn @ 0.2%) + (Tomato no. 575)} for both the consecutive years, 2021-22 and 2022-23.

- Ascorbic acid content (%) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost values for ascorbic acid content was noted in the treatment combination T_8V_2 {(Zn @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)}, while the least possible amount ascorbic acid content was recorded in the combination $T_{12}V_1$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)} for both the consecutive years, 2021-22 and 2022-23.

- Carotenoid content (mg/g) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost values for carotenoid content was observed in the treatment combination $T_{11}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)}, while the least possible value carotenoid content was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years, 2021-22 and 2022-23.

- Lycopene content (mg/kg fresh weight) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years, across all growth stages. The utmost values for lycopene content was found in the combination T_9V_1 {(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)}, while the least amount of TSS content was recorded in the combination T_1V_2 {(Control) + (Yellow Jubilee)} for both the consecutive years, 2021-22 and 2022-23.

5.3. Effects of foliar application of boron, zinc and seaweed extract on economics of tomato

- Cost of cultivation (₹/ha) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years. The maximum cost of cultivation was perceived in the treatment combination $T_{12}V_2$ (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee), while the minimum cost of cultivation was recorded in the treatment combination T_1V_1 {(Control) + (Tomato no. 575)}.

- Gross monetary returns (₹/ha) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years. The highest gross monetary returns was observed in the treatment combination $T_{12}V_2$ (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee), while the least gross monetary returns was recorded in the treatment combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- Net monetary returns (₹/ha) showed significant positive results with the conjugated effect of boron, zinc, and seaweed extract in both years. The highest net monetary returns was perceived in the treatment combination $T_{12}V_2$ (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee), while the least net monetary returns was recorded in the treatment combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

- The conjugated effect of boron, zinc, and seaweed extract in both years showed significant positive results for benefit cost ratio (B:C). The highest B:C ratio was observed in the treatment combination $T_{12}V_2$ (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee), while the least B:C ratio was recorded in the combination T_1V_1 {(Control) + (Tomato no. 575)} for both the consecutive years 2021-22 and 2022-23.

CONCLUSION

The findings demonstrated a distinct and uniform enhancement in growth, yield, and quality metrics in plants undergone the treatment with boron, zinc, and seaweed extract. The treatment $T_{12}V_2$ {(Zn at 0.2% + B at 0.2% + ANSE at 0.4%) + (Yellow Jubilee variety)} demonstrated the most substantial enhancements in growth and yield metrics, continuously surpassing the control (T_1V_1) over both years. This treatment combination led to earlier flowering, fruit initiation, and picking, reducing the overall time for crop maturity. The yield ascribing parameters, such as the no. of fruits per plant, average fruit weight, polar and equatorial fruit diameter, and yield per plant, exhibited significant enhancement with treatment $T_{12}V_2$, resulting in a notable improvement in total marketable production and harvest duration. Similarly for the biochemical parameters improved phenol content was deteced in the treatment combination $T_{12}V_2$ {(Zn @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)} and highest sugar content (reducing, non reducing and total sugar) in $T_{12}V_1$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Tomato no. 575)}, where as for other biochemical parameters varied results were observed *i.e.* increased protein content in T9V1 {(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)}, improved TSS in T_7V_2 {(Zn @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)}, maximum ascorbic content in T_8V_2 {(Zn @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)} and increased carotenoid and Lycopene contents in treatment combinations $T_{11}V_2$ {(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)} and T_9V_1 {(B @ 0.2% + ANSE t @ 0.2%) + (Tomato no. 575)} respectively. From an economic perspective, the highest cost of cultivation was recorded combination $T_{12}V_2$ attributed to additional inputs of zinc, boron, seaweed extract and seed cost. However, the economic returns more than compensated for this, as $T_{12}V_2$ produced the highest gross and net monetary returns. Furthermore, this treatment combination also showed the highest benefit-cost ratio (B:C), indicating a favorable return on investment in contrast to the control treatment (T_1V_1) relying on traditional cultivation practices without micronutrients and seaweed extract. This study provides strong evidence that adopting foliar treatments with micronutrients along with seaweed extract can lead to higher yields, better fruit quality, and improved economic returns, making it a viable and beneficial practice for sustainable tomato farming.

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APPENDICES

Appendix 1: ANOVA table for Plant height at 30 DAT

Year2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.800		
Factor A	11	2,653.791	**241.254	814.707
Factor B	1	16.144	**16.144	54.518
Interaction A X B	11	56.565	**5.142	17.365
Error	46	13.622	0.296	
Total	71	2,741.921		

Year2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	2.554		
Factor A	11	4,191.096	**381.009	778.045
Factor B	1	25.431	**25.431	51.931
Interaction A X B	11	89.393	**8.127	16.595
Error	46	22.526	0.490	
Total	71	4,331.000		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.642		
Factor A	11	3,379.023	**307.184	794.183
Factor B	1	20.503	**20.503	53.007
Interaction A X B	11	72.011	**6.546	16.925
Error	46	17.792	0.387	
Total	71	3,489.971		

Appendix 2: ANOVA table for Plant height (cm) 60 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.665		
Factor A	11	1,897.570	**172.506	742.949
Factor B	1	2,307.597	**2,307.597	9,938.340
Interaction A X B	11	124.059	**11.278	48.572
Error	46	10.681	0.232	
Total	71	4,341.573		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	31.766		
Factor A	11	2,996.327	**272.393	731.891
Factor B	1	3,643.064	**3,643.064	9,788.506
Interaction A X B	11	195.723	**17.793	47.808
Error	46	17.120	0.372	
Total	71	6,884.000		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	9.762		
Factor A	11	2,415.545	**219.595	747.031
Factor B	1	2,937.026	**2,937.026	9,991.343
Interaction A X B	11	157.850	**14.350	48.817
Error	46	13.522	0.294	
Total	71	5,533.704		

