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Abdul Malica
M.Sc. Scholar, Department of Vegetable Science, Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Siddipet, Telangana, India

Dr.Veena Joshi
Associate Professor, Department of Fruit Science, SKLTGHU, Mulugu, Telangana, India

Dr. M Rajasekhar
Professor, Dean of Horticulture & Dean of PG Studies, Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Telangana, India

Dr. S Mallesh
Assistant Professor, Department of Vegetable Science, Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Telangana, India

Dr. G Sathish
Assistant Professor, Department of Agricultural Statistics, Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Telangana, India

Corresponding Author:
Abdul Malica
M.Sc. Scholar, Department of Vegetable Science, Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Siddipet, Telangana, India

Effect of nano fertilizers on growth and yield of tomato (*Solanum lycopersicum* L.)

Md Abdul Malica, Dr.Veena Joshi, Dr. M Rajasekhar, Dr. S Mallesh and Dr. G Sathish

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Abstract
The present investigation entitled "Effect of nano fertilizers on growth and yield of tomato (*Solanum lycopersicum* L.)" was carried out in open field conditions during *rabi* season in the year 2023-2024 at Centre of Excellence fruits, Mulugu, Siddipet district.
The experiment was carried out with seven (7) treatments in Randomized Block Design in three (3) replications *i.e.* T_1: 100% RDF Control, T_2: 75% RDF +nano NPK@5 ml/L, T_3: 75% RDF +nano NPK@7.5 ml/L, T_4: 75%RDF +nano NPK@10 ml/L, T_5: 50% RDF +nano NPK@10 ml/L, T_6: 50% RDF +nano NPK@15 ml/L, T_7: 50% RDF +nano NPK@20 ml/L.
The results on growth parameters indicated that among all treatments, T_4: 75%RDF +nano NPK@10 ml/L recorded significantly maximum plant height (65.10, 74.45, 85.62 cm), maximum number of compound leaves per plant (24.45, 24.70, 25.13), maximum number of primary branches per plant (10.66, 13.62, 14.13) at 45, 90 DAT and at last harvest respectively compared to the other treatments.
The results on yield parameters revealed that significantly maximum fruit length (4.69 cm), maximum average fruit diameter (5.66 cm), maximum average fruit weight (66.20 g) minimum number of days taken to first fruit set (32.46 days), minimum number of days for first harvest (54.20 days), maximum number of fruits per cluster (6.30), maximum number of fruits per plant (15.66), maximum fruit yield per plant (2.86 kg), maximum fruit yield per plot (18.50 kg), maximum fruit yield per hectare (31.38 t) were recorded in the treatment T_4: 75%RDF +nano NPK@10 ml/L compared to the other treatments

Keywords: Nano NPK, tomato, treatments, growth and yield

Introduction
The tomato, "*Solanum lycopersicum* L.", is a prominent member of the Solanaceae family with a chromosome number of 2n=2x=24. It originated in the South American Andes region (Rick, 1969) [14]. As one of the most highly valued vegetables worldwide, the tomato is often called "protective food" due to its high concentrations of nutritive phytochemicals, including carotenoids such as lycopene and provitamin A carotene, as well as flavonoids, phenolic acids, ascorbic acid, and essential minerals like calcium, iron, and phosphorus.
As per the area (National Horticultural Board, 2018-2019 estimates) of tomato in India is 778000 ha and production is 19397 MT and major tomato producing states are Telangana, Andhra Pradesh, Madhya Pradesh, Karnataka, Tamil Nadu, Orissa, Gujarat, West Bengal, Chhattisgarh, Maharashtra and Bihar. In Telangana, tomato is cultivated in an area of 0.025 million hectares a with production of 0.88 million metric tonnes (Department of Horticulture, Govt. of Telangana 2022-2023) [5].
Tomatoes are abundant in minerals, vitamins B and C, essential amino acids, sugars, dietary fibers, iron, and phosphorus. They can be eaten fresh in salads or cooked in sauces, soups, and meat or fish dishes. Tomatoes are also processed into purees, juices, and ketchup, and their fruits are preserved in different ways to be used in various culinary dishes. Ripe, fresh tomatoes are commonly used in salads and other dishes, while canned and dried tomatoes are significant processed products economically (Collins *et al.*, 2022) [4].
The health benefits of eating tomatoes include their effectiveness in lowering cholesterol levels and blood pressure, thanks to their vitamin B and potassium content. When included in a well-

balanced diet, tomatoes can help maintain a healthy heart (Collins *et al*., 2022) [4].

