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GENETIC, PHYSIOLOGICAL, AND BIOCHEMICAL REACTIONS OF TOMATO TO ORGANIC AND INORGANIC FERTILIZERS ACROSS DIFFERENT ENVIRONMENTAL CONDITIONS

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Abstract

The tomato (Solanum lycopersicum L.) is a crop of significant nutritional and economic value, with its development and output greatly affected by nutrient management and environmental factors. This research examines the genetic, physiological, and biochemical responses of several tomato genotypes to organic and inorganic fertilizers under diverse environmental conditions. A two-factor factorial experiment was performed using chosen tomato cultivars to compare the effects of organic fertilizers (compost, farmyard manure) and inorganic fertilizers (NPK) under varying environmental conditions. Results indicated substantial differences across treatments and genotypes. Organic fertilizers enhanced root growth, chlorophyll concentration, and antioxidant enzyme activity, hence improving stress resilience under severe environmental circumstances. Conversely, inorganic fertilizers facilitated fast vegetative development and production under mild circumstances, although were less efficacious in stress-prone situations. Biochemical research revealed increased concentrations of phenolics and flavonoids in plants subjected to organic treatment, indicating improved defensive mechanisms. Genotypic variations significantly influenced nutrition absorption efficiency and stress resilience. The results indicate that combining organic and inorganic fertilization methods, with the selection of sensitive genotypes, may sustainably enhance tomato output across various environmental.

INTRODUCTION

The tomato (Solanum lycopersicum L.) is among the most extensively planted and eaten plants worldwide, owing to its nutritional significance, economic worth, and contribution to food security. The growth and productivity are significantly affected by environmental variables, including temperature, humidity, light intensity, and soil properties [1-2]. Alongside environmental factors, the type and availability of nutrients provided by fertilizers are crucial in influencing plant health, growth, and production. Tomatoes exhibit a diverse array of forms, sizes, colors, and tastes. They may be classified into

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categories depending on their development patterns (determinate vs indeterminate), applications (slicing, paste, cherry, etc.), and other attributes [3]. Rio Grande, Roma, and Cherry tomatoes originate from Italy and are optimal for sauces, pastes, and canning. Their attributes include medium- to large-sized fruit, solid flesh with low moisture content, and resistance to cracking and blossom end rot. Their preferred cultivation occurs in a warm environment. They typically reach maturity within 75 to 80 days. Large, round tomatoes, referred to as slicing tomatoes, are particularly delectable when consumed fresh, especially in salads and sandwiches. These tomatoes are large, robust, and densely fleshed. Brandywine, Cherokee Purple, Big Beef. Conventional spherical tomatoes are often seen at stores. Cherry tomatoes are small, round fruits that are often very flavorful and commonly used in salads or as snacks. Grape tomatoes are somewhat bigger than cherry tomatoes; they are oblong and tasty and often used in salads or as snacks. Heirloom tomatoes, which are open-pollinated varieties passed down through generations, are often esteemed for their unique tastes and colors. Oxheart tomatoes are substantial, heart-shaped varieties characterized by their fleshy texture and little seed content, making them ideal for slicing and culinary sauces. Campari tomatoes are small- to medium-sized varieties recognized for their juiciness and sweetness, often used in their fresh form. Tomatoes are a staple commodity in Pakistan's regional markets. Due to their essential role in Pakistani cuisine, they are in constant demand throughout the year. The domestic tomato market is substantial, with elevated consumption rates in both rural and urban regions. Most tomatoes are employed in Pakistan. Tomatoes constitute a significant agricultural crop that enhances the economies of several countries via trade, employment, and production. China is the world's leading tomato producer, with an annual output exceeding 60 million tons. Ammonium sulfate (NH2SO4) supplies sulfur and nitrogen, essential for crops requiring these nutrients. Superphosphate ($Ca(H_2PO_4)_2$) is synthesized by the reaction of sulfuric acid with rock phosphate, providing soluble phosphorus essential for root development. $Ca(H_2PO_4)_2$ [7]·H_2O, known as triple superphosphate, has a greater phosphorus concentration than superphosphate and is used for crops with elevated requirements. Potassium Chloride (KCl), often known as muriate of potash, is the most extensively used potassium fertilizer, enhancing resistance to disease and drought. Potassium Sulfate (K_2SO_4) supplies sulfur and potassium without the use of chloride, benefiting sensitive crops. NPK fertilizers are combinations of nitrogen (N), phosphorous (P), and potassium (K) in varying proportions to satisfy certain crop requirements. While inorganic fertilizers have significant beneficial effects on plants, they may also have detrimental consequences, such as ecological imbalances resulting from abuse or improper application, which may lead to nutrient runoff, water pollution, and eutrophication of aquatic systems. Continuous use of inorganic fertilizers without organic additions may compromise soil structure, diminish microbial activity, and ultimately deplete soil organic matter. Excessive application may lead to nutritional imbalances, potentially harming plants, diminishing crop quality, and increasing susceptibility to diseases and pests. We must now reconcile the need for high-yield agriculture with the imperative to mitigate environmental harm in the global agricultural context [9]. The management of controlled and open fields exerts distinct influences on crop resilience, pest management, and resource use. The juxtaposition of conventional and organic nutrient inputs presents a complicated scenario concerning the optimal equilibrium between crop genetic expression and ecological factors. This study is essential for shaping the discourse on sustainable agricultural practices by analyzing various production scenarios via a comprehensive perspective that considers genetic factors. This information enables the modification of tomato cultivars to suit specific climates and agricultural practices, perhaps enhancing production stability and nutritional quality [12]. The findings of this research may guide future agricultural policies and practices toward a more genetically harmonious and sustainable approach to food production [13]. This research seeks to examine the holistic responses of tomato plants to organic and inorganic fertilizers across various environmental conditions. The study will find optimum fertilization options that boost tomato yield via an analysis of genetic, physiological, and biochemical changes, while ensuring environmental sustainability and soil health.

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Materials and Methods

2.2. PHYSIOLGICAL ATTRIBUTES

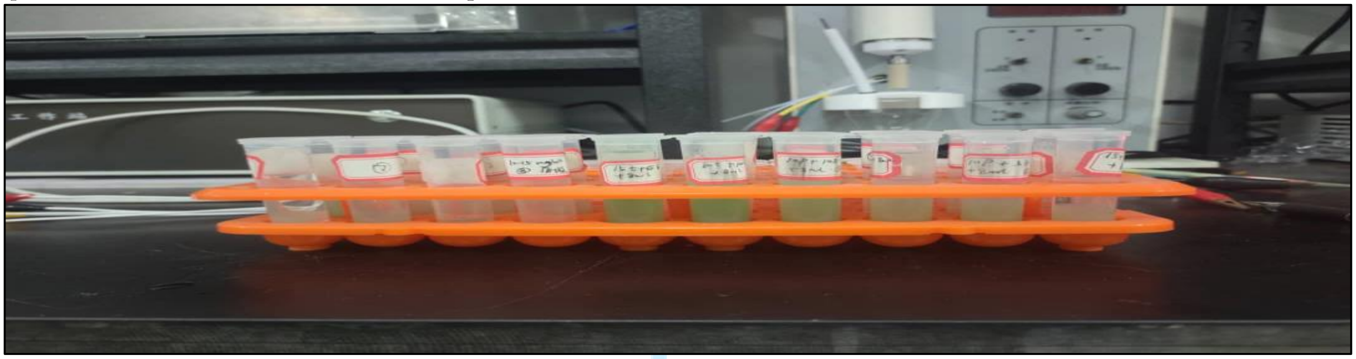
2.2.1 Chlorophyll Content

Chlorophyll a and b, total chlorophyll, and carotenoids were quantified using Arnon's (1949) methodology. Fresh leaves, weighing 0.2 g, were subjected to cutting, followed by extraction with 20% acetone overnight at 4°C. The extracts were centrifuged for five minutes at 10,000 RPM. Using a spectrophotometer (Hitachi-220, Japan), we quantified the absorbance of the supernatant at wavelengths of 645, 663, and 480 nm. The concentrations of carotenoids, chlorophyll a, and chlorophyll b were determined using the specified formulas.Chl a (mg/g f.wt.) = 2.69 (OD 645)-2.17 (OD 663) V/1000.

The formula for chloride b is [22.9(OD 645)-4.68(OD 663)] (mg/g f.wt.V/1000W.

Carotenoids (mg/g f.wt.) = 100 Ac/Em,

where V is the sample and W is the weight of fresh tissue.