Appendix 3:ANOVA table for Plant height (cm) 90 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.665		
Factor A	11	1,897.570	**172.506	742.949
Factor B	1	2,307.597	**2,307.597	9,938.340
Interaction A X B	11	124.059	**11.278	48.572
Error	46	10.681	0.232	
Total	71	4,341.573		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	48.340		
Factor A	11	6,240.915	**567.356	1,170.218
Factor B	1	21,673.843	**21,673.843	44,704.088
Interaction A X B	11	222.952	**20.268	41.805
Error	46	22.302	0.485	
Total	71	28,208.352		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	12.222		
Factor A	11	5,031.488	**457.408	1,259.041
Factor B	1	17,473.191	**17,473.191	48,095.924
Interaction A X B	11	179.781	**16.344	44.987
Error	46	16.712	0.363	
Total	71	22,713.394		

Appendix 4: ANOVA table for Plant height (cm) at 1st harvest

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.895		
Factor A	11	3,743.449	**340.314	1,592.112
Factor B	1	13,816.058	**13,816.058	64,636.607
Interaction A X B	11	324.080	**29.462	137.833
Error	46	9.832	0.214	
Total	71	17,894.315		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.656		
Factor A	11	5,815.690	**528.699	1,616.878
Factor B	1	21,544.351	**21,544.351	65,887.374
Interaction A X B	11	491.346	**44.668	136.604
Error	46	15.041	0.327	
Total	71	27,867.084		

Pooled Mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.156		
Factor A	11	4,722.392	**429.308	1,679.994
Factor B	1	17,467.665	**17,467.665	68,355.471
Interaction A X B	11	402.726	**36.611	143.270
Error	46	11.755	0.256	
Total	71	22,605.695		

Appendix 5: ANOVA table for Number of leaves 30 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.227		
Factor A	11	4,860.038	**441.822	1,422.090
Factor B	1	1,432.081	**1,432.081	4,609.436
Interaction A X B	11	243.103	**22.100	71.134
Error	46	14.291	0.311	
Total	71	6,549.741		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	11.478		
Factor A	11	8,006.564	**727.869	1,323.318
Factor B	1	2,358.014	**2,358.014	4,287.037
Interaction A X B	11	400.356	**36.396	66.170
Error	46	25.302	0.550	
Total	71	10,801.713		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	2.349		
Factor A	11	6,336.139	**576.013	1,376.672
Factor B	1	1,866.441	**1,866.441	4,460.803
Interaction A X B	11	316.931	**28.812	68.860
Error	46	19.247	0.418	
Total	71	8,541.106		

Appendix 6:ANOVA table for Number of leaves 60 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.520		
Factor A	11	16,375.315	**1,488.665	5,633.201
Factor B	1	12,741.815	**12,741.815	48,215.824
Interaction A X B	11	294.606	**26.782	101.346
Error	46	12.156	0.264	
Total	71	29,424.412		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	72.312		
Factor A	11	26,969.937	**2,451.812	5,515.804
Factor B	1	20,987.139	**20,987.139	47,214.436
Interaction A X B	11	484.458	**44.042	99.080
Error	46	20.447	0.445	
Total	71	48,534.294		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	19.740		
Factor A	11	21,343.298	**1,940.300	5,877.834
Factor B	1	16,607.037	**16,607.037	50,308.420
Interaction A X B	11	383.824	**34.893	105.703
Error	46	15.185	0.330	
Total	71	38,369.083		

Appendix 7: ANOVA table for Number of leaves 90 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.426		
Factor A	11	16,072.612	**1,461.147	6,097.695
Factor B	1	30,518.739	**30,518.739	127,361.592
Interaction A X B	11	645.625	**58.693	244.940
Error	46	11.023	0.240	
Total	71	47,248.424		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	121.326		
Factor A	11	26,471.013	**2,406.456	4,396.580
Factor B	1	50,265.472	**50,265.472	91,834.709
Interaction A X B	11	1,063.850	**96.714	176.695
Error	46	25.178	0.547	
Total	71	77,946.838		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	34.029		
Factor A	11	20,948.443	**1,904.404	5,194.131
Factor B	1	39,780.702	**39,780.702	108,499.145
Interaction A X B	11	842.344	**76.577	208.858
Error	46	16.866	0.367	
Total	71	61,622.385		

Appendix 8: Number of leaves at 1st harvest

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.041		
Factor A	11	18,361.219	**1,669.202	6,506.303
Factor B	1	58,674.309	**58,674.309	228,703.835
Interaction A X B	11	1,053.166	**95.742	373.190
Error	46	11.801	0.257	
Total	71	78,100.536		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	115.372		
Factor A	11	30,241.680	**2,749.244	5,410.709
Factor B	1	96,632.292	**96,632.292	190,179.302
Interaction A X B	11	1,734.771	**157.706	310.378
Error	46	23.373	0.508	
Total	71	128,747.487		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	27.839		
Factor A	11	23,935.223	**2,175.929	6,608.485
Factor B	1	76,479.378	**76,479.378	232,274.468
Interaction A X B	11	1,372.062	**124.733	378.825
Error	46	15.146	0.329	
Total	71	101,829.647		

Appendix 9: ANOVA table for Number of branches 30 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.092		
Factor A	11	16.849	**1.532	39.147
Factor B	1	1.047	**1.047	26.750
Interaction A X B	11	1.474	**0.134	3.425
Error	46	1.800	0.039	
Total	71	21.261		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.174		
Factor A	11	30.954	**2.814	39.414
Factor B	1	1.921	**1.921	26.904
Interaction A X B	11	2.705	**0.246	3.444
Error	46	3.284	0.071	
Total	71	39.038		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.124		
Factor A	11	23.266	**2.115	39.130
Factor B	1	1.448	**1.448	26.784
Interaction A X B	11	2.046	**0.186	3.440
Error	46	2.486	0.054	
Total	71	29.370		