Key nutrients play crucial roles in plant development: Nitrogen (N) supports the growth of new stems and leaves, as it is an essential component of chlorophyll, which gives leaves their green color and enables photosynthesis. Phosphorus (P) is vital for the development of flowers, fruits, and root systems. Potassium (K) helps maintain healthy roots, supports the growth of flowers and fruits, and enhances a plant's ability to withstand stress, such as drought.

Nanotechnology is an innovative scientific approach that involves using materials and equipment to manipulate the physical and chemical properties of substances at the molecular level. This technology explores biological systems and applies them across various fields, from medicine to agriculture. It focuses on tiny structures, typically less than 100 nano meters in size (1 nm = 10^{-9} meters). Nanotechnology has diverse applications, including in agriculture, medicine, air and water pollution control, solar cells, and electronics (Panda *et al.*, 2020) [12].

In agriculture, the use of nano nutrient-based fertilizers can address the issues caused by inorganic fertilizers, such as environmental pollution, leaching, increased salinity, toxicity, and plant damage. Nano nutrient-based fertilizers are highly soluble, offer precise nutrient concentrations, and control nutrient release due to their larger surface area and targeted activity. Additionally, they are more environmentally safe compared to commercially used inorganic fertilizers (Abdel *et al.*, 2017) [1].

Nano fertilizers are developed by encapsulating plant nutrients within nanomaterials, applying thin nanomaterial coatings on nutrients, and delivering them as nano-sized emulsions. The nano-sized pores and stomatal openings in plant leaves enable the uptake and deep penetration of these materials, resulting in higher nutrient use efficiency (NUE). Nano fertilizers enhance the transport and delivery of nutrients through plasmodesmata, which are nano-sized channels (50–60 nm) between cells. This improved NUE and reduced nutrient loss lead to increased productivity (by 6–17%) and better nutritional quality in field crops.

The growth and yield of vegetable crops largely depend on the quality and quantity of fertilizers used. However, the loss of mineral nutrients through leaching and runoff into surface and groundwater, as well as excessive volatilization, raises significant concerns due to both economic losses and environmental pollution. The widespread use of chemical fertilizers has led to serious environmental issues, including the accumulation of heavy metals in soil and plant systems (Abdel *et al.*, 2017) [1]. Conventional application methods often result in the overdosing of chemical fertilizers, exacerbating these problems.

Nanotechnology is an emerging field of research that leverages nanomaterials smaller than 100 nm to create concentrated sources of plant nutrients with enhanced absorption rates, improved utilization efficiency, and minimal losses. One of the most significant applications of nanotechnology is in the development of nano fertilizers, which enhance plants' nutrient absorption capabilities (Mousavi and Rezaei, 2011; Srilatha, 2011; Ditta, 2012) [10, 15, 6]. Nano fertilizers are produced by encapsulating plant nutrients within nanomaterials, applying thin nanomaterial coatings to the nutrients, and delivering them as nano-sized emulsions.

Materials and Methods

The experiment was conducted at Centre of Excellence for fruits, Mulugu, Siddipet district. The experimental site lies at 78°49' East longitude and 18°31' North latitude and altitude of 451 m above mean sea level.

The location is characterized by semi-arid tropical zone with average rainfall of 80.95 mm and average maximum and minimum temperatures of 32.0 °C, 14.0 °C respectively.

Variety US-440 is used for the experiment, collected from COE, Mulugu Siddipet district. Plant is semi determinate, fruits are flat Round shaped with good firmness, Tolerant to tomato leaf curl virus and heat. Grown in both *rabi* and *kharif* seasons. Maturity 60-70 days. Average fruit weight is 70-80 g and yields 25-40 t/ha.

The experimentation site was cleaned and made free of weeds, grasses and stones. The site was leveled evenly on the surface, the plots were set according to the treatments and designs. Each treatment was replicated thrice in Randomized Block Design (RBD) and each treatment consisted of twenty five plants placed at a spacing of 60 x 45 cm.

