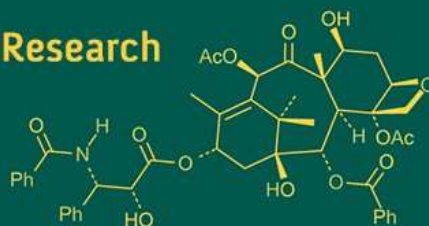
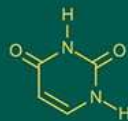
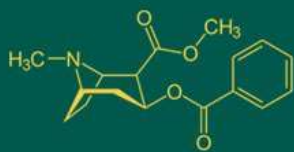


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Effect of nano urea and nano DAP on growth, yield and economics of tomato (*Solanum lycopersicum* L.)

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Abstract

A field experiment was conducted during Rabi 2022-23 at New-Orchard, MARS, University of Agricultural Sciences, Raichur, to study the effect of nano urea and nano DAP on growth and yield of tomato. There were ten treatments consisting of different doses of RNP (three treatments with 25% RNP, three with 50% RNP, three with 75% RNP and one with 100% RDF) with different doses of nano urea and nano DAP sprayed at 30 & 45 DAT. Results revealed that application of 75% RNP as basal + nano urea & nano DAP spray @ 6 ml l⁻¹ each at 30 and 45 DAT has produced significantly higher plant height, leaf area per plant and chlorophyll content of leaves. It has resulted in enhanced yield (93.70 t ha⁻¹) by 22.73% over RDF (72.40 t ha⁻¹). It was profitable too in terms of higher net returns (Rs. 6,99,056 ha⁻¹) and B: C ratio (3.94) of tomato production. Results confirmed that reduced rate of conventional fertilizer can be substituted by foliar application of nano fertilizers to enhance nutrient use efficiency and economics.

Keywords: Tomato, nano urea, nano DAP

Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the genus *Solanum* under Solanaceae family. It is a herbaceous sprawling plant grows upto 1-3 m in height with weak woody stem. The flowers are yellow in color and the fruits of cultivated varieties vary in size from cherry tomatoes, about 1-2 cm in size to beefsteak tomatoes, about 10 cm or more in diameter. Most cultivars produce red fruits when ripe. Tomato is the world's largest vegetable crop in terms of area and production after potato and sweet potato, but it tops the list of canned vegetables. Tomato is one of the most important "protective foods" because of its special nutritive value. It is one of the most versatile vegetables with wide usage in Indian culinary tradition. Tomatoes are used for soup, salad, pickles, ketchup, puree, sauces and in many other ways it is also used as a salad vegetable. Tomato has very few competitors in the value addition chain of processing.

The growth and yield of vegetable crops are mainly depends on the quality and quantity of fertilizers used. Loss of mineral nutrients through leaching and runoff to surface and ground water along with abundant volatilization constitute growing concerns owing to economic losses and environmental pollution. The recent use of chemical fertilizers has resulted in many serious, environmental problems such as accumulation of heavy metals in soil and plant systems. (Abdel Wahab *et al.*, 2018) ^[1]. Conventional application techniques are resulting in seriously overdosing of chemical fertilizers. Nanotechnology is a promising field of research which utilizes nano materials of less than 100 nm size, may offer an unprecedented opportunity to develop concentrated sources of plant nutrients having higher-absorption rate, utilization efficacy, and minimum losses. One of the most important uses of nano technology is nanofertilizer, which improves the ability of the plants to absorb nutrients (Mousavi & Rezai (2011) ^[10], Srilatha (2011) ^[14], Ditta (2012) ^[6]. Nano fertilizers are being prepared by encapsulating plant nutrients into nano materials, employing thin coating of nano materials on plant nutrients, and delivering in the form of nano-sized emulsions. Nanopores and stomatal openings in plant leaves facilitate nanomaterial uptake and their penetration deep inside leaves leading to higher nutrient use efficiency (NUE). Nano fertilizers have higher transport and delivery of nutrients through plasmodesmata, which are nano sized (50-60 nm) channels between cells.