Appendix 10: ANOVA table for Number of branches 60 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.317		
Factor A	11	94.246	**8.568	150.114
Factor B	1	5.479	**5.479	95.993
Interaction A X B	11	5.854	**0.532	9.325
Error	46	2.625	0.057	
Total	71	108.521		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.582		
Factor A	11	173.173	**15.743	149.884
Factor B	1	10.028	**10.028	95.471
Interaction A X B	11	10.756	**0.978	9.310
Error	46	4.832	0.105	
Total	71	199.370		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.437		
Factor A	11	130.690	**11.881	150.597
Factor B	1	7.592	**7.592	96.227
Interaction A X B	11	8.108	**0.737	9.344
Error	46	3.629	0.079	
Total	71	150.455		

Appendix 11:ANOVA table for Number of branches 90 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.238		
Factor A	11	200.912	**18.265	194.085
Factor B	1	27.765	**27.765	295.041
Interaction A X B	11	11.274	**1.025	10.891
Error	46	4.329	0.094	
Total	71	244.518		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.413		
Factor A	11	339.419	**30.856	193.128
Factor B	1	46.889	**46.889	293.475
Interaction A X B	11	19.049	**1.732	10.839
Error	46	7.349	0.160	
Total	71	413.119		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.313		
Factor A	11	265.603	**24.146	194.733
Factor B	1	36.695	**36.695	295.943
Interaction A X B	11	14.917	**1.356	10.937
Error	46	5.704	0.124	
Total	71	323.232		

Appendix 12: ANOVA table for Number of branches at 1st harvest

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.536		
Factor A	11	230.390	**20.945	180.376
Factor B	1	23.688	**23.688	203.999
Interaction A X B	11	23.360	**2.124	18.289
Error	46	5.341	0.116	
Total	71	283.314		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.914		
Factor A	11	389.766	**35.433	180.344
Factor B	1	40.174	**40.174	204.472
Interaction A X B	11	39.409	**3.583	18.235
Error	46	9.038	0.196	
Total	71	479.301		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.720		
Factor A	11	304.839	**27.713	181.210
Factor B	1	31.275	**31.275	204.505
Interaction A X B	11	30.864	**2.806	18.347
Error	46	7.035	0.153	
Total	71	374.733		

Appendix 13: ANOVA table for Diameter of stem (mm) 30 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.019		
Factor A	11	1.570	**0.143	128.635
Factor B	1	0.056	**0.056	50.570
Interaction A X B	11	0.036	**0.003	2.982
Error	46	0.051	0.001	
Total	71	1.732		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.018		
Factor A	11	1.584	**0.144	128.666
Factor B	1	0.057	**0.057	50.645
Interaction A X B	11	0.040	**0.004	3.218
Error	46	0.051	0.001	
Total	71	1.750		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.016		
Factor A	11	1.580	**0.144	126.405
Factor B	1	0.058	**0.058	50.861
Interaction A X B	11	0.039	**0.004	3.156
Error	46	0.052	0.001	
Total	71	1.746		

Appendix 14: ANOVA table for Diameter of stem (mm) 60 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.096		
Factor A	11	8.450	**0.768	128.013
Factor B	1	0.304	**0.304	50.699
Interaction A X B	11	0.204	**0.019	3.094
Error	46	0.276	0.006	
Total	71	9.331		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.101		
Factor A	11	8.679	**0.789	127.081
Factor B	1	0.311	**0.311	50.058
Interaction A X B	11	0.209	**0.019	3.065
Error	46	0.286	0.006	
Total	71	9.586		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.097		
Factor A	11	8.622	**0.784	129.303
Factor B	1	0.319	**0.319	52.564
Interaction A X B	11	0.214	**0.019	3.216
Error	46	0.279	0.006	
Total	71	9.531		

Appendix 15: ANOVA table for Diameter of stem (mm) 90 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.184		
Factor A	11	16.325	**1.484	128.108
Factor B	1	0.587	**0.587	50.640
Interaction A X B	11	0.392	**0.036	3.078
Error	46	0.533	0.012	
Total	71	18.021		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.194		
Factor A	11	16.801	**1.527	125.760
Factor B	1	0.609	**0.609	50.118
Interaction A X B	11	0.403	**0.037	3.019
Error	46	0.559	0.012	
Total	71	18.565		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.186		
Factor A	11	16.560	**1.505	126.192
Factor B	1	0.592	**0.592	49.632
Interaction A X B	11	0.398	**0.036	3.031
Error	46	0.549	0.012	
Total	71	18.284		

Appendix 16: ANOVA table for Diameter of stem at 1st harvest (mm)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.199		
Factor A	11	17.305	**1.573	128.365
Factor B	1	0.621	**0.621	50.712
Interaction A X B	11	0.413	**0.038	3.063
Error	46	0.564	0.012	
Total	71	19.102		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.204		
Factor A	11	17.781	**1.616	124.929
Factor B	1	0.650	**0.650	50.214
Interaction A X B	11	0.429	**0.039	3.014
Error	46	0.595	0.013	
Total	71	19.659		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.203		
Factor A	11	17.561	**1.596	127.509
Factor B	1	0.642	**0.642	51.288
Interaction A X B	11	0.422	**0.038	3.067
Error	46	0.576	0.013	
Total	71	19.405		