In 98 celled protrays using coco peat as the substrate, the seeds were sown. All prescribed cultural procedures, such as drenching, irrigation, and spraying, was regularly carried out to raise healthy nursey seedlings.

Seeds of US – 440 were sown in portrays on (24.11.2023) and watered at regular intervals The seeds germinated within four days after sowing and the seedlings were transplanted to main field at 25 days after sowing on(18.12.2023).

Main field was prepared and the recommended dose of fertilizer 150:60:60 kg/ha of N: P: K was applied in control plot, and the remaining plots were applied with recommended dose of fertilizer at 75%, 50%. Nitrogen was applied in the form of urea (46.2%) while phosphorus was applied as Single Super Phosphate (16% P_2O_5) and potash as Murate Of Potash (60.1% K_2O).

Treatments

T_1 - 100% RDF Control
T_2 - 75% RDF + nano NPK @5 ml/L
T_3 - 75% RDF + nano NPK @ 7.5 ml/L
T_4 - 75% RDF + nano NPK @ 10 ml/L
T_5 - 50% RDF + nano NPK @ 10 ml/L
T_6 - 50% RDF + nano NPK @ 15 ml/L
T_7 - 50% RDF + nano NPK @ 20 ml/L

Methodology

Note: RDF for tomato is 150:60:60 Kg/ha (N: P: K)
2 sprays of Nano NPK was given during the crop growth period
Nano N spray was given at 30 and 60 days after transplanting
Nano P spray was given at 15 and 45 days after transplanting
Nano K spray was given at 45 and 75 days after transplanting

Well decomposed farmyard manure (FYM) was applied at the rate of 25 t/ ha and recommended dose of NPK fertilizers (150:60:60 kg/ha) one third of nitrogen and entire dose of phosphorus and potash were applied in the form of urea, single super phosphate and murate of potash respectively before transplanting. Remaining dose of nitrogen was applied in equal doses, *i.e*., 30 and 60 days after transplanting. The data collection was carried out on five randomly tagged plants per treatment and replication. days after planting were recorded and the data was statistically analysed.

Results and Discussion

A. Vegetative growth parameters

Effect of nano fertilizers on growth parameters of tomato is depicted in Table 1. The results showed that the maximum amount of Growth parameters like plant height at 45 days after transplanting (DAT) The tallest plants (65.10 cm), When the plants were 90 days after being transplanted (DAT), there were seen to be significant disparities in their height. The tallest plants (74.45 cm), According to the results of the most recent harvest, there were discernible variations in plant height between the treatments. Significantly maximum plant height (85.62 cm) in treatment T_4: 75%RDF +nano NPK @ 10 ml/L. The number of compound leaves that were produced maximum at 45 (DAT) (24.45), maximum number of compound leaves (24.70) at 90 DAT, number of compound leaves maximum (25.13) at last harvest in T_4. At the 45-day observation period, there were discernible variations in the number of primary branches that each plant possessed among the various treatments maximum number of primary branches (10.66) at 45 DAT. The maximum number of main branches per plant is quite high (13.62) at 90 DAT maximum number of primary branches per plant (14.13) at last harvest these values were recorded in T_4 treatment T_4: 75%RDF +nano NPK @ 10 ml/L.

The results are in support with earlier findings of Ajirloo *et al.* (2015) [2] in tomato, Rathnayaka *et al.* (2018) [13], Mishra *et al.* (2020) [9], Panda *et al.* (2020) [12], Ali *et al.* (2021) [3] in tomato.

The use of nano fertilizers on the leaves had a substantial impact on the plant height, number of compound leaves and number of primary branches per plant. NPK is essential to crop development, foliar spraying with NPK nano fertilizer significantly contributed to the increase in most growth parameters.Nano fertilizers, used in the soil and as sprays, were particularly effective. Potassium nano fertilizer enhanced shoot and root growth and increased plant height, likely because nitrogen helps with cell division and growth. The tiny size and large surface area of nano fertilizers make it easier for plants to absorb nutrients.