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2.2.2 Total Free Amino Acids

Van Slyke and Hamilton (1943) introduced an equation to determine the total quantity of accessible amino acids. Fresh leaf tissue (0.5 g) was diced and extracted using 10 ml of 200 mM phosphate buffer at pH 7.0. Subsequently, 1 mL of extract was introduced into two 25 mL test tubes, each containing corresponding destupes (10% pyridine) and color reagent solution (2%). One hundred milliliters of distilled water was used to dissolve two grams of ninhydrin for the manufacture of the ninhydrin solution. The test tube was submerged in a pot of boiling water for roughly thirty minutes. Subsequently, each test tube was diluted to a final amount of 50 mL using distilled water. The optical density at 570 nm of the colored solution was determined using a spectrophotometer.

2.2.3 Total Free Proteins

The color of Bradford reagent is used to identify soluble proteins. Bradford reagent consists of 0.1g of Coomassie Brilliant Blue dye, 5 ml of 95% ethanol, and 100 ml of phosphoric acid. Thereafter, the mixture is passed through two or three filters after dilution to a level of one liter.

2.2.3.1 Techniques

Bradford (1976) published a protocol for quantifying the total amount of soluble protein. 0.25 g of fresh leaves and 5 ml of phosphate buffer (pH 7.0) were minced together using a pestle and mortar. The substance was kept for the entire night in order to facilitate the extraction of all the proteins. After centrifuging them for 20 minutes at 8000 rpm, the protein levels were measured by collecting the supernatant. After extraction, 5 ml of Bradford dye and 1 ml of supernatant were added.

2.2.4 Proline

Proline was determined using the methodology outlined by Bates et al. (1973). A 10 mL solution of sulfo-salicylic acid was used to completely homogenise a 0.5 g sample of freshly collected shoot tissue. No. 2 filter paper was used to process the homogenate. Twenty millilitres of 6 M orthophosphoric acid and thirty millilitres of glacial acetic solution with 1.25 g of ninhydrin were heated in a test tube for one hour, along with two millilitres of the filtered liquid. Die Reaktion wurde durch ein kaltes Bad gestoppt. We extracted the reaction mixture with four millilitres of toluene and vigorously agitated it with a continuous airflow for one to two minutes. After the pigment containing toluene was eliminated,

2.2.5 Glycine Betane

Finely powdered dry plant material weighing 0.5 g should be manually stirred with 20 ml of purified water for an entire day at 25 degrees Celsius. After filtering the sample, store the filtrate in the freezer until required. Upon preparation of the extract, amalgamate it in a 1:1 ratio with H2SO4. Take 0.5 milliliters of the extracted liquid and put it into a strong glass centrifuge tube, then place it in cold water for one hour to cool it down. After it cools, add the IK-I2 (periodide) reagent and mix it gently with a vortex. Keep the tubes at a temperature between 0 and 4°C for sixteen hours. Spin them in a centrifuge at 10,000 revolutions per minute for 15 minutes at 0 degrees Celsius. Use a glass tube and a gentle suction method to take out the liquid on top while keeping it cold.

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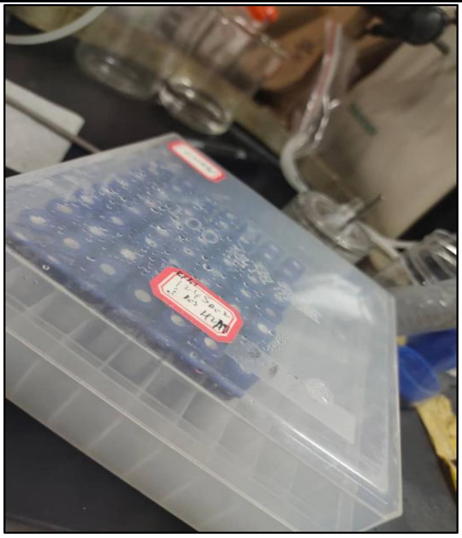
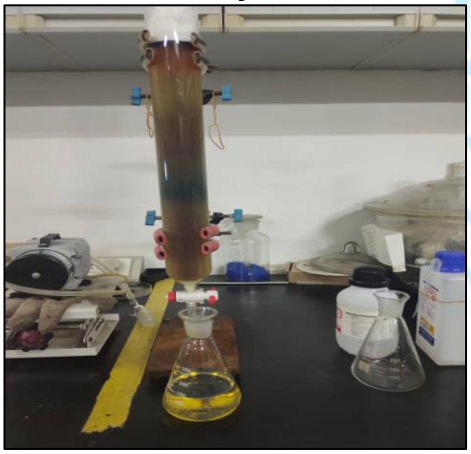


2.2.6 Total Phenolic

We evaluated total soluble phenolics using the Folin-Ciocalteu reagent and the Julkenen-Titto (1985) technique. After extracting 0.5 g of fresh plant material in 80% acetone, the extract was centrifuged at 12,000 rpm to isolate the supernatant. 100 millilitres of the extract were mixed with 2.5 millilitres of 20% sodium carbonate and 0.5 millilitres of Folin-Ciocalteu phenol reagent. We generated the mixture and vortexed it in five millilitres. The absorbance of the reaction mixture was measured at 750 nm.



2.2.7 Peroxidase and catalase

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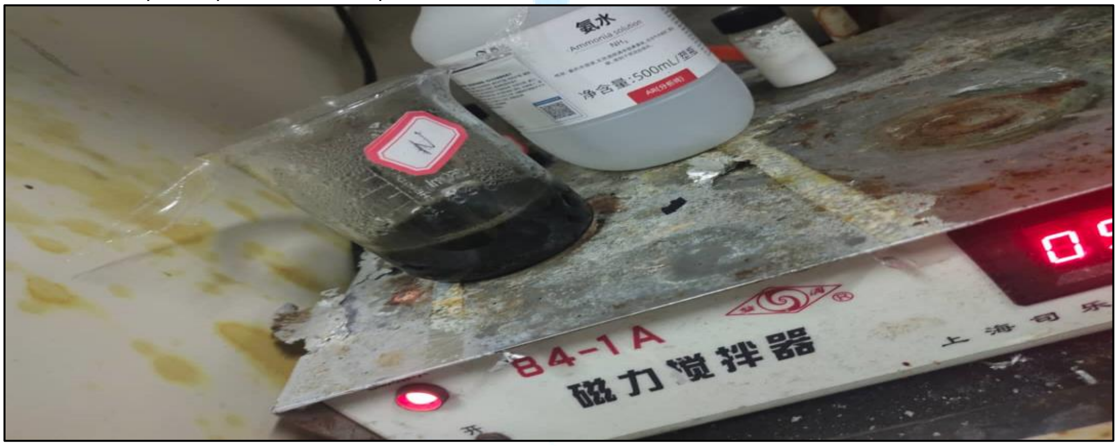
The Chance and Maehly (1955) approach was used, with few modifications, to assess the activities of CAT and POD. 5.9 mM H2O2 and 50 mM phosphate buffer (pH 7.8) were combined with 0.1 mL of enzyme extract, and the resulting liquid was further diluted to a final volume of 3 mL. The absorbance was measured at 240 nm every 20 seconds. The decomposition rate of M of H2O2 per minute was used as the units for CAT activity. One unit was defined as an absorbance change of 0.01 units per minute. A reaction solution of 40 mM H2O2, 20 mM guaiacol, and 50 mM phosphate buffer (pH 7.0) was used to evaluate POD activity. The introduction of 0.1 mL of an enzyme extract resulted in a change every 20 seconds.

2.2.8 Superoxide Dismutase (SOD)

The Giannopolitis and Ries (1977) method was used to assess SOD activity. Fifty litres of enzyme extract were amalgamated with fifty millilitres of phosphate buffer (pH 7.8). After incorporating the enzyme extract into the reaction solution, researchers introduced 50 M nitrobluetetrazolium (NBT). NBT was solubilised in ethanol, 1.3 mM riboflavin, 13 mM methionine, and 75 mM EDTA. Subsequently, this device was placed in a dimly lit location and enveloped with aluminium foil. We exposed the subject to 30 W fluorescent illumination for five minutes. It was important to check how much the nitro blue tetrazolium (NBT) reaction was reduced at 560 nm to measure the activity of superoxide dismutase (SOD). The enzyme quantity was used to determine the needed amount of SOD for a spectrophotometer to achieve a 50% output in a single unit.



2.2.9 Ionic content

2.2.9.1 Shoot and root ionic content

Sulphuric acid and hydrogen peroxide were used to decompose the dried root and ground shoot substance (0.5 g) in Wolf's (1982) method for the determination of several nutrients (Na^+, K^+, and Cl^-).

2.2.9.2 Shoot and root Cl^-

100 mg each of the shoot and root samples were crushed, and 10 ml of water were heated to 80°C until the volume was halved. The volume was again increased with distilled water until it equaled 10 mL. A chloride meter was used to determine the Cl content (Jenway, PCLM 3).