Appendix 27:ANOVA table for Days to flower initiation

Year 2022

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.930		
Factor A	11	680.515	**61.865	263.932
Factor B	1	946.706	**946.706	4,038.892
Interaction A X B	11	8.606	**0.782	3.338
Error	46	10.782	0.234	
Total	71	1,647.539		

Year 2023

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.795		
Factor A	11	539.147	**49.013	264.913
Factor B	1	749.972	**749.972	4,053.523
Interaction A X B	11	6.757	**0.614	3.320
Error	46	8.511	0.185	
Total	71	1,305.182		

Pooled mean

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.829		
Factor A	11	607.743	**55.249	263.945
Factor B	1	845.416	**845.416	4,038.838
Interaction A X B	11	7.726	**0.702	3.355
Error	46	9.629	0.209	
Total	71	1,471.342		

Appendix 18: ANOVA table for Days to 50% flowering

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.303		
Factor A	11	777.569	**70.688	377.947
Factor B	1	1,197.028	**1,197.028	6,400.138
Interaction A X B	11	9.008	**0.819	4.378
Error	46	8.603	0.187	
Total	71	1,992.512		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.231		
Factor A	11	615.855	**55.987	377.001
Factor B	1	948.359	**948.359	6,386.012
Interaction A X B	11	7.112	**0.647	4.354
Error	46	6.831	0.149	
Total	71	1,578.388		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.166		
Factor A	11	694.328	**63.121	374.259
Factor B	1	1,069.122	**1,069.122	6,339.094
Interaction A X B	11	8.107	**0.737	4.370
Error	46	7.758	0.169	
Total	71	1,779.481		

Appendix 19: ANOVA table for Days to fruit initiation

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.948		
Factor A	11	731.384	**66.489	40,716.599
Factor B	1	1,235.649	**1,235.649	756,683.124
Interaction A X B	11	185.228	**16.839	10,311.785
Error	46	0.075	0.002	
Total	71	2,156.285		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.172		
Factor A	11	579.443	**52.677	88,223.329
Factor B	1	978.847	**978.847	1,639,381.941
Interaction A X B	11	146.573	**13.325	22,316.480
Error	46	0.027	0.001	
Total	71	1,708.062		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.895		
Factor A	11	660.323	**60.029	754.998
Factor B	1	1,107.823	**1,107.823	13,933.253
Interaction A X B	11	161.541	**14.686	184.702
Error	46	3.657	0.080	
Total	71	1,934.238		

Appendix 20:ANOVA table forDays to first picking

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	29.228		
Factor A	11	1,456.400	**132.400	18,412.641
Factor B	1	4,179.713	**4,179.713	581,265.688
Interaction A X B	11	69.485	**6.317	878.472
Error	46	0.331	0.007	
Total	71	5,735.157		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	24.402		
Factor A	11	1,206.186	**109.653	43,393.982
Factor B	1	3,461.671	**3,461.671	1,369,915.059
Interaction A X B	11	57.247	**5.204	2,059.521
Error	46	0.116	0.003	
Total	71	4,749.623		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	26.648		
Factor A	11	1,328.116	**120.738	21,114.745
Factor B	1	3,811.928	**3,811.928	666,633.802
Interaction A X B	11	63.192	**5.745	1,004.642
Error	46	0.263	0.006	
Total	71	5,230.147		

Appendix 21: ANOVA table for Leaf chlorophyll index 30 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	4.928		
Factor A	11	1,545.299	**140.482	291,557.266
Factor B	1	476.439	**476.439	988,807.512
Interaction A X B	11	31.230	**2.839	5,892.192
Error	46	0.022	0.000	
Total	71	2,057.918		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.348		
Factor A	11	1,592.424	**144.766	1,635.669
Factor B	1	480.997	**480.997	5,434.654
Interaction A X B	11	40.764	**3.706	41.871
Error	46	4.071	0.089	
Total	71	2,118.604		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.912		
Factor A	11	1,568.447	**142.586	6,277.345
Factor B	1	478.569	**478.569	21,068.988
Interaction A X B	11	35.637	**3.240	142.630
Error	46	1.045	0.023	
Total	71	2,085.611		

Appendix 22: ANOVA table for Leaf chlorophyll index 60 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	5.679		
Factor A	11	3,035.330	**275.939	219,425.349
Factor B	1	469.763	**469.763	373,553.244
Interaction A X B	11	120.028	**10.912	8,676.878
Error	46	0.058	0.001	
Total	71	3,630.858		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	6.007		
Factor A	11	3,037.120	**276.102	267,907.627
Factor B	1	470.105	**470.105	456,153.164
Interaction A X B	11	120.072	**10.916	10,591.650
Error	46	0.047	0.001	
Total	71	3,633.351		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	5.488		
Factor A	11	3,036.530	**276.048	40,816.996
Factor B	1	469.645	**469.645	69,442.599
Interaction A X B	11	120.365	**10.942	1,617.951
Error	46	0.311	0.007	
Total	71	3,632.339		

Appendix 23: ANOVA table for Leaf chlorophyll index 90 DAT

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	4.257		
Factor A	11	2,537.684	**230.699	165,492.755
Factor B	1	2,027.205	**2,027.205	1,454,226.035
Interaction A X B	11	171.173	**15.561	11,162.880
Error	46	0.064	0.001	
Total	71	4,740.383		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	6.037		
Factor A	11	2,539.453	**230.859	42,891.443
Factor B	1	2,028.319	**2,028.319	376,842.042
Interaction A X B	11	171.336	**15.576	2,893.879
Error	46	0.248	0.005	
Total	71	4,745.393		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	2.995		
Factor A	11	2,512.713	**228.428	4,194.247
Factor B	1	2,028.095	**2,028.095	37,238.495
Interaction A X B	11	165.315	**15.029	275.946
Error	46	2.505	0.054	
Total	71	4,711.623		