Yield attribute characters

The findings of the investigation revealed that a maximum increase in the yield parameters like maximum average fruit length (4.69 cm), maximum average fruit diameter (5.66 cm), maximum average fruit weight (66.20 gm), the number of days it took for the first fruit to set (32.46 days), the number of days it took for the first harvest ((54.20 days), the number of fruits per cluster (6.33), the number of fruits per plant (15.66), the fruit yield per plant (2.86 kg/plant), the fruit yield per plot (18.50 kg/plot) and the fruit yield per hectare (31.38 t) were recorded in treatment T_4: 75%RDF +nano NPK @ 10 ml/L on par with T_7 50% RDF +nano NPK @ 20 ml/L and T_5 50% RDF +nano NPK @ 10 ml/L, followed by

Studies found that using different combinations of RDF and nano fertilizers greatly increased fruit yield. This is because more flowers per plant lead to more fruit. Proper amounts of nitrogen and phosphorus help plants grow better by improving nutrient use. This results in more flowers and fruits. Nitrogen also benefits soil microbes, which boosts flower production. This means more fruits per plant, more frequent harvests and higher fruit density. Higher levels of nitrogen, phosphorus and potassium also improve plant health, leaf size, and fruit size, leading to greater fruit weight and overall yield.

The results are in support with earlier findings of Mishra *et al.* (2020) [9] in tomato, Merghany *et al.* (2019) [8] in cucumber, Lekshmi *et al.* (2022) [7] in okra.

Table 1: Effect of nano fertilizer on growth parameters on tomato

Table 1.1: Effect of RDF and nano fertilizers on plant height (cm) at different growth stages in tomato.

Plant height (cm)			
Treatments	**45 DAT**	**90 DAT**	**At last harvest**
T_1: 100% RDF Control	53.69 c	61.81d	70.40 d
T_2: 75% RDF +nano NPK @ 5 ml/L	57.49 bc	67.34 b	73.33 cd
T_3: 75% RDF +nano NPK @ 7.5 ml/L	60.87 ab	64.02 cd	73.80 c
T_4: 75%RDF +nano NPK @ 10 ml/L	65.10 a	74.45 a	85.62 a
T_5: 50% RDF +nano NPK @ 10 ml/L	61.28 ab	63.31 cd	72.16 cd
T_6: 50% RDF +nano NPK @ 15 ml/L	58.94 b	64.70 c	76.86 b
T_7: 50% RDF +nano NPK @ 20 ml/L	64.72 a	73.43 a	83.86 a
S.E(m) ±	1.45	0.73	0.99
LSD at 5%	4.47	2.25	3.05

Table 1.2: Effect of RDF and nano fertilizers on number of compound leaves per plant at different growth stages in tomato.

Number of compound leaves per plant			
Treatments	**45 DAT**	**90 DAT**	**At last harvest**
T_1: 100% RDF Control	18.40 b	18.53 b	19.13 b
T_2: 75% RDF +nano NPK @ 5 ml/L	16.26 b	19.33 b	19.46 b
T_3: 75% RDF +nano NPK @ 7.5 ml/L	17.60 b	19.66 b	19.73 b
T_4: 75%RDF +nano NPK @ 10 ml/L	24.45 a	24.70 a	25.13 a
T_5: 50% RDF +nano NPK @ 10 ml/L	18.13 b	20.46 b	20.13 b
T_6: 50% RDF +nano NPK @ 15 ml/L	17.66 b	19.86 b	19.86 b
T_7: 50% RDF +nano NPK @ 20 ml/L	19.53 b	23.73 a	24.46 a
S.E(m) ±	1.21	0.99	1.07
LSD at 5%	3.74	2.93	3.32

Table 1.3: Effect of RDF and nano fertilizers on number of primary branches per plant at different growth stages in tomato.