2.2.9.3 Shoot and root Na^+ and K^+ Ca^2

A flame photometer (Jenway, PFP-7) was used to determine the presence of the cations Na+, K+, and Ca_2+ Na+ and K+ standards were constructed in a graded series with standard curves varying between 5 and 25 $mgL^{-1.}$ Total quantities were computed after standard curves were compared to the Na+ and K+ results from the flame photometer.

Results

4.2. PHYSIOLOGICAL ATTRIBUTES

Chlorophyll contents

The Giannopolitis and Ries (1977) method was used to assess SOD activity. Fifty litres of enzyme extract were combined with fifty millilitres of phosphate buffer at pH 7.8. After incorporating the enzyme extract into the reaction solution, we introduced 50 M nitrobluetetrazolium (NBT). NBT was solubilised in ethanol, 1.3 mM riboflavin, 13 mM methionine, and 75 mM EDTA. We then placed this device in a gloomy location and covered it with aluminium foil.

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It was thereafter subjected to 30 W fluorescent illumination for a period of five minutes. Measuring how well nitro blue tetrazolium (NBT) was reduced at 560 nm was important for figuring out the activity of SOD. We used the enzyme quantity to determine the required amount of SOD for a spectrophotometer, aiming for a 50% output in a single unit.

Tomato Variety	Conventional Control (SPAD)	Organic Field (SPAD)	Organic Greenhouse (SPAD)	Inorganic Greenhouse (SPAD)
Roma	61	45	51	61
Rio Grande	56	43	49	56
Cherry	62	41	51	62

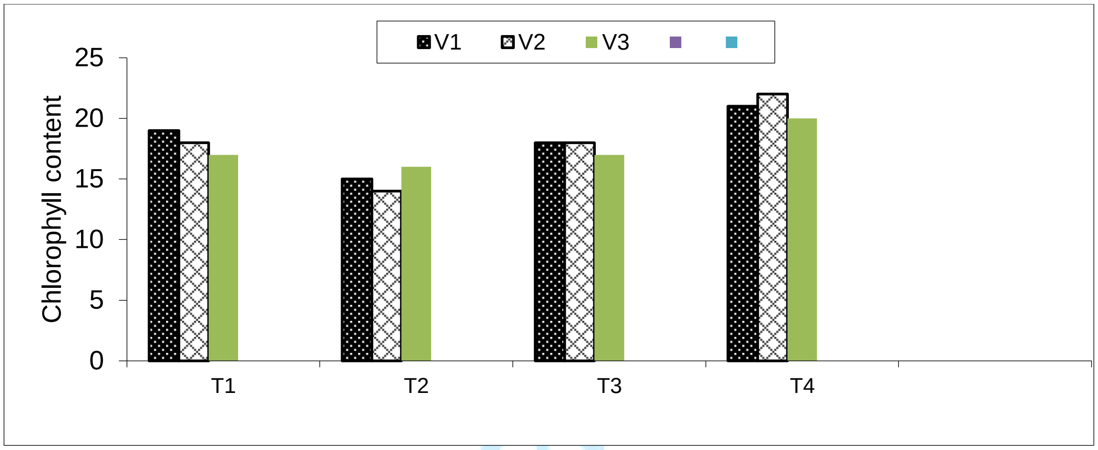

Fig 9: Effect of different environmental and treatment levels on Chlorophyll Content of Solanum *lycopersicum*

Total Free Amino Acids

The traditionally cultivated control group of Roma tomatoes exhibited around 1.7 mg/g of total free amino acids. When cultivated organically, whether in fields or greenhouses, the amino acid concentration dropped somewhat to 1.2 or 1.5 mg/g. Nonetheless, the use of inorganic techniques in the greenhouses yielded amino acid concentrations equivalent to the control at 1.7 mg/g. The control group of the Rio Grande cultivar, cultivated conventionally, had 1.7 mg/g of total free amino acids. Organic farming reduced the figure to 1.1 to 1.5 mg/g, particularly in greenhouse environments. Simultaneously, inorganic greenhouse farming attained the maximum amino acid concentration, equalling the control group at 1.7 mg/g. The cherry tomatoes had a comparable impact. No specific organic therapy achieved the 1.7 mg/g amino acid level of the control group. Organic techniques decreased the concentrations to 1.2 to 1.5 mg/g. Nonetheless, inorganic greenhouse farming yielded the greatest total free amino acid content, equalling the control group at 1.7 mg/g. In all instances, the organic tomatoes exhibited a lower concentration of amino acids compared to the conventionally cultivated varieties. Controlled greenhouse settings enhanced amino acid levels for both organic and inorganic approaches. However, inorganic farming in greenhouses consistently yielded the greatest total free amino acid content across all three kinds, matching the traditional control groups.

Tomato Variety	Conventional Control (mg/g)	Organic Field (mg/g)	Organic Greenhouse (mg/g)	Inorganic Greenhouse (mg/g)
Roma	1.7	1.2	1.5	1.7
Rio Grande	1.7	1.1	1.5	1.7
Cherry	1.7	1.2	1.5	1.7

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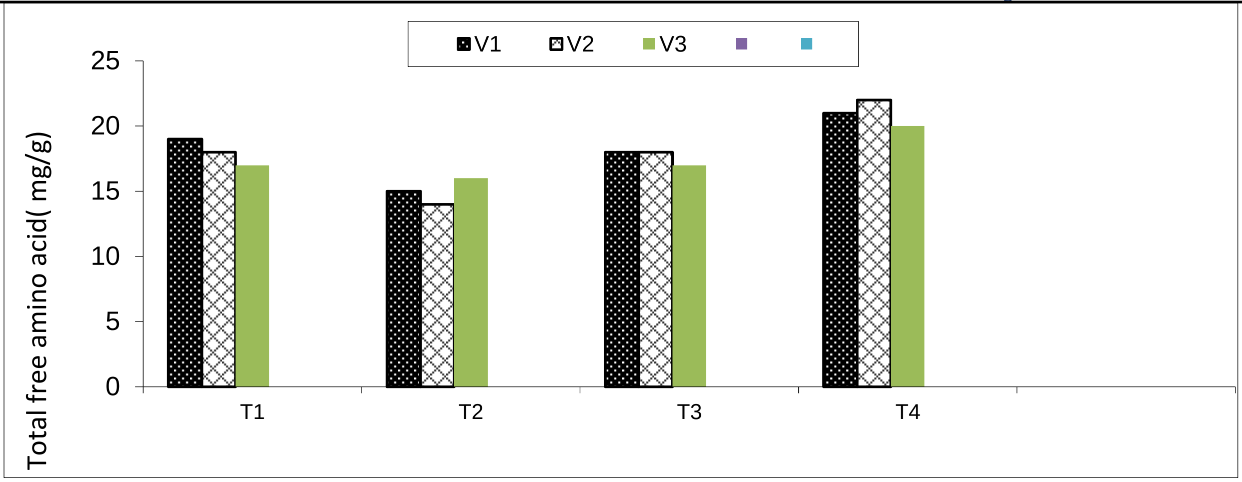

Fig 10: Effect of different environmental and treatment levels on Amino Acid Content of *Solanum lycopersicum.*

Free Protein

The control group of traditionally cultivated Roma tomatoes had around 13.6 mg/g of free protein. When cultivated organically, whether in fields or greenhouses, the protein concentration dropped to 10.5 or 11.8 mg/g. Nonetheless, the use of inorganic techniques in the greenhouses yielded protein levels equivalent to the control at 13.6 mg/g. The control group of the Rio Grande cultivar, cultivated conventionally, exhibited 12.6 mg/g of free protein. Organic farming reduced the figure to 9.5 or 11.8 mg/g, particularly in greenhouse environments. Simultaneously, inorganic greenhouse farming attained the maximum protein level, equalling the control group at 12.6 mg/g. The cherry tomatoes had a comparable impact. No specific organic therapy achieved the 12.1 mg/g protein level of the control group. Organic techniques decreased the concentrations to 9.8 or 11.2 mg/g. Nonetheless, inorganic greenhouse cultivation yielded the greatest free protein concentration, equalling the control group at 12.1 mg/g. In all instances, the organic tomatoes had lower protein levels than the conventionally cultivated varieties. Controlled greenhouse settings enhanced protein levels for both organic and inorganic approaches. However, inorganic cultivation in the greenhouses consistently yielded the greatest free protein content among all three kinds, matching the traditional control groups.

