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Impact of Nano Urea and Zinc Foliar Applications on Growth and Yield Parameters of Radish (*Raphanus sativus* L.) cv. Pusa Chetki Across Two Seasons

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in the Orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalainagar during February to April 2024 and in a farmer's field, Anthiyur, Erode during June to August 2024 in two seasons. It was laid out in randomized block design with eleven treatments replicated thrice. The treatments comprised with combinations of nano urea and zinc foliar applications along with a control. The results of the experiment revealed

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that the maximum values for pre- harvest observations *viz*., shoot length, number of leaves, leaf area; post- harvest observations like weight of shoot, weight of root, root: shoot ratio, length of root, grith of root, root yield plot^{-1}, root yield hectare^{-1} and biochemical attributes like ascorbic acid and calcium content were recorded in the plots which received the application of basal RDF plus foliar spray of 0.4 per cent nano urea plus 0.1 per cent nano Zn. It was engrossing to observe that the nutrient uptake of nitrogen, phosphorus, potassium, zinc and benefit cost ratio were also influenced the maximum by the same treatment. This was followed by the treatment which received the application of basal RDF plus foliar spray of 0.4 per cent nano urea plus 0.05 per cent nano Zn and the least values for all attributes was noted in control.

Keywords: Raphanus sativus; calcium content; nutrient management; environmental risks; nanotechnology.

1. INTRODUCTION

Radish (*Raphanus sativus* L.) is a short duration crop which belongs to the family Brassicaceae. It is an important edible root vegetable consumed throughout the world. The most popular eating part of this crop is root, although the whole plant is edible and the tops are used as leafy vegetable (Thakur et al*.,* 2023). This nutrient-rich vegetable, providing 50 mg of calcium, 138 mg of potassium, 22 mg of phosphorus, 15 mg of Vitamin C, and a range of essential minerals in every 100 g serving, making it a valuable addition to a healthy diet. (Kumar et al*.,* 2022). Radish occupies an important position in the production and consumption among the vegetables globally, but there are still many problems and challenges in its nutrient management. The nutrient management of vegetables is very important for the rational use of nutrients in our country and for coordination of economic, agronomic and environmental benefits (Yousaf et al*.,* 2021). Among alternative methods of fertilization, nano technology stands out as a promising approach for enhancing productivity, improving fertilizer use efficiency, and minimizing environmental risks (Salama et al*.,* 2020).

1.1 Nanotechnology

Nanotechnology is an emerging field that had gained high significant attention in recent years and had the prospective to improve the agriculture with its novel applications. Nanotechnology also boosts the agricultural and horticultural productivity without causing decontamination in soil, water, and protection against several insects, pests and microbial diseases (Kottegoda et al*.,* 2012). Nano urea is an innovative agricultural input, based on nanotechnology launched by Indian Farmers Fertilizer Cooperative Limited (IFFCO) in 2021. It is the world's first nano urea liquid and has no residual effect. One 500 ml bottle of nano urea is enough for applying twice over an acre of the crop plant as foliar spray. Moreover, it does not contaminate soil, air and water bodies and is completely safe for human, animals, birds, rhizosphere organisms and the environment at the recommended levels of application (Kiran and Samal, 2021). Among the alternate methods of plant nutrient application, foliar application of zinc increased the photosynthetic activity, which ultimately resulted in improving the plant growth (Pandav et al., 2016). Nano zinc promotes superior physiological growth, increases plant uptake of P, and consistency in fruit size and shape. Due to their small size, nano zinc can be readily absorbed by plants either directly or through stomatal holes when sprayed on the leaves. Following entry through the leaves, they are transferred to various plant sections through phloem translocation and metabolically absorbed in accordance with the needs of the plant (Vaishya et al*.,* 2022).