The higher NUE and significantly lesser nutrient losses of nano fertilizers lead to higher productivity (6-17%) and nutritional quality of field crops.

Materials and Methods

A field experiment was conducted during *rabi* 2022-23 at New-Orchard, MARS, Department of Horticulture, UAS, Raichur Karnataka (16°15'N, 77°21'E, altitude 389 m). The soil of experimental site was red sandy loam in texture (sand-55.1%, silt 13.3% and clay 30.8%). The soil pH was 7.2 with electrical conductivity 0.29 dS m⁻¹. The soil was low in available nitrogen (228.50 kg ha⁻¹), medium in available phosphorous (45.32 kg ha⁻¹) and potassium (292.14 kg ha⁻¹). The experiment was laid out in Randomized Complete Block Design with three replications. There were ten treatments consisting of different doses of RNP (three treatments with 25% RNP, three with 50% RNP, three with 75% RNP and one with 100% RDF) with different doses of nano urea and nano DAP (2, 4 & 6 ml l⁻¹) sprayed at 30 and 45 days after transplanting (DAT). Whereas, recommended dose of K was applied to all the treatments. Arka Abhed was selected for the study. The healthy seedlings of 30 days old were transplanted at 90 cm × 45 cm apart in paired row on raised beds. For recording various growth and yield attributes, ten plants were selected from each plot through random sampling technique and plastic-coated labels were tied to each observational plant for easy identification. The height of ten selected plants was recorded at 30 days interval starting from the date of transplanting. Leaf area per plant (cm²) was determined by using Biovis PSM digital leaf area meter. Five leaves from each plant were collected for recording the observation at 30, 60 and 90 days after transplanting and the mean value was multiplied by the number of leaves per plant. The chlorophyll content of leaves was measured using chlorophyll meter (Model: SPAD plus 502) designed by Spectrum Technologies, Inc. The economics was worked out based on the prevailing market price for the existing year. Data analysis and interpretation was done using Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [12].

Results and Discussion

Effect of nano urea and nano DAP on growth attributes

Plant height

Plant height of tomato was significantly influenced by different levels of chemical and nano fertilizers (Table 1). Application of 75% RNP as basal + 6 ml NUS + 6 ml NDS spray @ 30 and 45 DAT (T₉) recorded significantly higher plant height. However, it was comparable with application of 75% RNP as basal + 4 ml NUS + 4 ml NDS spray @ 30 and 45 DAT (T₈). Significantly dwarf plants of tomato were recorded in T₁ (application of 25% RNP as basal + 2 ml NUS + 2 ml NDS spray at 30 and 45 DAT). Significant increase in plant height might be due to the fact that basal application of conventional fertilizers along with foliar spray of nano fertilizers increased activity of enzymes and auxin metabolism in the plant, which in turn enlarge the cell and cell elongation might resulted in taller plants. These outcomes are consistent with those reported for tomato by Ajirloo *et al.* (2015) [2] and okra by Lekshmi *et al.* (2022) [7].

Leaf area per plant

Leaf area per plant significantly affected by the application of different levels of chemical and nano fertilizers (Table 1). Significantly higher leaf area per plant was noticed from the treatment T₉ (75% RNP + 6 ml NUD + 6 ml NDS @ 30 and

45 DAT) with 3951.92 cm² and it was found on par with T₈-75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT (3672.03 cm²) followed by T₇ (3305.77 cm²) as compared to other treatments. However, the minimum leaf area per plant (2386.69 cm²) was recorded with T₁-25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT. Nitrogen and phosphate fertilisers are known to enhance plant growth, which in turn influences leaf development and expansion. The increased leaf area of the tomato was mostly due to a greater number of leaves. Leaf area per plant is critical for understanding plant development and photosynthesis, according to Chaudhary *et al.* (2012). Application of 75 percent RNP followed by nano urea @ 6 ml and nano-DAP @ 6 ml spray at 30 and 45 DAT resulted in greater leaf area per plant, this might be attributed to the higher nutrient usage efficiency of nano-N and nano-P fertilizers. This is consistent with the study of Ajirloo *et al.* (2015) [2] on tomato, Merghany *et al.* (2019) [8] on cucumber, Lekshmi *et al.* (2022) [7] on okra.