Tomato Variety	Conventional Control (mg/g)	Organic Field (mg/g)	Organic Greenhouse (mg/g)	Inorganic Greenhouse (mg/g)
Roma	13.6	10.5	11.8	13.6
Rio Grande	12.6	9.5	11.8	12.6
Cherry	12.1	9.8	11.2	12.1

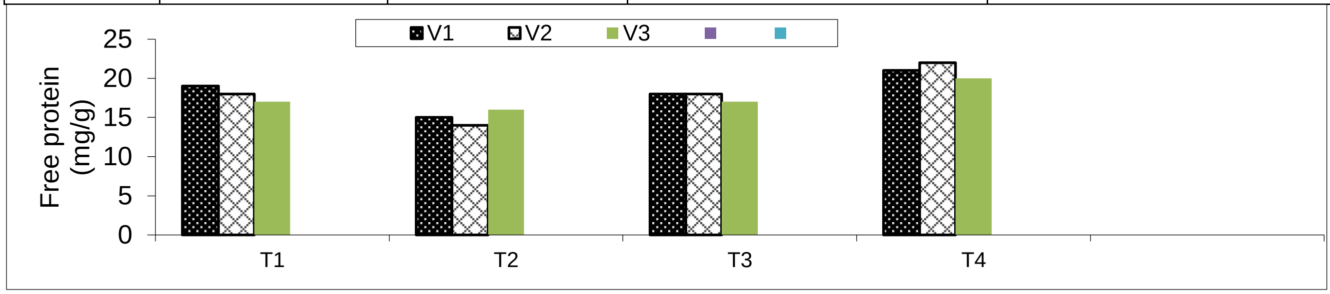

Fig 11: Effect of different environmental and treatment levels on Protein Content of Solanum lycopersicum.

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Proline

The investigation of the Roma variety indicated that normal farming (without protection) yielded around 13.6 μmol/g of proline. When adopting organic cultivation, either in open fields or greenhouses, they achieved just 10.5 or 11.8 μmol/g. Nonetheless, the inorganic growing method used inside the greenhouses yielded a proline concentration equivalent to that of the control group—13.6 μmol/g. The untreated Rio Grande group had 12.6 μmol/g of proline, which was produced using conventional procedures. The greenhouses were optimising their organic farming by reducing proline levels, resulting in measurements of 9.5 and 11.8 μmol/g, respectively. Meanwhile, the inorganic greenhouse increased proline levels, resulting in a value identical to that of the control group, which was 12.6 μmol/g. The cherry tomatoes had a comparable impact. No specific organic therapy achieved the 12.1 μmol/g proline level of the control group. Organic techniques decreased the amounts to 9.8 or 11.2 μmol/g. Inorganic greenhouse farming yielded the greatest proline level, equalling the control group at 12.1 μmol/g. In all instances, the organic tomatoes had lower proline levels than their conventionally cultivated counterparts. Controlled greenhouse settings facilitated the augmentation of proline levels using both organic and inorganic techniques. However, inorganic cultivation in the greenhouses consistently yielded the greatest proline content among all three kinds, matching the traditional control groups. Proline Content in Tomato Varieties by Farming Method (μmol/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	13.6 μmol/g	10.5 μmol/g	11.8 μmol/g	13.6 μmol/g
Rio Grande	12.6 μmol/g	9.5 μmol/g	11.8 μmol/g	12.6 μmol/g
Cherry	12.1 μmol/g	9.8 μmol/g	11.2 μmol/g	12.1 μmol/g

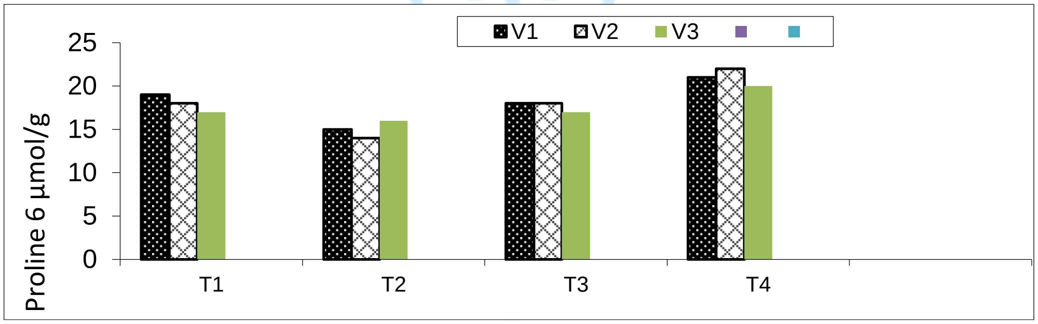

Fig 12: Effect of different environmental and treatment levels on Proline Content of Solanum lycopersicum.

Glycine betaine

The control group of traditionally produced Roma tomatoes had around 1.8 mg/g of glycine betaine. When cultivated organically, whether in fields or greenhouses, the glycine betaine concentration fell slightly to 1.5 or 1.7 mg/g. Nonetheless, the use of inorganic techniques in the greenhouses yielded glycine betaine concentrations equivalent to the control at 1.8 mg/g. The control group of the Rio Grande cultivar, cultivated conventionally, had 1.8 mg/g of glycine betaine. Organic farming reduced the figure to 1.4 or 1.7 mg/g, particularly in greenhouse environments. At the same time, growing plants in an inorganic greenhouse reached the highest level of glycine betaine, matching the control group's 1.8 mg/g. The cherry tomatoes had a comparable impact. No specific chemical therapy achieved the 1.8 mg/g glycine betaine level of the control group. Organic techniques decreased the concentrations to 1.5 or 1.7 mg/g. However, growing tomatoes in an inorganic greenhouse produced the highest glycine betaine level, matching the control group at 1.8 mg/g. In all instances, the organic tomatoes exhibited lower levels of glycine betaine compared to the conventionally cultivated varieties. Controlled greenhouse settings enhanced glycine betaine levels using both organic and inorganic means. However, inorganic cultivation in greenhouses consistently yielded the greatest glycine betaine level across all three kinds, matching the traditional control groups.

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Glycine Betaine Content in Tomato Varieties by Farming Method (mg/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	1.8 mg/g	1.5 mg/g	1.7 mg/g	1.8 mg/g
Rio Grande	1.8 mg/g	1.4 mg/g	1.7 mg/g	1.8 mg/g
Cherry	1.8 mg/g	1.5 mg/g	1.7 mg/g	1.8 mg/g

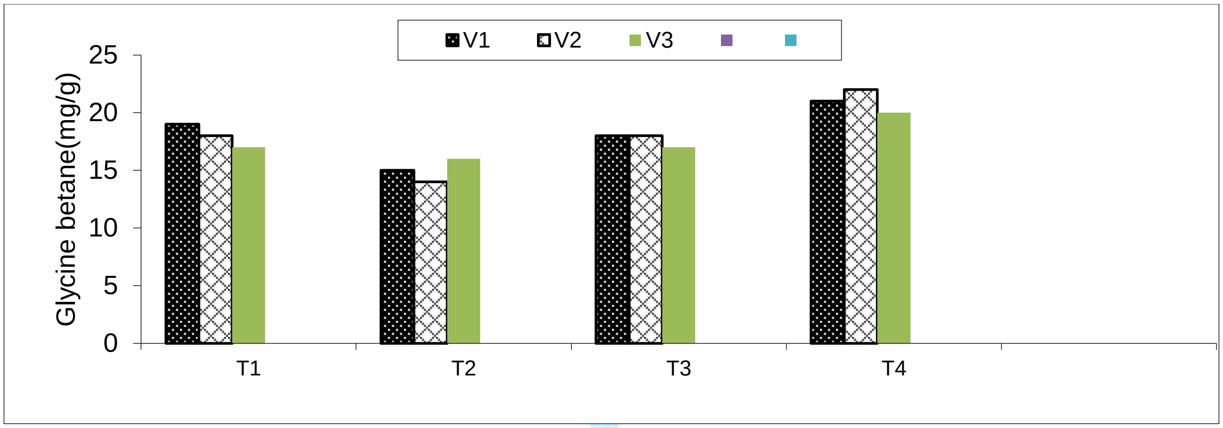

Fig 13: Effect of different environmental and treatment levels on Glycine betane of *Solanum lycopersicum.*

4.1.1. Total Phenolic

The control group, when cultivated normally, has around 3.1 mg/g of total phenolic compounds. The phenolic content significantly decreased in the agriculturally cultivated areas and farms, measuring 2.5 gm/g and 2.8 mg/g. Nonetheless, by using inorganic methods in greenhouses, the phenolic concentrations were adjusted to align with the control at 3.1 mg/g. The Rio Grande species indicated that the traditionally cultivated control group had 3.3 mg/g of total phenolic compounds. The organic method was particularly effective in the varied use of greenhouse cultivation techniques, namely 2.3 and 2.8 mg/g. Moreover, the outcomes of inorganic greenhouse farming had the greatest uniformity in phenolic levels, matching the control group at 3.3 mg/g. The cherry tomatoes had a comparable impact. No specific organic treatment achieved the 3.3 mg/g phenolic level of the control group. Organic techniques decreased the concentrations to 2.4 to 3.0 mg/g. Inorganic greenhouse farming yielded the greatest total phenolic content, equalling the control group at 3.3 mg/g. In all instances, the organic tomatoes exhibited lower phenolic content compared to their conventionally cultivated counterparts. Controlled greenhouse settings enhanced phenolic levels for both organic and inorganic approaches. However, inorganic farming in the greenhouses consistently yielded the greatest total phenolic content across all three kinds, matching the traditional control groups.