2. MATERIALS AND METHODS

The field experiment was carried out to evaluate the Effect of nano urea and zinc on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki at Orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalainagar during February to April 2024 and in a farmer's field, Anthiyur, Erode district during June to August 2024 in season 1 and 2. The experiment was laid out in randomized block design with three replications, measuring a net plot size of 3m × 2m = 6 m^2.The healthy and disease-free authentic seeds of radish variety Pusa Chetki were obtained from Gujarat seeds company, Anand Industrial estate, Anand, Gujarat – 388 001, was used for conducting experiments. Seeds were sown in recommended spacing of 30 x 10 x 15 cm in paired row planting system. The treatments involved in the study were 11 in numbers i.e., T_1- Control (FYM alone), T_2 - RDF (50:100:50 kg NPK ha^{-1}), T_3 - Basal

RDF + FS of 0.2% nano urea, T_4 - Basal RDF + FS of 0.3% nano urea , T_5 - Basal RDF + FS of 0.4% nano urea , T_6 - Basal RDF + FS of 0.2% nano urea + 0.05% nano Zn, T_7 - Basal RDF + FS of 0.2% nano urea + 0.1% nano Zn, T_8 - Basal RDF + FS of 0.3% nano urea + 0.05% nano Zn, T_9 - Basal RDF + FS of 0.3% nano urea + 0.1% nano Zn, T_{10} - Basal RDF + FS of 0.4% nano urea + 0.05% nano Zn and, T_{11} - Basal RDF + FS of 0.4% nano urea+ 0.1 % nano Zn.

Fig. 1. General view of experimental field (season 1)

Fig. 2. General view of experimental field (season 2)

Fig. 3. Nano urea   Nano zinc

Water soluble fertilizers (nano urea and nano zinc) were used for foliar application. Nano urea was obtained from Indian Farmers Fertilizer Cooperative Limited, Uttar Pradesh. Nano zinc oxide was obtained from Dr. Linnfield Laboratories Pvt. Ltd., Punjab. The Farm yard manure for season 1 was obtained from the orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University and for season 2, it was obtained from a cattle farm, Anthiyur. It was used @ 25 t ha^{-1} as soil application. The major nutrients viz., nitrogen, phosphorous and potassium were applied through urea, single super phosphate and muriate of potash respectively as soil application. The inorganic fertilizers were obtained from the orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University and from a fertiliser shop, Anthiyur for season 1 and 2 respectively. As per the treatment details, nano urea and nano zinc were applied as foliar spray using knapsack sprayer. An interval of five days was maintained between the foliar application of nano urea and nano zinc. All other cultural operations were kept normal and uniform for all treatments as per package of practices recommended for this crop during the course of study. The observations were recorded by selecting five plants rand**o**mly from each plot. Experimental data was analysed statistically.

3. RESULTS AND DISCUSSION

Significant variation of various growth and yield traits were observed among all the treatments when compared to control. Among the treatments, application of Basal RDF dose of NPK + FS of 0.4 per cent nano urea + 0.1 per cent nano Zn (T_{11}), registered the maximum growth attributes *viz.,* shoot length, number of leaves $plant^{-1}$ and shoot weight in radish cv. Pusa Chetki (Tables 1 & 3) in both seasons. The favourable response of maximum shoot length in radish was due to the application of nitrogen and zinc in nano form which have higher permeability and speed of action. The results of an investigation in broccoli by Awan et al. (2021), indicated that there was an enhancing effect of nano zinc particles on vegetative growth like plant height, number of leaves and leaf area and increase in vegetative growth was due to its role in maintaining the structural stability of cell membranes. This result of the present study is consistent with what was found in kohlrabi by Al-Baghdadi and Shammari (2024), who stated that the foliar fertilization treatments with the nano-nitrogen was superior in all vegetative growth and yield characteristics. This is due to the major role played by the nitrogen fertilizer, as it enters into the construction of chlorophyll, contributes to the vital reactions of amino and nuclear acids, builds proteins and is involved in all processes. The reactions associated with protoplasm, the enzymatic reactions, the process of photosynthesis, and stimulating the production of growth regulators make the parts of the plant juicy and prolongs their stay green for a longer period, especially since preparation is manufactured with nano-specifications and that the nanoparticles have a high ability to penetrate and enter the various plant tissues, especially those added as a spray on the shoots.