Chlorophyll content of leaves

The highest chlorophyll content of leaves (65.89) was noticed in treatment T₉ (75% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT) and this was on par with T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) with 61.37, followed by T₇ (75% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) with 54.13 over rest of the treatments. Significantly the lowest chlorophyll content of leaves (35.65) was recorded in treatment T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT). This could be because nano-sized particles with a large surface area promote nutrient absorption and utilisation and they also have a smart delivery system, i.e., a controlled release pattern of nutrients, which increases crop nutrient use efficiency, as concluded by Merghany *et al.* (2019) [8] in cucumber, AL-Kaby *et al.* (2021) [4] in okra and Saitheja *et al.* (2022) [13] in green gram.

Effect of nano urea and nano DAP on yield

Significant differences were observed in yield and yield components viz., average fruit weight (g), number of fruits per plant, fruit yield per plant (kg) and fruit yield per hectare (t) due to different levels of chemical and nano fertilizers (Table 2).

Average fruit weight

Average fruit weight was significantly influenced by the application of nano formulated nitrogen and phosphorous fertilizers and the values ranged from 64.93 g to 105.63 g. Application of 75 percent RNP followed by foliar spray of nano urea @ 6 ml and nano DAP @ 6 ml at 30 and 45 DAT (T₉) recorded significantly higher average fruit weight (105.63 g) and this treatment found on par with T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) which had 99.83 g average fruit weight. Followed by T₇ (75% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) with 91.55 g, whereas, the lowest average fruit weight (64.93 g) was observed in T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT). This could be due to better nutrient uptake, particularly nitrogen and phosphorous, in nano formulations involved in several plant functions such as photosynthesis, carbohydrate transformation and higher dry matter accumulation, which could have resulted in more diversion of photo assimilates to developing fruits, leading to increased fruit weight. These findings are consistent with those of Ajirloo *et al.* (2015) [2] and Mishra *et al.* (2020) [9] for tomato, Lekshmi *et al.* (2022) [7] for okra and Saitheja *et al.* (2022) [13] for green gram.

Number of fruits per plant

Number of fruits per plant differed significantly among treatments; it varied from 27.84 to 45.13. Maximum number of fruits per plant (45.13) was recorded from treatment T₉ consists of application of 75 percent RNP followed by foliar spray of 6 ml nano urea and 6 ml nano DAP at 30 and 45 DAT, followed by T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) with 43.48, which were found on par with each other. Meanwhile, T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) showed the minimum number of fruits per plant (27.84). This could be owing to foliar nano fertiliser application, which plays an important role in prolonged vegetative development, metabolism of RNA, proteins and DNA synthesis. Enhanced vegetative development and a balanced C:N ratio result in enhanced carbohydrate synthesis, which promotes an increased number of fruits. The current findings correspond with those of Ajirloo *et al.* (2015)^[2] and Mishra *et al.* (2020)^[9] in tomato and Lekshmi *et al.* (2022)^[7] in okra.

Fruit yield per plant

Fruits yield per plant differed significantly among treatments and it was varied from 1.92 to 3.82 kg. Significantly higher fruit yield per plant was noticed in the treatment T₉ (75% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT) with 3.82 kg and it was found on par with treatment T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) with 3.75 kg. The lesser fruit yield per plant (1.92 kg) was observed in T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT). This might be due to the fact that nitrogen and phosphorus activate several enzymes, such as catalase and tryptophan synthetase and participate in chlorophyll synthesis and other physiological activities that promote plant growth and development, thereby increasing fruit yield. Nitrogen and phosphorus application decreased chlorosis and created healthy green leaves, resulting in greater assimilate synthesis and partitioning of fruit development, which may boost fruit production and eventually fruit output. These findings are consistent with those of Panda *et al.* (2020)^[11] in tomato, Merghany *et al.* (2019)^[8] in cucumber and Lekshmi *et al.* (2022)^[7] in okra.