Total Phenolic Content in Tomato Varieties by Farming Method (mg/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	3.1 mg/g	2.5 mg/g	2.8 mg/g	3.1 mg/g
Rio Grande	3.3 mg/g	2.3 mg/g	2.8 mg/g	3.3 mg/g
Cherry	3.3 mg/g	2.4 mg/g	3.0 mg/g	3.3 mg/g

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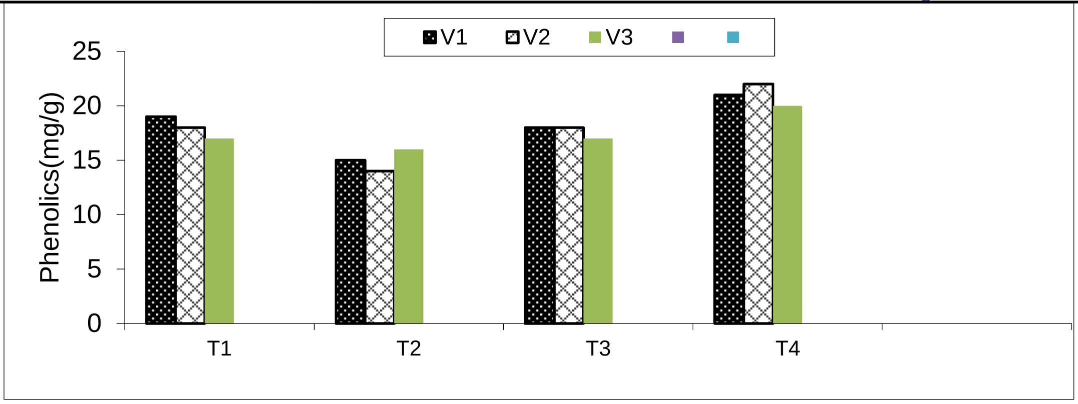

Fig 14: Effect of different environmental and treatment levels on Phenolics of Solanum lycopersicum.

Peroxidase

Initially, let us concentrate on the Roma tomatoes. The enhancement of peroxidase levels in the organically cultivated region reduced it to 102 or 112 units/g in the field or greenhouse, respectively. Significantly, a common mistake among farmers transitioning to inorganic methods in greenhouses resulted in peroxidase levels equivalent to the control at 133 units/g. Inorganic approaches in the greenhouses were used only on Roma tomatoes until the peroxidase concentration reached parity with the control at 133 units/g. The control group, cultivated using the conventional approach and utilising the Rio Grande variety, had 125 units/g of peroxidase. Concurrently, organic agriculture exhibited a somewhat reduced peroxidase concentration, ranging from 95 to 105 units/g, particularly when the crops were cultivated in a greenhouse. The non-organic greenhouse recorded the highest peroxidase level, with the plant exhibiting 125 units/g, identical to the control group. The cherry tomatoes had a comparable impact. No specific organic therapy achieved the 131 units/g peroxidase level of the control group. Organic treatments lowered the amounts to 100 or 112 units per gram. Nonetheless, inorganic greenhouse farming yielded the greatest peroxidase concentration, equalling the control group at 131 units/g. In all instances, the organic tomatoes exhibited lower peroxidase levels compared to the conventionally cultivated varieties. Controlled greenhouse settings enhanced peroxidase levels for both organic and inorganic techniques. However, inorganic cultivation in the greenhouses consistently yielded the greatest peroxidase content across all three kinds, matching the traditional control groups.

Peroxidase Content in Tomato Varieties by Farming Method (units/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	133 units/g	102 units/g	112 units/g	133 units/g
Rio Grande	125 units/g	95 units/g	105 units/g	125 units/g
Cherry	131 units/g	100 units/g	112 units/g	131 units/g

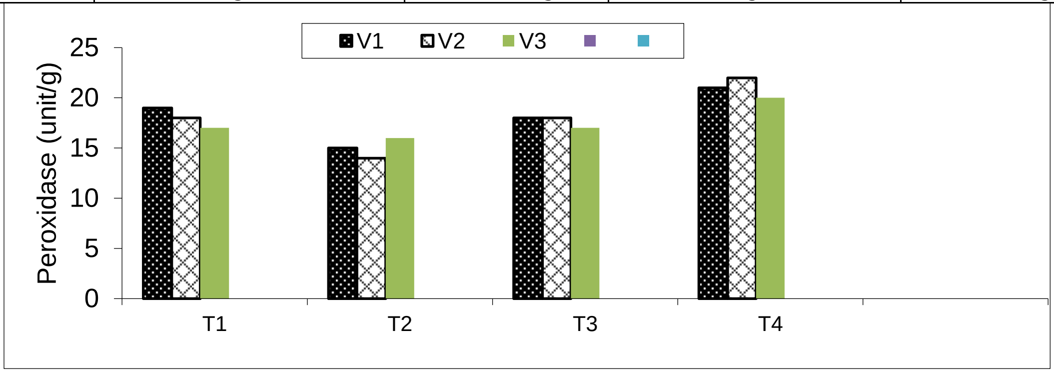

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Fig 15: Effect of different environmental and treatment levels on Peroxidase of *Solanum lycopersicum.*

4.1.1. Superoxidase

Examining the Roma tomatoes first, the normally cultivated control group had around 146 units/g of superoxide. When cultivated organically, whether in fields or greenhouses, the superoxide concentration decreased to 120 or 132 units/g. Nonetheless, the use of inorganic techniques in the greenhouses yielded superoxide levels equivalent to the control at 146 units/g. The control group of the Rio Grande cultivar, cultivated conventionally, had 145 units/g of superoxide. Organic farming reduced that figure to 115 or 125 units/g, particularly in greenhouse environments. Inorganic greenhouse farming attained the maximum superoxide concentration, equalling the control group at 145 units/g. The cherry tomatoes had a comparable impact. No specific chemical therapy achieved the 151 units/g superoxide level seen in the control group. Organic treatments lowered the amounts to 120 or 132 units per gram. Nonetheless, inorganic greenhouse farming yielded the greatest superoxide concentration, equalling the control group at 151 units/g. The organic tomatoes had lower levels of superoxide compared to the conventionally cultivated varieties. Controlled greenhouse settings facilitated the elevation of superoxide levels via both organic and inorganic means. However, inorganic cultivation in the greenhouses consistently yielded the highest superoxide levels across all three kinds, matching the traditional control groups.

Superoxide Content in Tomato Varieties by Farming Method (units/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	146 units/g	120 units/g	132 units/g	146 units/g
Rio Grande	145 units/g	115 units/g	125 units/g	145 units/g
Cherry	151 units/g	120 units/g	132 units/g	151 units/g

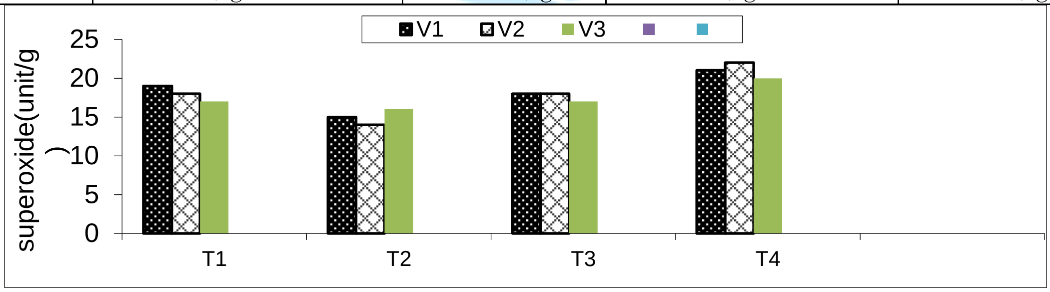

Fig 16: Effect of different environmental and treatment levels on Superoxidase of Solanum lycopersicum

.4.3. BIOCHEMICAL ATTRIBUTES

Sodium

Investigations conducted with Roma tomatoes indicated that those cultivated without organic content had the greatest salt concentration of 0.7 mg per gram. When tomatoes are cultivated organically in fields or greenhouses, the salt content decreases to 0.5 to 0.6 mg/g. When the greenhouses were used inorganically, the salt levels increased to 0.7 mg/g. The control group had the same result of 0.7 mg/g of sodium using Rio Grande tomatoes. The salinity level decreased to 0.4 or 0.5 mg/g as a result of organic farming, mostly conducted in greenhouses. Simultaneously, greenhouse inorganic farming had the greatest sodium concentration of 0.7 mg/g. The tomatoes grown using organic farming also exhibited a similar pattern. No viable methods existed to reduce the sodium concentration to 0.7 mg/g. Both conventional and novel approaches provide results of 0.4 mg/g and 0.5 mg/g, respectively, in all situations. Furthermore, the greenhouse cultivation produced the maximum salt concentration of 0.7 mg/g. The use of glasshouses and organic farming consequently led to higher salt levels. Nevertheless, the use of inorganic agricultural inputs in the greenhouse consistently resulted in the greatest salt levels among the three varieties.