Appendix 24: ANOVA table for Leaf chlorophyll index at 1st harvest

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.991		
Factor A	11	2,457.705	**223.428	94,016.728
Factor B	1	2,126.716	**2,126.716	894,906.179
Interaction A X B	11	181.864	**16.533	6,957.001
Error	46	0.109	0.002	
Total	71	4,770.386		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.186		
Factor A	11	2,460.545	**223.686	1,723.513
Factor B	1	2,086.146	**2,086.146	16,073.877
Interaction A X B	11	167.891	**15.263	117.601
Error	46	5.970	0.130	
Total	71	4,720.738		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.822		
Factor A	11	2,458.336	**223.485	6,486.008
Factor B	1	2,106.300	**2,106.300	61,129.268
Interaction A X B	11	174.249	**15.841	459.734
Error	46	1.585	0.034	
Total	71	4,741.293		

Appendix 25: ANOVA table for Equatorial fruit diameter (cm)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.945		
Factor A	11	1,504.683	**136.789	1,554.116
Factor B	1	58.503	**58.503	664.675
Interaction A X B	11	232.748	**21.159	240.394
Error	46	4.049	0.088	
Total	71	1,800.927		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.945		
Factor A	11	1,504.683	**136.789	1,554.116
Factor B	1	58.503	**58.503	664.675
Interaction A X B	11	232.748	**21.159	240.394
Error	46	4.049	0.088	
Total	71	1,800.927		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.168		
Factor A	11	1,887.543	**171.595	1,547.365
Factor B	1	73.332	**73.332	661.277
Interaction A X B	11	292.004	**26.546	239.378
Error	46	5.101	0.111	
Total	71	2,259.148		

Appendix 26: ANOVA table for Polar fruit diameter (cm)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.620		
Factor A	11	847.950	**77.086	730.028
Factor B	1	504.323	**504.323	4,776.072
Interaction A X B	11	125.085	**11.371	107.690
Error	46	4.857	0.106	
Total	71	1,482.836		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.620		
Factor A	11	847.950	**77.086	730.028
Factor B	1	504.323	**504.323	4,776.072
Interaction A X B	11	125.085	**11.371	107.690
Error	46	4.857	0.106	
Total	71	1,482.836		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.650		
Factor A	11	1,063.795	**96.709	714.208
Factor B	1	632.699	**632.699	4,672.579
Interaction A X B	11	156.984	**14.271	105.395
Error	46	6.229	0.135	
Total	71	1,860.356		

Appendix 27: ANOVA table for Number of locules

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	11.893		
Factor A	11	36.902	**3.355	3.224
Factor B	1	85.543	**85.543	82.205
Interaction A X B	11	24.438	**2.222	2.135
Error	46	47.868	1.041	
Total	71	206.644		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.889		
Factor A	11	30.040	**2.731	2.363
Factor B	1	104.064	**104.064	90.057
Interaction A X B	11	42.814	**3.892	3.368
Error	46	53.155	1.156	
Total	71	233.961		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.742		
Factor A	11	14.411	**1.310	9.296
Factor B	1	101.791	**101.791	722.314
Interaction A X B	11	13.728	**1.248	8.856
Error	46	6.483	0.141	
Total	71	137.155		

Appendix 28: ANOVA table for Number of fruits per plant

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	26.707		
Factor A	11	223.123	**20.284	3,180.456
Factor B	1	13.665	**13.665	2,142.677
Interaction A X B	11	5.188	**0.472	73.956
Error	46	0.293	0.006	
Total	71	268.977		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	60.110		
Factor A	11	501.929	**45.630	3,038.883
Factor B	1	30.756	**30.756	2,048.278
Interaction A X B	11	11.720	**1.065	70.958
Error	46	0.691	0.015	
Total	71	605.205		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	41.688		
Factor A	11	348.558	**31.687	3,032.505
Factor B	1	21.315	**21.315	2,039.921
Interaction A X B	11	8.114	**0.738	70.592
Error	46	0.481	0.010	
Total	71	420.156		

Appendix 29: ANOVA table for Average fruit weight (g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.104		
Factor A	11	1,706.890	**155.172	2,033.412
Factor B	1	121.569	**121.569	1,593.066
Interaction A X B	11	512.387	**46.581	610.405
Error	46	3.510	0.076	
Total	71	2,345.460		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	20.308		
Factor A	11	51,424.341	**4,674.940	337.761
Factor B	1	40,575.798	**40,575.798	2,931.568
Interaction A X B	11	23,017.929	**2,092.539	151.184
Error	46	636.685	13.841	
Total	71	115,675.062		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	3.719		
Factor A	11	16,750.231	**1,522.748	423.756
Factor B	1	11,282.600	**11,282.600	3,139.767
Interaction A X B	11	5,316.425	**483.311	134.498
Error	46	165.299	3.593	
Total	71	33,518.274		

Appendix 30: ANOVA table for Yield per plant (kg)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.121		
Factor A	11	4.248	**0.386	3,538.448
Factor B	1	0.034	**0.034	315.674
Interaction A X B	11	0.204	**0.019	169.977
Error	46	0.005	0.000	
Total	71	4.613		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.238		
Factor A	11	8.352	**0.759	3,756.600
Factor B	1	0.070	**0.070	345.985
Interaction A X B	11	0.392	**0.036	176.284
Error	46	0.009	0.000	
Total	71	9.061		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.175		
Factor A	11	6.133	**0.558	3,734.509
Factor B	1	0.051	**0.051	343.618
Interaction A X B	11	0.288	**0.026	175.278
Error	46	0.007	0.000	
Total	71	6.654		