Fruit yield per hectare

Application of nano formulated nitrogen and phosphorous fertilizers influenced on fruit yield per hectare and the data ranged from 44.32 to 93.70 tonnes. T₉ (75% RNP + 6 ml

NUS + 6 ml NDS @ 30 and 45 DAT) registered maximum fruit yield per hectare (93.70 t) which was on par with T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) with 90.68 tonnes, followed by T₇ (75% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) with 81.26 tonnes. The lowest fruit yield per hectare (44.32 t) was noticed in T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT). Tomato fruit yield was primarily determined by yield parameters such as average fruit weight, number of fruits per plant and fruit yield per plant. These yield qualities were improved by applying 75 percent RNP followed by foliar sprays of 6 ml nano urea and 6 ml nano DAP at 30 and 45 DAT (T₉). Because of the interaction between nanoparticles and fertilization, increasing concentrations of nitrogen and phosphorous elements in the fruits resulted in an increase in growth and yield (Al Jabri *et al.*, 2020)^[3]. These findings are consistent with those of Mishra *et al.* (2020)^[9] in tomato and Lekshmi *et al.* (2022)^[7] in okra.

Effect of nano urea and nano DAP on economics

Among the different treatments, applying 75 percent RNP followed by foliar sprays of 6 ml nano urea and 6 ml nano DAP at 30 and 45 DAT (T₉) has incurred greater cost of cultivation of tomato (Rs. 2,37,945 ha⁻¹) as compared to all other treatments (Table 5). Whereas, the lowest cost of cultivation (Rs. 2,23,887 ha⁻¹) was observed in the treatment T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT). Significantly higher gross returns, net returns and B:C were noticed in 75 percent RNP followed by foliar spray of 6 ml nano urea and 6 ml nano-DAP at 30 and 45 DAT (T₉) (Rs. 9,37,000 ha⁻¹, Rs. 6,99,056 ha⁻¹ & 3.94, respectively). Followed by T₈ (75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT) with Rs. 9,06,800 ha⁻¹, Rs. 6,72,216 ha⁻¹ and 3.87, respectively. Whereas, the lower gross returns, net returns and B:C were noticed in T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) with Rs. 4,43,200 ha⁻¹, Rs. 2,19,313 ha⁻¹ and 1.98, respectively. Due to the increased fruit output of the tomato, which eventually contributes to better gross returns, the application of 75 percent RNP followed by a foliar spray of 6 ml nano urea and 6 ml nano DAP at 30 and 45 DAT (T₉) resulted in the highest benefit-cost ratio. T₁ (25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT) had the lowest benefit-cost ratio, which may have been caused by a decreased fruit production. Mishra *et al.* (2020)^[9] for the tomato and Bayan *et al.* (2021)^[5] for the broad bean both reported findings that were similar.

Table 1: Effect of nano urea and nano DAP on growth attributes in tomato

Treatments	Plant height (cm)	Leaf area per plant (cm ²)	Chlorophyll content (SPAD value)
T ₁ 25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	95.33	2386.69	35.65
T ₂ 25% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	99.92	2452.08	37.18
T ₃ 25% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	103.05	2575.35	40.87
T ₄ 50% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	109.68	2642.73	42.73
T ₅ 50% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	112.82	2896.20	45.92
T ₆ 50% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	117.58	3168.48	50.11
T ₇ 75% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	127.35	3305.77	54.13
T ₈ 75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	139.78	3672.03	61.37
T ₉ 75% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	150.08	3951.92	65.89
T ₁₀ RDF (250:250:250 kg NPK ha ⁻¹)	110.79	2780.42	43.56
Mean	116.64	2983.17	47.74
S. Em.±	4.07	120.36	2.30
CD at 5%	12.17	357.60	6.83