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Sodium (Salt) Content in Tomato Varieties by Farming Method (mg/g)

Tomato Variety	Conventional Control	Organic Field	Organic Greenhouse	Inorganic Greenhouse
Roma	0.7 mg/g	0.5 mg/g	0.6 mg/g	0.7 mg/g
Rio Grande	0.7 mg/g	0.4 mg/g	0.5 mg/g	0.7 mg/g
Cherry	0.7 mg/g	0.4 mg/g	0.5 mg/g	0.7 mg/g

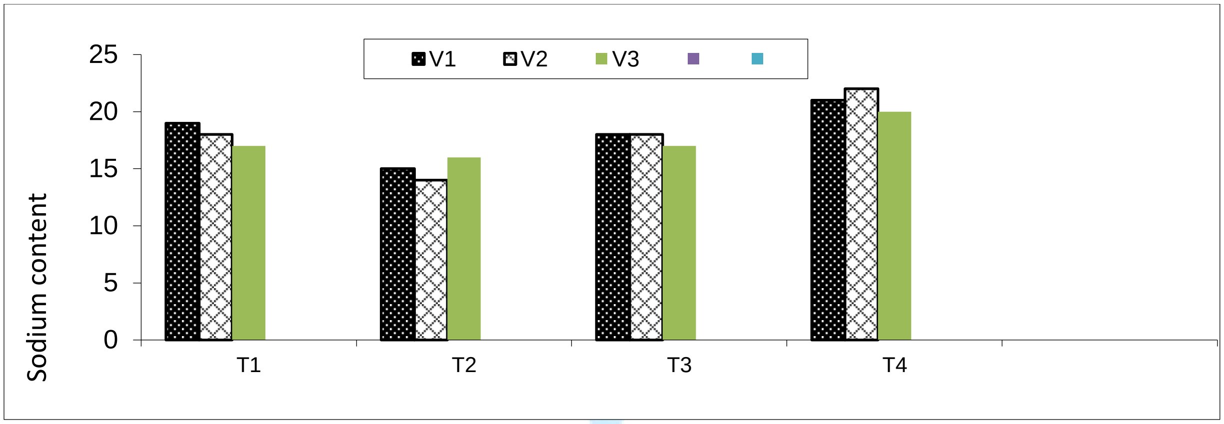

Fig 17: Effect of different environmental and treatment levels on Sodium Content of Solanum lycopersicum.

Chlorine

Investigations conducted with Roma tomatoes indicated that those cultivated without organic content had the greatest salt concentration of 0.7 mg per gram. When tomatoes are cultivated organically in fields or greenhouses, the salt content decreases to 0.5 to 0.6 mg/g. When the greenhouses were used inorganically, the salt levels increased to 0.7 mg/g. The control group had the same result of 0.7 mg/g of sodium using Rio Grande tomatoes. The salinity level decreased to 0.4 or 0.5 mg/g as a result of organic farming, mostly conducted in greenhouses. Simultaneously, greenhouse inorganic farming had the greatest sodium concentration of 0.7 mg/g. The tomatoes grown using organic farming also exhibited a similar pattern. No viable methods existed to reduce the sodium concentration to 0.7 mg/g. Both conventional and novel approaches provide results of 0.4 mg/g and 0.5 mg/g, respectively, in all situations. Furthermore, the greenhouse cultivation produced the maximum salt concentration of 0.7 mg/g. The use of glasshouses and organic farming consequently led to higher salt levels. Nevertheless, the use of inorganic agricultural inputs in the greenhouse consistently resulted in the greatest salt levels among the three varieties.

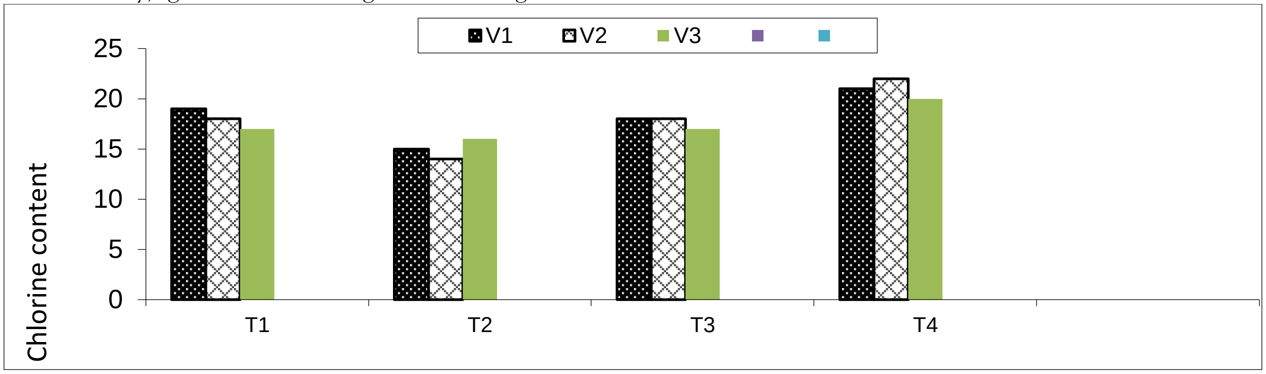

Fig 18: Effect of different environmental and treatment levels on Chlorine Content of *Solanum lycopersicum.*

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Calcium

The conventionally cultivated Roma tomatoes in the control group had just 1.4 mg of calcium per gram. The calcium level decreased marginally to 1.2 mg/g in the inorganic specimens cultivated in the greenhouses. Nonetheless, the inorganic greenhouse tomatoes reached the greatest concentration at 1.4 mg/g once again. This was the case, although the Rio Grande variant exhibited similar behaviour. The control group of calcium measured 1.4 mg/g. Organic approaches, namely the greenhouse approach, decreased to 1.1 or 1.2 mg/g. Subsequently, reintroducing inorganic materials in the greenhouse elevated the calcium concentration to 1.4 mg/g. The situation is analogous with the cherry tomatoes. No treatment exhibited 1.4 mg/g of calcium, while organic irrigation reduced it to 1.1 or 1.2 mg/g. Moreover, the inorganic Cherry tomatoes had the maximum calcium concentration at 1.4 mg/g. Consequently, the organic tomatoes exhibited lower calcium levels in all instances compared to the inorganic varieties. Furthermore, with the regulation of the greenhouse environment, calcium levels exhibited enhancement for both organic and inorganic approaches. However, the sustained use of inorganic materials in the greenhouse led to the cultivation of tomatoes with the greatest calcium concentration.

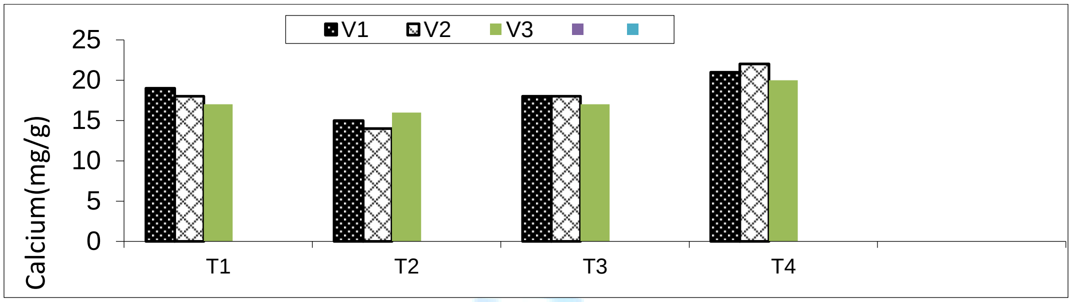

Fig 19: Effect of different environmental and treatment levels on Calcium Content of Solanum lycopersicum.