Appendix 31: ANOVA table forYield per hectare (q)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	-4.484		
Factor A	11	601,796.428	**54,708.766	162,649.999
Factor B	1	2,972.094	**2,972.094	8,836.080
Interaction A X B	11	25,382.422	**2,307.493	6,860.212
Error	46	15.473	0.336	
Total	71	630,161.933		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	32,666.777		
Factor A	11	1,145,612.448	**104,146.586	3,670.820
Factor B	1	9,560.250	**9,560.250	336.967
Interaction A X B	11	53,794.311	**4,890.392	172.370
Error	46	1,305.088	28.371	
Total	71	1,242,938.873		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	8,193.104		
Factor A	11	851,440.142	**77,403.649	11,778.456
Factor B	1	5,821.048	**5,821.048	885.785
Interaction A X B	11	36,732.940	**3,339.358	508.148
Error	46	302.295	6.572	
Total	71	902,489.529		

Appendix 32: ANOVA table for Harvest duration

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	8.837		
Factor A	11	165.319	**15.029	265.245
Factor B	1	-0.008	**0.008	-0.141
Interaction A X B	11	2.971	**0.270	4.766
Error	46	2.606	0.057	
Total	71	179.726		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.732		
Factor A	11	186.198	**16.927	229.910
Factor B	1	0.150	**0.150	2.043
Interaction A X B	11	6.985	**0.635	8.625
Error	46	3.387	0.074	
Total	71	198.452		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	4.587		
Factor A	11	175.288	**15.935	348.163
Factor B	1	0.026	**0.026	0.578
Interaction A X B	11	4.594	**0.418	9.125
Error	46	2.105	0.046	
Total	71	186.601		

Appendix 33: ANOVA table for TSS (°Brix)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.066		
Factor A	11	5.208	**0.473	11,135.562
Factor B	1	13.424	**13.424	315,710.578
Interaction A X B	11	7.833	**0.712	16,747.701
Error	46	0.002	0.000	
Total	71	26.534		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	-0.000		
Factor A	11	5.254	**0.478	1,375.543
Factor B	1	13.537	**13.537	38,980.853
Interaction A X B	11	7.903	**0.718	2,068.801
Error	46	0.016	0.000	
Total	71	26.710		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.014		
Factor A	11	5.285	**0.480	5,101.185
Factor B	1	13.468	**13.468	142,983.204
Interaction A X B	11	7.848	**0.713	7,574.164
Error	46	0.004	0.000	
Total	71	26.619		

Appendix 34: ANOVA table for Reducing sugar (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	1.836	**0.167	8,876.269
Factor B	1	0.252	**0.252	13,399.832
Interaction A X B	11	0.957	**0.087	4,624.023
Error	46	0.001	0.000	
Total	71	3.046		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	-0.000		
Factor A	11	14.523	**1.320	22,462.759
Factor B	1	14.056	**14.056	239,141.650
Interaction A X B	11	7.570	**0.688	11,709.023
Error	46	0.003	0.000	
Total	71	36.151		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	4.598	**0.418	21,890.737
Factor B	1	2.636	**2.636	138,065.966
Interaction A X B	11	2.635	**0.240	12,547.746
Error	46	0.001	0.000	
Total	71	9.870		

Appendix 35: ANOVA table for Non-reducing sugar (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.001		
Factor A	11	1.152	**0.105	812.427
Factor B	1	0.115	**0.115	895.677
Interaction A X B	11	0.812	**0.074	572.685
Error	46	0.006	0.000	
Total	71	2.086		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.008		
Factor A	11	86.458	**7.860	231.509
Factor B	1	201.419	**201.419	5,932.734
Interaction A X B	11	48.621	**4.420	130.193
Error	46	1.562	0.034	
Total	71	338.069		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.001		
Factor A	11	21.712	**1.974	227.841
Factor B	1	47.973	**47.973	5,537.491
Interaction A X B	11	11.472	**1.043	120.386
Error	46	0.399	0.009	
Total	71	81.557		

Appendix 36: ANOVA table for Total soluble sugar (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	0.754	**0.069	872.091
Factor B	1	0.026	**0.026	334.365
Interaction A X B	11	0.511	**0.046	591.700
Error	46	0.004	0.000	
Total	71	1.295		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.008		
Factor A	11	135.504	**12.319	362.574
Factor B	1	109.028	**109.028	3,209.052
Interaction A X B	11	48.360	**4.396	129.399
Error	46	1.563	0.034	
Total	71	294.462		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.001		
Factor A	11	34.603	**3.146	362.418
Factor B	1	28.200	**28.200	3,248.863
Interaction A X B	11	12.351	**1.123	129.363
Error	46	0.399	0.009	
Total	71	75.555		

Appendix 37: ANOVA table for Total phenol content (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	8.462		
Factor A	11	2,311.667	**210.152	213.275
Factor B	1	68.870	**68.870	69.893
Interaction A X B	11	53.524	**4.866	4.938
Error	46	45.326	0.985	
Total	71	2,487.849		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.060		
Factor A	11	1,613.818	**146.711	7,996.789
Factor B	1	2.233	**2.233	121.692
Interaction A X B	11	1,712.033	**155.639	8,483.460
Error	46	0.844	0.018	
Total	71	3,328.988		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.854		
Factor A	11	1,254.181	**114.016	430.602
Factor B	1	11.575	**11.575	43.715
Interaction A X B	11	421.785	**38.344	144.813
Error	46	12.180	0.265	
Total	71	1,701.574		

Appendix 38: ANOVA table for Total soluble protein (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1.346		
Factor A	11	263.608	**23.964	206.569
Factor B	1	20.990	**20.990	180.930
Interaction A X B	11	47.343	**4.304	37.099
Error	46	5.337	0.116	
Total	71	338.623		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.214		
Factor A	11	199.886	**18.171	123.773
Factor B	1	40.631	**40.631	276.749
Interaction A X B	11	210.320	**19.120	130.233
Error	46	6.753	0.147	
Total	71	457.805		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.597		
Factor A	11	104.009	**9.455	150.470
Factor B	1	30.004	**30.004	477.478
Interaction A X B	11	52.711	**4.792	76.258
Error	46	2.891	0.063	
Total	71	190.212		