Number of per primary branches plant			
Treatments	**45 DAT**	**90 DAT**	**At last harvest**
T_1: 100% RDF Control	8.40 ^{d}	9.33 ^{d}	10.20 ^{c}
T_2: 75% RDF +nano NPK @ 5 ml/L	9.26 ^{cd}	10.66 ^{cd}	10.73 ^{c}
T_3: 75% RDF +nano NPK @ 7.5 ml/L	9.46 ^{bcd}	11.33 ^{bc}	11.26 ^{bc}
T_4: 75%RDF +nano NPK @ 10 ml/L	10.66 ^{a}	13.62 ^{a}	14.13 ^{a}
T_5: 50% RDF +nano NPK @ 10 ml/L	10.00 ^{abc}	11.66 ^{bc}	11.33 ^{bc}
T_6: 50% RDF +nano NPK @ 15 ml/L	9.46 ^{bcd}	10.93 ^{bc}	10.80 ^{c}
T_7: 50% RDF +nano NPK @ 20 ml/L	10.40 ^{ab}	12.26 ^{ab}	12.40 ^{b}
S.E (m) ±	0.35	0.48	0.46
LSD at 5%	1.08	1.50	1.43

Table 2: Effect of nano fertilizer on yield parameters on tomato

Table 2.1: Effect of RDF and nano fertilizers on average fruit length (cm), average fruit diameter (cm) and average fruit weight (g) in tomato.

Treatments	Average fruit length (cm)	Average fruit diameter (cm)	Average fruit weight (g)
T_1: 100% RDF Control	4.27 ^{b}	3.60 ^{c}	55.03 ^{f}
T_2: 75% RDF +nano NPK @ 5 ml/L	4.34 ^{b}	4.13 ^{c}	57.16 ^{e}
T_3: 75% RDF +nano NPK @ 7.5 ml/L	4.34 ^{b}	4.28 ^{bc}	60.23 ^{d}
T_4: 75%RDF +nano NPK @ 10 ml/L	4.69 ^{a}	5.66 ^{a}	66.20 ^{a}
T_5: 50% RDF +nano NPK @ 10 ml/L	4.40 ^{b}	4.13 ^{c}	60.00 ^{d}
T_6: 50% RDF +nano NPK @ 15 ml/L	4.39 ^{b}	4.29 ^{bc}	61.18 ^{c}
T_7: 50% RDF +nano NPK @ 20 ml/L	4.47 ^{b}	5.12 ^{ab}	65.33 ^{b}
S.E(m) ±	0.06	0.34	0..24
LSD at 5%	0.20	1.05	0.74

Table 2.2: Effect of RDF and nano fertilizers on number days taken for first fruit set and first harvest in tomato.

Treatments	Number of days taken for first fruit set (days)	Number of days taken to first harvest (days)
T_1: 100% RDF Control	35.13 ^{a}	66.00 ^{a}
T_2: 75% RDF +nano NPK @ 5 ml/L	34.13 ^{ab}	64.00 ^{b}
T_3: 75% RDF +nano NPK @ 7.5 ml/L	34.40 ^{ab}	62.80 ^{c}
T_4: 75%RDF +nano NPK @ 10 ml/L	32.46 ^{c}	54.20 ^{d}
T_5: 50% RDF +nano NPK @ 10 ml/L	33.93 ^{b}	56.53 ^{e}
T_6: 50% RDF +nano NPK @ 15 ml/L	33.93 ^{b}	55.60 ^{f}
T_7: 50% RDF +nano NPK @ 20 ml/L	33.60 ^{b}	53.40 ^{g}
S.E(m) ±	0.30	0.25
LSD at 5%	0.95	0.79

Table 2.3: Effect of RDF and nano fertilizers on number of fruits per cluster and number of fruits per plant in tomato.

Treatments	Number of fruits per cluster	Number of fruits per plant
T_1: 100% RDF Control	5.13 ^{c}	9.93 ^{d}
T_2: 75% RDF +nano NPK @ 5 ml/L	5.26 ^{c}	11.86 ^{cd}
T_3: 75% RDF +nano NPK @ 7.5 ml/L	5.33 ^{c}	12.00 ^{cd}
T_4: 75%RDF +nano NPK @ 10 ml/L	6.30 ^{a}	15.66 ^{a}
T_5: 50% RDF +nano NPK @ 10 ml/L	5.76 ^{b}	13.66 ^{abc}
T_6: 50% RDF +nano NPK @ 15 ml/L	5.33 ^{c}	12.66 ^{bc}
T_7: 50% RDF +nano NPK @ 20 ml/L	6.00 ^{b}	14.66 ^{ab}
S.E(m)±	0.08	0.83
LSD at 5%	0.27	2.55

Table 2.4: Effect of RDF and nano fertilizers on fruit yield per plant (kg), fruit yield per plot (kg) and fruit yield per hectare (t) in tomato.