Magnesium

The control group of normally cultivated Roma tomatoes exhibited around 0.8 mg of magnesium per gram. Interestingly, the magnesium concentration increased marginally to 0.9 mg/g, both in the field and in the greenhouse throughout the natural cultivation of the crops. Both organic processes in the greenhouse context ultimately achieved the greatest magnesium content of 1.0 mg/g. The control group, cultivated using conventional methods, had a magnesium content of 0.9 mg/g for the Rio Grande variety. The transition to organic farming resulted in a significant decline in magnesium levels, down to 0.7 or 0.8 mg/g, particularly in greenhouse environments. Simultaneously, using inorganic methods in the greenhouse resulted in the maximum magnesium concentration of 1.0 mg/g. Cherry tomatoes had a comparable impact. No specific organic therapy exceeded 0.9 mg/g of magnesium. Organic techniques lowered the amounts to 0.7 to 0.8 mg/g. Inorganic greenhouse farming yielded the greatest magnesium concentration at 1.0 mg/g. Organic methods increased magnesium levels in Roma, but inorganic gardening always produced the highest magnesium amounts in all three types in controlled greenhouse environments, clearly showing the key results.

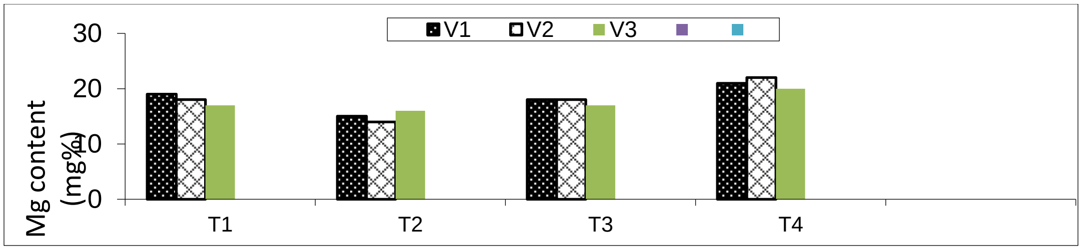

Fig 20: Effect of different environmental and treatment levels on Magnesium Content of Solanum lycopersicum.

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Potassium

Roma tomatoes are the most susceptible kind. The normally cultivated control group exhibited around 2.2 mg of potassium per gram. The potassium concentration decreased to 2.0 or 2.1 mg/g when cultivated organically, whether in fields or greenhouses. Nonetheless, the use of inorganic techniques in the greenhouses resulted in potassium levels increasing to 2.3 mg/g, the highest recorded quantity. Additionally, the Rio Grande variety included a control group cultivated using conventional methods, which likewise exhibited 2.2 mg/g of potassium determined from wild growth. It was noted that organic farming failed to achieve even half of this figure, reducing the average level to 1.8 or 2.0 mg/g along the roadside. However, in the non-organic greenhouses, the highest potassium concentration recorded was 2.2 mg/g. The impact on cherry tomatoes was almost the same. The standard organic approach treated the control group, resulting in a potassium level of 2.2 mg/g. No organic substrate attained the control limit of 2.2 mg/g. Other substrates decreased the potassium level, for instance, to 1.8 mg/g or within the range of 2.0 mg/g. Furthermore, among the enumerated potassium levels, the lowest values recorded were 1.0 and 1.5 mg/g. In all instances, the organic tomatoes had lower levels of potassium compared to the conventionally cultivated varieties. Controlled greenhouse settings facilitated the enhancement of potassium levels for both organic and inorganic approaches. However, inorganic cultivation in the greenhouses consistently yielded the greatest potassium levels across all three kinds.

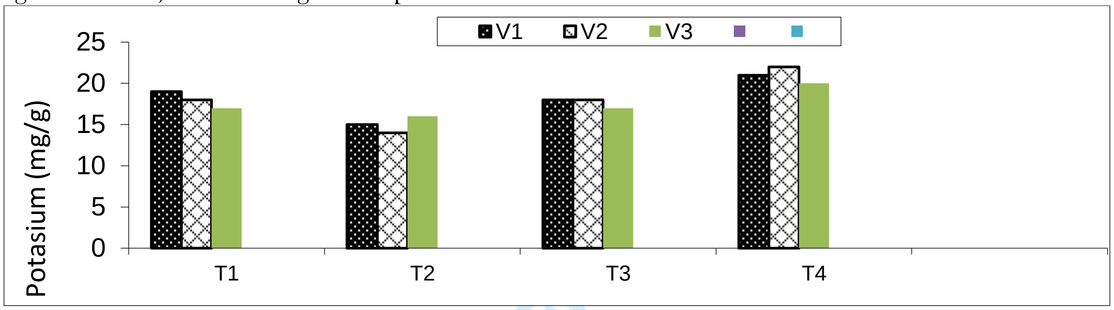

Fig 21: Effect of different environmental and treatment levels on Potasssium Content of Solanum lycopersicum.

4.4. GENOTYPICAL ATTRIBUTES

Ripening Time

The control group of Variety 1 (Roma) had an average ripening duration of 60 days. The organic treatment decreased the ripening duration from 75 days in a natural setting to 70 days in a controlled environment. The minimum ripening duration in a controlled environment with inorganic treatment was 59 days. The control group for Variety 2 (Rio Grande) needed an average of 61 days to mature. In a greenhouse study trial, the duration of the organic treatment was reduced from 76 days in the natural environment to 71 days. The shortest ripening period was sixty days under controlled conditions with non-organic treatment. The majority's inclusion of the control group in Variety 3 required 55 days. The organic treatment duration was 70 days in the natural environment, but it decreased to 64 days after the shift from natural to controlled conditions. These data suggest that, in conjunction with organic therapies, inorganic treatments consistently prioritise their efficacy in expediting the resolution of ripening difficulties.

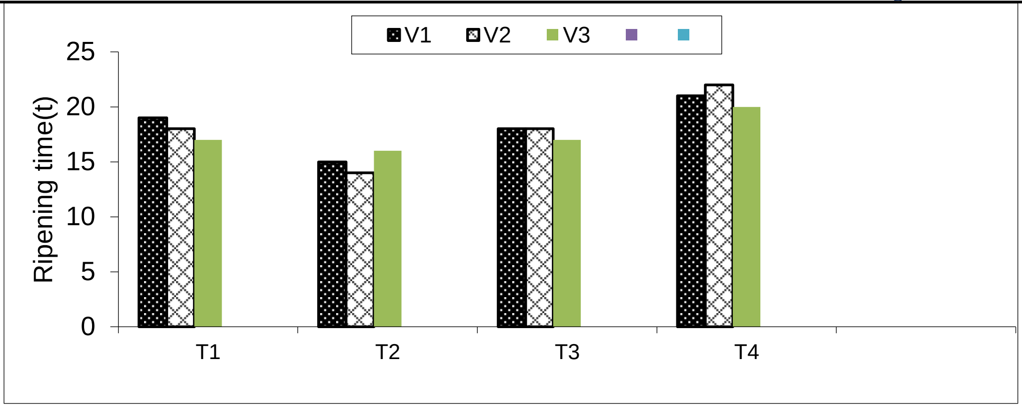

Fig 8: Effect of different environmental and treatment levels on Ripening Time of *Solanum lycopersicum.*

Shelf Life

Untreated Roma tomatoes may last for a duration of up to one week. By adopting organic practices, tomatoes cultivated in open fields or greenhouses may retain freshness for an additional two days. The greenhouse produced the optimal result—all Roma tomatoes remained viable for the whole duration of 12 days. Notably, the Rio Grande had performed well. The control group allowed the tomatoes to decay within a week, but the organic farm fields preserved them for 9 days, and the greenhouse farms extended their freshness for up to 12 days before deterioration occurred. No treatment extended their shelf life to one week, but organic farms achieved nine days, and greenhouse farms reached up to eleven days before the tomatoes deteriorated. Organic approaches yielded a significant improvement, and the regulated environment proved to be the most effective. In the end, the cherry tomatoes emerged victorious. The control group lasted 11 days, surpassing the other kinds. However, the organic agricultural fields received one additional day, totalling 12 days. When cultivated organically in greenhouses, they remained viable for a whole two weeks prior to deterioration. In all instances, organic farming may prolong shelf life, and implementing it in a controlled greenhouse environment enhances this effect further. It is impressive how they managed to prolong the freshness of those tomatoes! Please inform me whether my conversational explanation clarifies the information better than only providing the numbers.