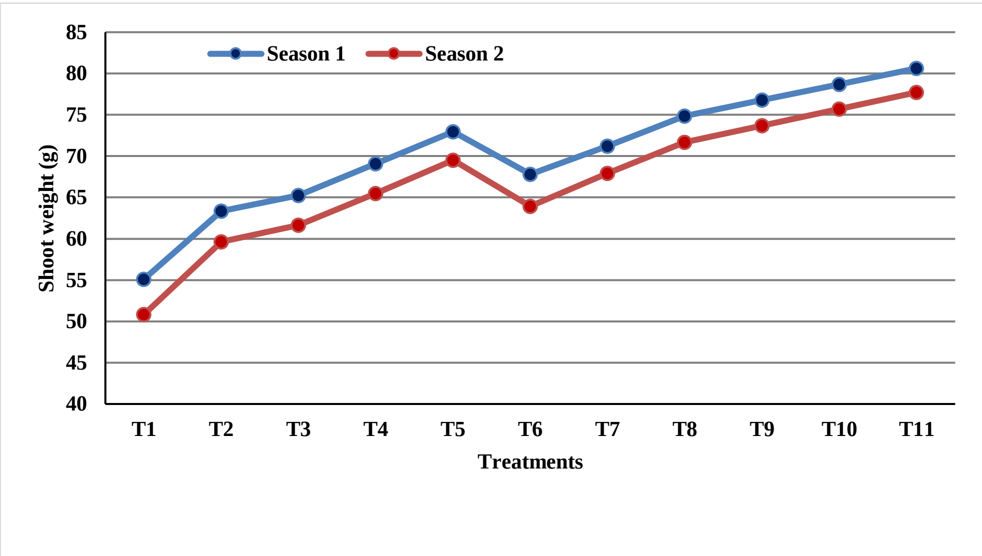

Fig. 4. Effect of nano urea and zinc on shoot weight in Radish

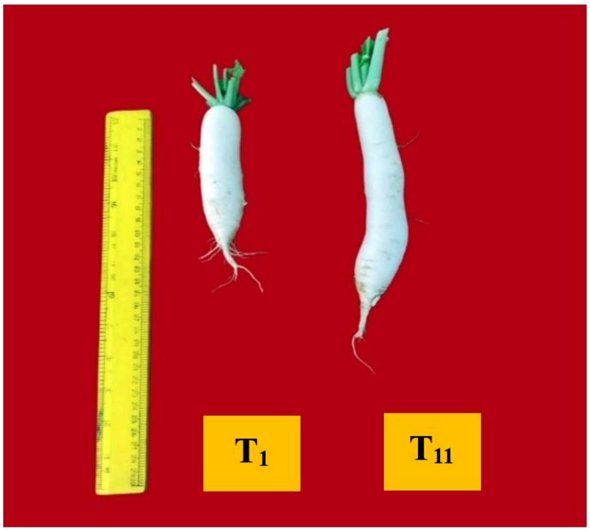

Fig. 5. Root length (Season-1)

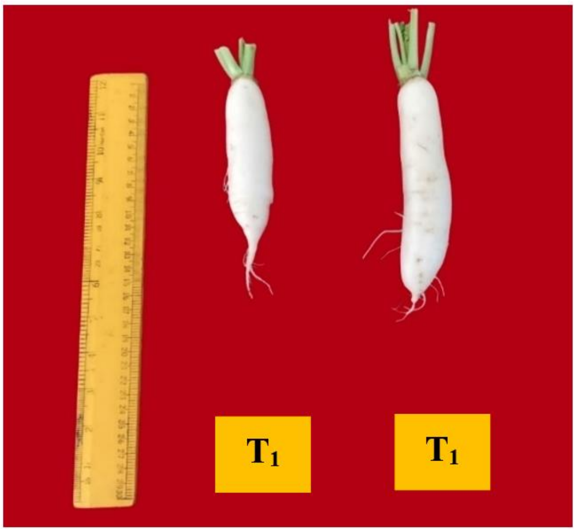

Fig. 6. Root length (Season-2)