Note: RDF: Recommended dose of fertilizer

NUS: Nano urea spray

RNP: Recommended dose of Nitrogen and Phosphorous

NDS: Nano DAP spray

DAT: Days after transplanting *Recommended K is common for all treatments

Table 2: Effect of nano urea and nano DAP on yield attributes in tomato

Treatments		Average fruit weight (g)	No. of fruits per plant	Fruit yield per plant (kg)	Fruit yield per hectare (t)
T ₁	25% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	64.93	27.84	1.92	44.32
T ₂	25% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	67.89	29.89	2.34	54.69
T ₃	25% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	69.54	31.54	2.62	64.07
T ₄	50% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	76.35	34.85	2.85	69.75
T ₅	50% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	81.58	37.12	3.06	74.94
T ₆	50% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	88.58	38.58	3.35	79.63
T ₇	75% RNP + 2 ml NUS + 2 ml NDS @ 30 and 45 DAT	91.55	39.05	3.40	81.26
T ₈	75% RNP + 4 ml NUS + 4 ml NDS @ 30 and 45 DAT	99.83	43.48	3.75	90.68
T ₉	75% RNP + 6 ml NUS + 6 ml NDS @ 30 and 45 DAT	105.63	45.13	3.82	93.70
T ₁₀	RDF (250:250:250 kg NPK ha ⁻¹)	84.24	36.16	3.00	72.40
Mean		83.01	36.36	3.01	72.54
S. Em.±		2.47	1.39	0.12	2.93
CD at 5%		7.38	4.12	0.32	8.70

Note: RDF: Recommended dose of fertilizer

NUS: Nano urea spray

RNP: Recommended dose of Nitrogen and Phosphorous

NDS: Nano DAP spray

DAT: Days after transplanting

Recommended K is common for all treatments

Table 3: Economics of tomato production as influenced by application of nano urea and nano DAP

Treatments		Treatment cost (Rs. ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C
T ₁	25% RNP + 2 ml NUS & 2 ml NDS @ 30 & 45 DAT	14612.12	223887	443200	219313	1.98
T ₂	25% RNP + 4 ml NUS & 4 ml NDS @ 30 & 45 DAT	17972.12	227247	546900	319653	2.41
T ₃	25% RNP + 6 ml NUS & 6 ml NDS @ 30 & 45 DAT	21332.12	230607	640700	410093	2.78
T ₄	50% RNP + 2 ml NUS & 2 ml NDS @ 30 & 45 DAT	18364.36	227639	697500	469861	3.06
T ₅	50% RNP + 4 ml NUS & 4 ml NDS @ 30 & 45 DAT	21724.36	230999	749400	518401	3.24
T ₆	50% RNP + 6 ml NUS & 6 ml NDS @ 30 & 45 DAT	25084.36	234359	796300	561941	3.40
T ₇	75% RNP + 2 ml NUS & 2 ml NDS @ 30 & 45 DAT	21949.50	231225	812600	581376	3.51
T ₈	75% RNP + 4 ml NUS & 4 ml NDS @ 30 & 45 DAT	25309.50	234585	906800	672216	3.87
T ₉	75% RNP + 6 ml NUS & 6 ml NDS @ 30 & 45 DAT	28669.50	237945	937000	699056	3.94
T ₁₀	RDF (250:250:250 kg NPK ha ⁻¹)	22508.65	232984	724000	491016	3.11

Note: RDF: Recommended dose of fertilizer

NUS: Nano urea spray

RNP: Recommended dose of Nitrogen and Phosphorous

NDS: Nano DAP spray

DAT: Days after transplanting

Recommended K is common for all treatments

Conclusion

According to the experimental findings, it was concluded that application 75 percent of the recommended nitrogen and phosphorous as a basal dose and the full recommended dose of potassium, along with foliar application of nano urea and nano DAP @ 6 ml l⁻¹ sprayed at 30 and 45 DAT recorded higher plant height, leaf area per plant, chlorophyll content, average fruit weight, number of fruits per plant, fruit yield per plant and hectare, gross returns, net returns and benefit cost ratio of tomato as compared to other treatments. However, it was found on par 75 percent RNP along with nano urea and nano DAP spray @ 4 ml at 30 and 45 DAT. Both were found to be an effective option in terms of both productivity and profitability of tomato cultivation.

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