Yield

The effective cultivation and nourishment of Roma tomatoes resulted in a yield of 5 kg of fruit. This level of accomplishment is very commendable. Only organic approaches, both in open-air cultivation and greenhouses, resulted in a reduction of 3.5 kg to 4 kg per plant. In this instance, the greenhouse was perhaps the least successful of the two options. Their option to use inorganic fertilisers and insecticides proved to be optimal for the Roma plants. They consistently planted the same quantity of crops, 5 kg each time. The Rift tomatoes exhibited this response. The selected control plants were likewise close to that figure. Conversely, the yield of the aquaponic system declined to around 3 kg. One of the blueberry greenhouse setups distinguished itself once again with a yield of 4.8 kg per individual bush. The cherry tomatoes had the same findings. The control group had the highest output at 3.8 kg per plant, indicating that the plants grown without fertiliser significantly outperformed the others. Organic management signifies a reduction in output from 2.5 kg or 3 kg compared to the inorganic alternative, which is also influenced by weather conditions. The efficacy of non-organic technologies in the greenhouse resulted in a peak production of 3.8 kg.

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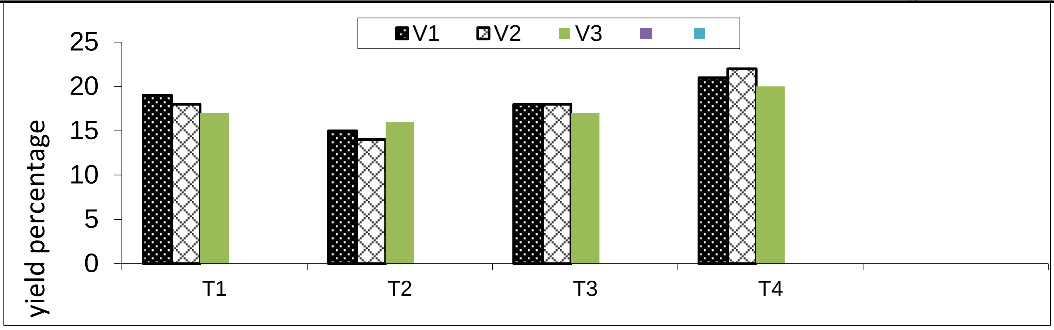

Fig 9: Effect of different environmental and treatment levels on Yield Percentage of Solanum lycopersicum.

Discussion

The results of this investigation demonstrate substantial disparities in the genetic, physiological, and biochemical responses of tomato plants to organic vs. inorganic fertilizers across different environmental circumstances. These results corroborate prior studies demonstrating that the interplay between nutrient sources and environmental conditions is crucial to plant performance [14].

Tomato plants subjected to organic fertilizers often exhibited superior root development, greater soil structure, and increased microbial activity, facilitating sustained growth under inadequate environmental circumstances. Organic inputs seemed to augment the activities of antioxidant enzymes (such as catalase and peroxidase) and elevate chlorophyll content, which are critical indications of stress tolerance and photosynthetic efficiency [15]. Conversely, inorganic fertilizers facilitated rapid vegetative development and elevated early yields, especially under regulated or moderate environmental conditions. Nonetheless, their efficacy diminished in severe circumstances (e.g., elevated temperatures or low humidity), maybe attributable to nutrient leaching, salt stress, or decreased microbial diversity in the rhizosphere. The findings indicate that whereas chemical fertilizers provide immediate advantages, their long-term durability and adaptability to climatic variability are limited. Genotypic variation significantly contributed as well. Certain tomato cultivars exhibited enhanced flexibility and superior nutrient usage efficiency, suggesting the existence of genetically regulated processes that affect nutrient absorption, metabolic regulation, and responses to environmental stress. This discovery illustrates the importance of choosing cultivars that are particular to their environment and sensitive to inputs for maximum yield. Tomatoes cultivated with organic fertilizers demonstrated elevated concentrations of secondary metabolites, including phenolics and flavonoids, which are advantageous for plant defense and human health. This supports the notion that organic systems often induce moderate stress responses in plants, thereby enhancing the synthesis of beneficial phytochemicals [16]. In conclusion, the findings underscore the need for integrated nutrient management techniques that amalgamate the immediate impacts of inorganic fertilizers with the enduring soil health advantages of organic additions. Moreover, recognizing and using tomato genotypes that respond favorably to sustainable fertilizing in certain environmental contexts will be essential for future breeding and cultivation initiatives. The results of this investigation demonstrate substantial disparities in the genetic, physiological, and biochemical responses of tomato plants to organic vs. inorganic fertilizers across different environmental circumstances. These results corroborate prior studies demonstrating that the interplay between nutrient sources and environmental conditions is crucial to plant performance [17].

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References

Dorais, M., Ehret, D. L., & Papadopoulos, A. P. (2008). Tomato (Solanum lycopersicum) health components: from the seed to the consumer. *Phytochemistry Reviews*, 7, 231-250.

Javaria, S., & Khan, M. Q. (2010). Impact of integrated nutrient management on tomato yield quality and soil environment. *Journal of plant nutrition*, *34*(1), 140-149.

Anisuzzaman, M., Rafii, M. Y., Jaafar, N. M., Izan Ramlee, S., Ikbal, M. F., & Haque, M. A. (2021). Effect of organic and inorganic fertilizer on the growth and yield components of traditional and improved rice (Oryza sativa L.) genotypes in Malaysia. *Agronomy*, *11*(9), 1830.

Adekiya, A. O., Ejue, W. S., Olayanju, A., Dunsin, O., Aboyeji, C. M., Aremu, C., ... & Akinpelu, O. (2020). Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. *Scientific Reports*, *10*(1), 16083.

Hussain, S. S., Ara, T., Raina, F. A., Gani, G., Hussain, N., Hussain, M., & Dar, S. R. (2015). Quality evaluation of different forms of compost and their effect in comparison with inorganic fertilizers on growth and yield attributes of wheat (Triticum aestivum L.). *Journal of Agricultural Science*, 7(1), 154.

Zhang, M., Sun, D., Niu, Z., Yan, J., Zhou, X., & Kang, X. (2020). Effects of combined organic/inorganic fertilizer application on growth, photosynthetic characteristics, yield and fruit quality of Actinidia chinesis cv 'Hongyang'. *Global Ecology and Conservation*, *22*, e00997.

Mani, P. K. (2017). Fertilizers in Vegetable Production. *Fundamentals of Vegetable Production*.

Johnston, A. E., & Richards, I. R. (2003). Effectiveness of the water-insoluble component of triple superphosphate for yield and phosphorus uptake by plants. *The Journal of Agricultural Science*, *140*(3), 267-274.

Huber, D., Römheld, V., & Weinmann, M. (2012). Relationship between nutrition, plant diseases and pests. In *Marschner's mineral nutrition of higher plants* (pp. 283-298). Academic Press.

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature plants*, *2*(2), 1-8.

ISSN: (e) 3007-1607 (p) 3007-1593

Ikard, S. J., Revil, A., Schmutz, M., Karaoulis, M., Jardani, A., & Mooney, M. (2014). Characterization of focused seepage through an earthfill dam using geoelectrical methods. *Groundwater*, *52*(6), 952-965.

Reeve, J. R., Hoagland, L. A., Villalba, J. J., Carr, P. M., Atucha, A., Cambardella, C., ... & Delate, K. (2016). Organic farming, soil health, and food quality: considering possible links. *Advances in agronomy*, *137*, 319-367.

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, *12*(6), 064016.

Ronga, D., Biazzi, E., Parati, K., Carminati, D., Carminati, E., & Tava, A. (2019). Microalgal biostimulants and biofertilisers in crop productions. *Agronomy*, *9*(4), 192.

Adhikary, D., Das, D., Ali, M. Y., Ullah, H., & Datta, A. (2023). Growth, grain yield, and water productivity of traditional rice landraces from coastal Bangladesh, as affected by salt stress. *Journal of Crop Improvement*, *37*(1), 60-73.

Olowe, O. A., Adefisoye, M. A., Adeoye-Isijola, M. O., & Olajuyigbe, O. O. Characterization, Bioactive Profiling and Evaluation of the Pharmacological Activities of Ethanol Extract of Lannea welwitschii (Hiern) Engl.

Ronga, D., Biazzi, E., Parati, K., Carminati, D., Carminati, E., & Tava, A. (2019). Microalgal biostimulants and biofertilisers in crop productions. *Agronomy*, *9*(4), 192.

Adhikary, D., Das, D., Ali, M. Y., Ullah, H., & Datta, A. (2023). Growth, grain yield, and water productivity of traditional rice landraces from coastal Bangladesh, as affected by salt stress. *Journal of Crop Improvement*, *37*(1), 60-73