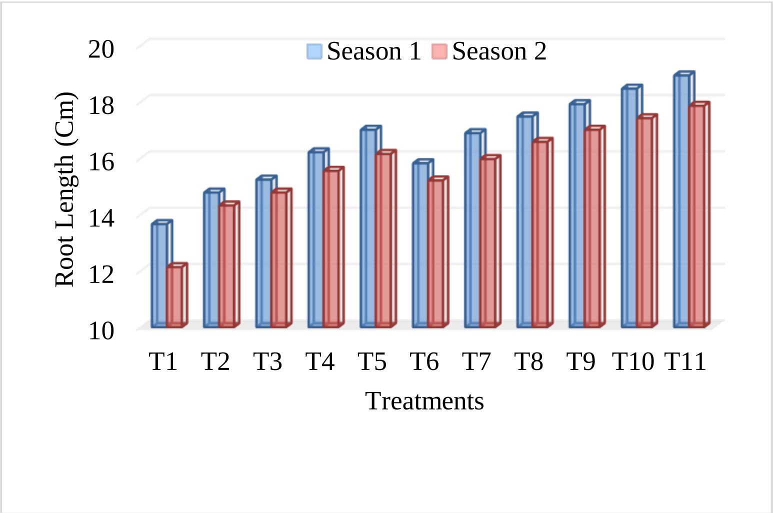

Fig. 7. Effect of nano urea and zinc on root lenght in Radish

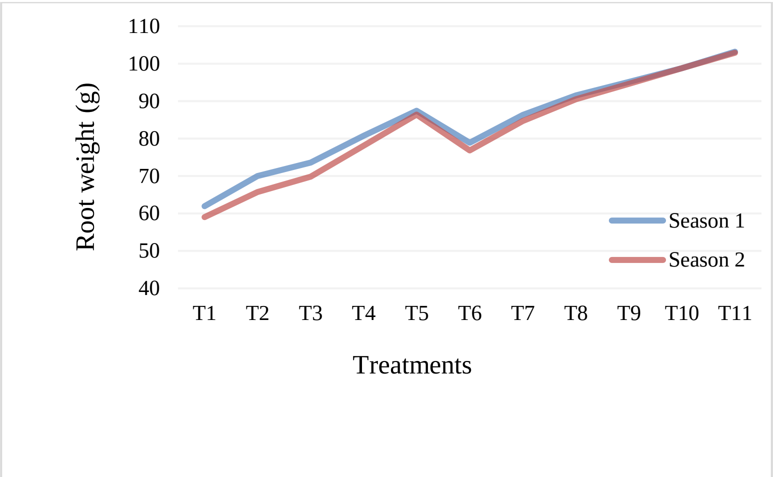

Fig. 8. Effect of nano urea and zinc on root weight in Radish

The data on effect of foliar nutrition with nano urea and zinc on various yield attributes *viz*., weight of root, root yield plot^{-1} and dry matter content in both seasons were recorded in the present investigation (Tables 1& 3) and are significant. Among the treatments, application of Basal RDF dose of NPK + FS of 0.4 per cent nano urea + 0.1 per cent nano Zn (T_{11}), recorded, the maximum values for length of root, weight of root, root yield plot^{-1} and dry matter content. The use of foliar nano urea and zinc sources had a substantial impact on the above said traits. The favourable response on dry matter might be due the fact that nano fertilizers is quickly absorbed by the plant and translocated at a faster rate which resulted in higher rate of photosynthesis and more dry matter accumulation (Bhatti et al*.,* 2023). An increase in root length and root grith might be due to effect of environment, soil texture and on time and balanced manuring practices (Baloch et al*.,* 2014). Increased photosynthates and more numbers along with greater size of leaves plant might also be one of the growth characteristics that influenced on the size of roots. Subramani et al*.* (2023) reported that, increased concentration of nano urea spray (0.4 per cent) had significant impact on fruit length and girth in okra, due to increased availability of N within the plant system. The findings are in consistent with the results of a study in tomato by Khanm et al*.* (2018), who reported that treating zinc oxide nano particles showed significant increase in root length and shoot length, since ZnO nanoparticles reactivity of phytohormones especially, indole acetic acid (IAA) involved in the phyto-stimulatory actions created oxygen vacancies and the oxygen deficient, increased the level of IAA in roots, which in turn indicate the increase in the growth rate of plants.The maximum values in the treatment T_{11}, might be due to production of plants with more shoot length and higher number of leaves which lead to an enhanced development of vegetative parts through the foliar spraying of nano urea and zinc. This ultimately boosted the nutrient absorption, photosynthesis and assimilation of photosynthates in the sink (Dubey et al*.,* 2023), which resulted in increased root weight in radish. Increased chlorophyll and photosynthesis in leaves, as well as an increase in root biomass as a result of increased nutrient use efficiency.