Treatments	Fruit yield per plant (kg)	Fruit yield per plot (kg)	Fruit yield per hectare (t)
T_1: 100% RDF Control	2.12 ^{d}	12.66 ^{c}	20.38 ^{e}
T_2: 75% RDF +nano NPK @ 5 ml/L	2.39 ^{bcd}	12.40 ^{c}	20.31 ^{e}
T_3: 75% RDF +nano NPK @ 7.5 ml/L	2.32 ^{cd}	13.96 ^{bc}	22.19 ^{de}
T_4: 75%RDF +nano NPK @ 10 ml/L	2.86 ^{a}	18.50 ^{a}	31.38 ^{a}
T_5: 50% RDF +nano NPK @ 10 ml/L	2.66 ^{ab}	13.76 ^{c}	23.50 ^{cd}
T_6: 50% RDF +nano NPK @ 15 ml/L	2.57 ^{abc}	15.46 ^{b}	25.77 ^{bc}
T_7: 50% RDF +nano NPK @ 20 ml/L	2.70 ^{ab}	17.86 ^{a}	28.22 ^{b}
S.E(m) ±	0.10	0.55	0.80
LSD at 5%	0.31	1.70	2.47

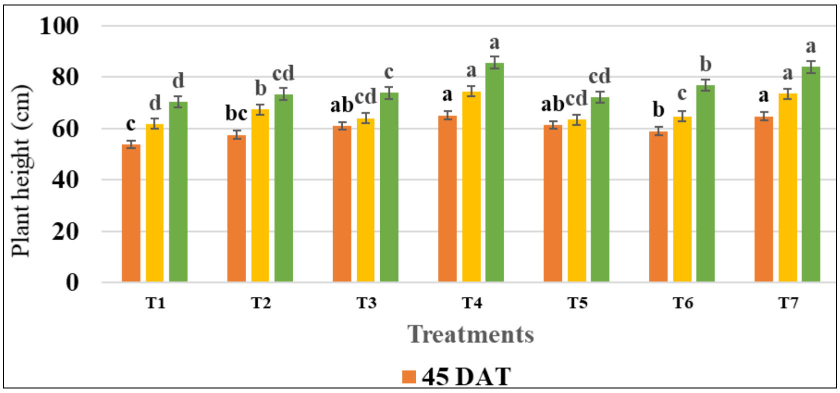

Fig 1: Effect of RDF and nano fertilizers on plant height (cm) at different growth stages in tomato.

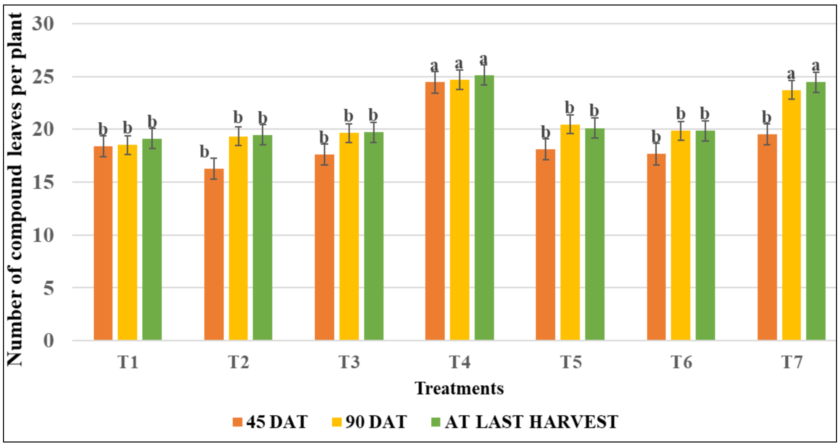

Fig 2: Effect of RDF and nano fertilizers on number of compound leaves per plant at different growth stages in tomato.