Appendix 39: ANOVA table for Ascorbic acid content (%)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.146		
Factor A	11	5.850	**0.532	37.353
Factor B	1	2.354	**2.354	165.357
Interaction A X B	11	16.586	**1.508	105.898
Error	46	0.655	**0.014	
Total	71	25.592		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.046		
Factor A	11	89.810	**8.165	127.948
Factor B	1	562.223	**562.223	8,810.666
Interaction A X B	11	228.171	**20.743	325.063
Error	46	2.935	0.064	
Total	71	883.186		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.090		
Factor A	11	29.344	**2.668	151.900
Factor B	1	122.934	**122.934	7,000.141
Interaction A X B	11	69.458	**6.314	359.554
Error	46	0.808	0.018	
Total	71	222.633		

Appendix 40: ANOVA table for Carotenoid content (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	0.002	**0.000	22.309
Factor B	1	0.004	**0.004	405.224
Interaction A X B	11	0.001	**0.000	9.758
Error	46	0.000	0.000	
Total	71	0.008		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	0.016	**0.001	214.515
Factor B	1	0.002	**0.002	304.572
Interaction A X B	11	0.026	**0.002	344.001
Error	46	0.000	0.000	
Total	71	0.044		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.000		
Factor A	11	0.005	**0.000	85.731
Factor B	1	0.000	**0.000	12.882
Interaction A X B	11	0.007	**0.001	127.678
Error	46	0.000	0.000	
Total	71	0.012		

Appendix 41: ANOVA table for Lycopene content (mg/100g)

Year 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.005		
Factor A	11	8.211	**0.746	680.970
Factor B	1	1.934	**1.934	1,764.233
Interaction A X B	11	1.980	**0.180	164.234
Error	46	0.050	0.001	
Total	71	12.180		

Year 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.044		
Factor A	11	2.876	**0.261	37.452
Factor B	1	17.189	**17.189	2,462.288
Interaction A X B	11	4.350	**0.395	56.642
Error	46	0.321	0.007	
Total	71	24.780		

Pooled mean

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.017		
Factor A	11	2.784	**0.253	133.742
Factor B	1	7.670	**7.670	4,052.766
Interaction A X B	11	1.818	**0.165	87.316
Error	46	0.087	0.002	
Total	71	12.376		

COST OF CULTIVATION:

Appendix 42: T1V1- (Control) + (Tomato number 575)

T1V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	Hired Human Labour					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	Working Capital (1to 7)	(Rs)				303595
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	Cost "A"(Items 9-11)	(Rs)				306265
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	Cost "B"(Items 12-13)	(Rs)				395265

Appendix 43: T1V2- (Control) + (Yellow jubilee)

T1V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**317695**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**320365**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**409365**

Appendix 44: T2V1- (Zinc @ 0.2%) + (Tomato 575)

T2V1						
S. No	**Item**	**Unit**			**Input/ha**	**Cost/Unit of input(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**304505**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**307175**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	**(Rs)**				**396175**

Appendix 45: T2V2-(Zinc @ 0.2%) + (Yellow Jubilee)

T2V2						
S. No	Item	Unit			Input/ha	Cost/Unit of input(Rs)
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**318605**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**321275**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	**(Rs)**				**410275**

Appendix 46: T3V1-(Boron @ 0.2%) + (Tomato 575)

T3V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**304295**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**306965**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**395965**

Appendix 47: T3V2-(Boron @ 0.2%) + (Yellow Jubilee)

T3V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**318395**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**321065**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**410065**

Appendix 48: T4V1-(*Ascophyllum nodosum* Seaweed Extract@ 0.2%) + (Tomato 575)

T4V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**304995**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**307665**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**396665**

Appendix 49: T4V2-(*Ascophyllum nodosum* seaweed extract @ 0.2%) + (Yellow Jubilee)

T4V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	15	400	6000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
5	Irrigation Charges	(Rs)				15000
6	Incidental Charges	(Rs)				3500
7	Repairing Charges	(Rs)				4500
8	**Working Capital (1to 7)**	**(Rs)**				**343595**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**346265**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**410765**

Appendix 50: T5V1-(*Ascophyllum nodosum*seaweed extract@ 0.4%) + (Tomato 575)

T5V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**306395**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**309065**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**398065**

Appendix 51: T5V2-(*Ascophyllum nodosum*seaweed extract@ 0.4%) + (Yellow Jubilee)

T5V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**320495**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**323165**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**412165**

Appendix 52:T6V1-(Zinc @ 0.2% + Boron @ 0.2%) + (Tomato 575)

T6V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	Hired Human Labour					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	Working Capital (1to 7)	(Rs)				303595
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	Cost "A"(Items 9-11)	(Rs)				306265
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**Cost "B"(Items 12-13)**	**(Rs)**				**396875**

Appendix 53: T6V2-(Zinc @ 0.2% + Boron @ 0.2%) + (Yellow Jubilee)

T6V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Zinc (0.2%)	Kgs.	1.4	650	910
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**319305**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**321975**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**410975**

Appendix 54: T7V1-(Zinc @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.2%) + (Tomato 575)

T7V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**305905**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**308575**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**397575**

Appendix 55: T7V2 (Zinc @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.2%) + (Yellow Jubilee)

T7V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**320005**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**322675**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**411675**

Appendix 56: T8V1-(Zinc @ 0.2% + *Ascophyllum nodosum* seaweed extract @ 0.4%) + (Tomato 575)