The interpretations are consistent with the study in potato by Al-juthery et al. (2020) in which he stated that nano nitrogen spray works along to reduce stomatal resistance and increase stomatal conductivity, which provides the plant with enough carbon dioxide and water to continue photosynthesis and withdraw nutrients from the soil, which leads to an increase in the growth and weight of the vegetative parts and also leads to significant increase in dry matter of vegetative under fertigation and foliar application of nano nitrogen. Many research findings reported that the application of nitrogenous fertilizer in different phases increases dry matter production. More nitrogen intake boosts photosynthesis and vegetative development. Nitrogen is one of the essential components of photosynthesis. Increased nitrogen fertilizer application allows for increased photosynthate synthesis (Tariq et al., 2011). Zinc enhanced the amount of auxin in the plant, which resulted in new shoots and increased dry matter production. Several workers reported increased nitrogen uptake as a result of zinc treatment (Rana and Kashif, 2014).

The results of the experimental study in both seasons indicated that foliar application of nano urea and zinc significantly influenced ascorbic acid and nutrient uptake in radish cv. Pusa Chetki (Tables 2 & 4). Increase in ascorbic acid content in treatment T_{11}, might be due to the fact that foliar application of nano urea and zinc increased the photosynthetic and metabolic activities, resulting in increased synthesis of acids, metabolites and glucose. The produced reserves may provide for synthesis of ascorbic acid. Shams (2019) reported that the contents of L-ascorbic acid of kohlrabi were significantly higher in plants when sprayed with nano urea. Chauhan and Hu (2023) stated that, the combined application of nano NPK and nano zinc can play a role in enhancing the ascorbic acid content in chilli, since zinc is known to be involved in the biosynthesis of ascorbic acid. Its balanced application in nano form improves zinc availability, leading to increased ascorbic acid levels in chilli. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients. In the next generation of nano fertilizer, the release of the fertilizer can be triggered by an environmental condition or simply be time released. Slow, controlled-release fertilizers have the potential to increase the efficiency of nutrient uptake. Nano particles as fertilizers are having high surface area, high reactivity, better catalytic activity and rapidly dispersible. These properties support in better uptake of nutrients by plants (Samadhan, 2022).

Table 1. Effect of nano urea and zinc on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki (Season-1)

Treatments	**Shoot length (cm)**	**No. of leaves plant^{-1}**	**Shoot weight (g)**	**Root weight (g)**	**Root yield plot^{-1} (kg)**	**Dry matter production (g/ plant$^{-1)}$**
T_1 - Control (FYM alone)	19.06	6.22	55.12	61.94	11.15	17.56
T_2 - RDF (50:100:50 kg NPK ha^{-1})	25.16	9.14	63.34	69.96	12.80	20.26
T_3 - Basal RDF + FS of 0.2% nano urea	26.28	9.42	65.26	73.56	13.67	21.38
T_4 - Basal RDF + FS of 0.3% nano urea	28.43	9.97	69.10	80.77	15.08	23.38
T_5 - Basal RDF + FS of 0.4% nano urea	30.47	10.49	72.94	87.41	17.26	25.41
T_6 - Basal RDF + FS of 0.2% nano urea + 0.05% nano Zn	27.89	9.73	67.81	78.92	14.85	23.09
T_7 - Basal RDF + FS of 0.2% nano urea + 0.1% nano Zn	29.84	10.27	71.23	86.33	16.99	25.17
T_8 - Basal RDF + FS of 0.3% nano urea + 0.05% nano Zn	31.78	10.76	74.86	91.52	18.43	27.29
T_9 - Basal RDF + FS of 0.3% nano urea + 0.1% nano Zn	33.02	11.03	76.78	95.14	19.41	29.23
T_{10} - Basal RDF + FS of 0.4% nano urea + 0.05% nano Zn	34.17	11.31	78.70	98.76	20.44	31.23
T_{11} - Basal RDF + FS of 0.4% nano urea+ 0.1 % nano Zn	35.24	11.57	80.62	103.19	21.67	33.09
S.Ed	0.36	0.12	0.94	1.12	0.22	0.33
CD (5%)	0.74	0.25	1.79	2.25	0.42	0.65