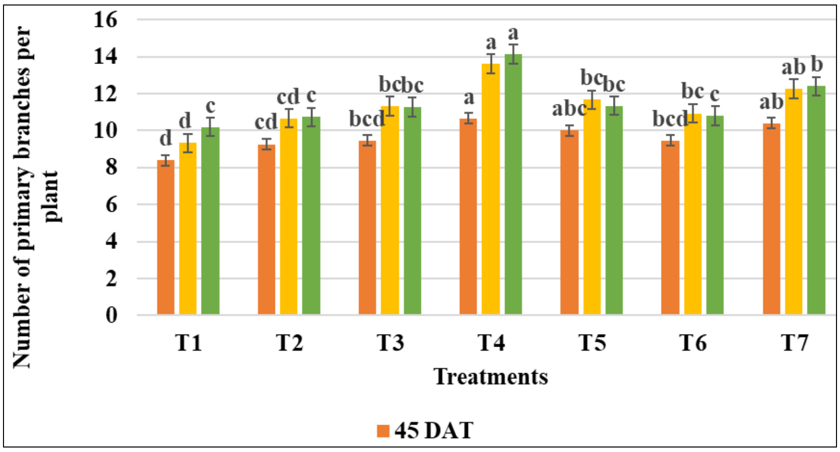

Fig 3: Effect of RDF and nano fertilizers on number of primary branches per plant at different growth stages in tomato.

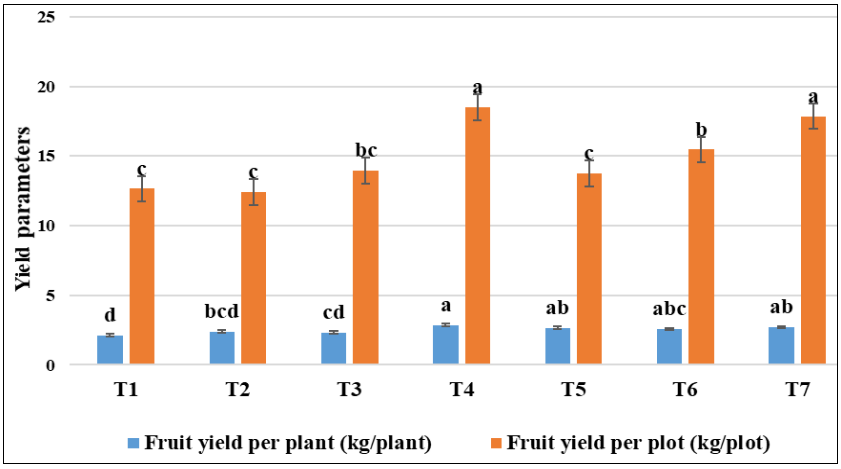

Fig 4: Effect of RDF and nano fertilizers on fruit yield per plant (kg/plant) and fruit yield per plot (kg/plot) in tomato.

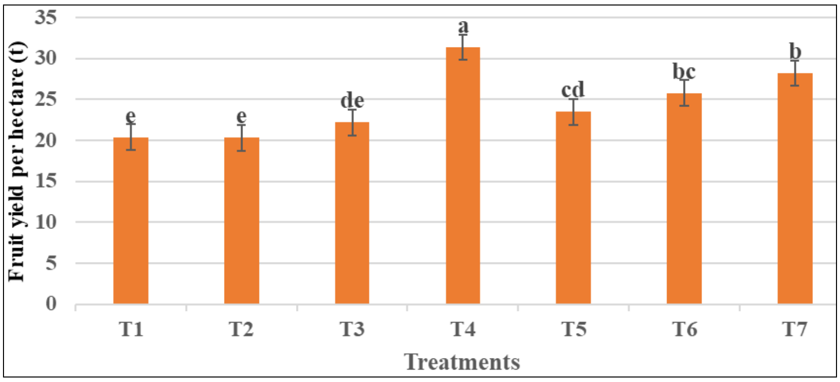

Fig 5: Effect of RDF and nano fertilizers on fruit yield per hectare (t/ha) in tomato.

Conclusion

It could be concluded from the present investigation that, nano fertilizers significantly influenced the growth and yield of tomato. Among the different levels of nano fertilizer maximum growth and yield of tomato were obtained from treatment T_4: 75% RDF +nano NPK @ 10 ml/L.

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