T8V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**307305**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**309975**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**398975**

Appendix 57: T8V2-(Zinc @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.4%) + (Yellow Jubilee)

T8V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Zinc (0.2%)	Kgs.	1.4	650	910
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**321405**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**324075**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**413075**

Appendix 58: T9V1-(Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract @ 0.2%) + (Tomato 575)

T9V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**305695**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**308365**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**397365**

Appendix 59: T9V2-(Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract @ 0.2%) + (Yellow Jubilee)

T9V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**319795**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**322465**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**411465**

Appendix 60: T10V1-(Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract @ 0.4%) + (Tomato 575)

T10V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompos t	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**307095**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**309765**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**398765**

Appendix 61: T10V2-(Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.4%) + (Yellow Jubilee)

T10V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**321195**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**323865**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**412865**

Appendix 62: T11V1-(Zinc @ 0.2% + Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.2%) + (Tomato 575)

T11V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Zinc (0.2%)	Kgs.	1.4	650	910
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**306605**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**309275**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**398275**

Appendix 63: T11V2-(Zinc @ 0.2% + Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.2%) + (Yellow Jubilee)

T11V2						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.2%)	L	1.4	1000	1400
		Zinc (0.2%)	Kgs.	1.4	650	910
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**320705**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**323375**
13	Rental Value of land	(Rs)	Months	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**412375**

Appendix 64: T12V1-(Zinc @ 0.2% + Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract@ 0.4%) + (Tomato 575)

T12V1						
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Tomato 575)	g	150	56	8,400
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Zinc (0.2%)	Kgs.	1.4	650	910
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7**	**(Rs)**				**308005**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**310675**
13	Rental Value of land	(Rs)	Month s	5	20000	100000
14	**COST "B"(Items 12-13)**	(Rs)				**399675**

Appendix 65: T12V2-(Zinc @ 0.2% + Boron @ 0.2% + *Ascophyllum nodosum* seaweed extract @ 0.4%) + (Yellow Jubilee)

T12V2							
S.No	**Item**	**Unit**		**Input/ha**	**Cost/Unit of input(Rs)**	**Total cost/ha(Rs)**
1	**Hired Human Labour**					
	Land preparation	Male	Day	10(2)	600	12000
	Weeding (2)	Male	Day	10(5)	600	60000
	Staking	Male	Day	12(4)	600	28000
	Treatment spray (3)	Male	Day	10(3)	600	54000
	Transplanting cost	Male	Day	10(2)	600	12000
	Harvesting (3)	Male	Day	20	600	36000
2	Machine Charges		Hours	5	400	2000
3	Nursery Raising	Seed Cost (Yellow Jubilee)	g	150	150	22,500
		Protray		125	40	5,000
		Cocopeat	Kg	60	36	2160
		Perlite	Kg	12.5	25	300
		Vermicompost	Kg	40	25	1000
		Vermiculite	Kg	12.5	35	450
4	Fertilizer	FYM	Tones	25	2500	62500
		N (Urea)	Kgs.	137.5	6	825
		P (SSP)	Kgs.	387.5	8.4	3255
		K (MOP)	Kgs.	112.5	19.6	2205
	Treatments	Seaweed Extract (0.4%)	L	2.8	1000	2800
		Zinc (0.2%)	Kgs.	1.4	650	910
		Boron (0.2%)	Kgs.	1.4	500	700
5	Irrigation Charges	(Rs)				1500
6	Incidental Charges	(Rs)				500
7	Repairing Charges	(Rs)				500
8	**Working Capital (1to 7)**	**(Rs)**				**322105**
9	Interest on working capital@6% annum (Rs)					2170
10	Depreciation In implements and Farm buildings	(Rs)				400
11	Land Revenue cess and taxes	(Rs)				100
12	**COST "A"(Items 9-11)**	**(Rs)**				**324775**
13	Rental Value of land	(Rs)	Months	5	20000	100000
4	**COST "B"(Items 12-13)**	(Rs)				**413775**

LIST OF PUBLICATIONS

S.No.	Title	Journal Name/ Indexing	Reference
1.	Estimation of seaweed extract and micronutrient potential to improve net returns by enhancing yield characters in tomato using correlation analysis.	Journal of Applied Biology and Biotechnology Scopus indexed	Choudhary D, Rawat M, Mashkey VK, Sharma V, Kundu P. (2025) Estimation of seaweed extract and micronutrient potential to improve net returns by enhancing yield characters in tomato using correlation analysis. *Journal of Applied Biology and Biotechnology*, 13(1), 243-249. http://doi.org/10.7324/JABB.2024.199958

LIST OF CONFERENCES

S.No.	Type of presentation	Title	Conducting university/ institute with Date
1	**Poster Presentation**	Seaweed extract as biostimulant for improvement of horticultural crops	ICRAHOR 2022 (International Conference On Recent Advances In Horticulture Research) under the aegis of Amity Food And Agriculture foundation, Amity, Amity University Uttar Pradesh, Noida, U.P. on 8th and 9th August 2022.
2	**Oral Presentation**	A study on foliar application of seaweed extract and micronutrients on the growth and yield of tomato (*Solanum lycopersicum* l.)	International conference on 'Precision Agriculture' organized by SVIAg, SVVV, Indore (M.P.) 26th and 27th September, 2022.
3	**Poster presentation**	Effect of seaweed extract (*Ascophyllum nodosum*) as biostimulant with micronutrients (boron and zinc) on the growth, yield and biochemical parameters of tomato (*Solanum lycopersicum* l.)	ICPPB 2023 (2nd International Conference On Plant Physiology And Biotechnology) organized by Lovely Professional University, Phagwara, Punjab, India on 20th and 21st April 2023.

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