RDF - Recommended dose of fertilizers, Basal - 25:100:50 Kg NPK ha^{-1}, FS – Foliar spray

Table 2. Effect of nano urea and zinc on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki (Season-1)

Treatments	**Root length (cm)**	**Ascorbic acid (mg 100 g^{-1})**	**Nutrient uptake**			
			N (kg ha^{-1})	**P (kg ha^{-1})**	**K (kg ha^{-1})**	**Zn (g ha^{-1})**
T_1 - Control (FYM alone)	13.66	19.20	28.44	6.11	36.74	14.12
T_2 - RDF (50:100:50 kg NPK ha^{-1})	14.78	23.15	42.39	8.68	48.94	26.87
T_3 - Basal RDF + FS of 0.2% nano urea	15.24	23.99	44.26	9.10	50.92	29.35
T_4 - Basal RDF + FS of 0.3% nano urea	16.21	25.58	48.00	9.94	54.88	34.31
T_5 - Basal RDF + FS of 0.4% nano urea	17.01	27.37	51.44	10.78	58.84	39.27
T_6 - Basal RDF + FS of 0.2% nano urea + 0.05% nano Zn	15.82	24.93	46.83	9.76	53.71	33.49
T_7 - Basal RDF + FS of 0.2% nano urea + 0.1% nano Zn	16.89	26.72	50.36	10.55	57.66	38.46
T_8 - Basal RDF + FS of 0.3% nano urea + 0.05% nano Zn	17.48	28.21	53.61	11.20	60.82	41.75
T_9 - Basal RDF + FS of 0.3% nano urea + 0.1% nano Zn	17.92	29.05	55.48	11.62	62.80	44.23
T_{10} - Basal RDF + FS of 0.4% nano urea + 0.05% nano Zn	18.47	29.90	57.35	12.04	64.78	46.71
T_{11} - Basal RDF + FS of 0.4% nano urea+ 0.1 % nano Zn	18.94	30.74	59.22	12.46	66.76	49.19
S.Ed	0.19	0.32	0.60	0.13	0.68	0.45
CD (5%)	0.39	0.67	1.25	0.26	1.43	0.95

RDF - Recommended dose of fertilizers, Basal - 25:100:50 Kg NPK ha^{-1}, FS – Foliar spray

Table 3. Effect of nano urea and zinc on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki (Season-2)

Treatments	Shoot length (cm)	No. of Leaves plant^{-1}	Shoot weight (g)	Root weight (g)	Root yield plot^{-1} (kg)	Dry matter production (g/ plant^{-1})
T_1 - Control (FYM alone)	18.94	6.98	50.84	59.02	10.56	16.48
T_2 - RDF (50:100:50 kg NPK ha^{-1})	24.98	8.27	59.63	65.73	11.96	19.05
T_3 - Basal RDF + FS of 0.2% nano urea	26.07	8.59	61.64	69.86	12.92	20.25
T_4 - Basal RDF + FS of 0.3% nano urea	28.13	9.13	65.47	78.12	14.16	22.43
T_5 - Basal RDF + FS of 0.4% nano urea	30.22	9.87	69.53	86.38	16.08	24.65
T_6 - Basal RDF + FS of 0.2% nano urea + 0.05% nano Zn	27.44	8.91	63.95	76.85	13.84	22.01
T_7 - Basal RDF + FS of 0.2% nano urea + 0.1% nano Zn	29.48	9.65	67.92	84.67	15.79	24.28
T_8 - Basal RDF + FS of 0.3% nano urea + 0.05% nano Zn	31.29	10.19	71.67	90.51	17.92	26.60
T_9 - Basal RDF + FS of 0.3% nano urea + 0.1% nano Zn	32.34	10.51	73.69	94.64	19.12	28.62
T_{10} - Basal RDF + FS of 0.4% nano urea + 0.05% nano Zn	33.38	10.83	75.71	98.77	20.25	30.71
T_{11} - Basal RDF + FS of 0.4% nano urea+ 0.1 % nano Zn	34.43	11.15	77.72	102.90	21.40	32.51
S.Ed	0.35	0.11	0.89	1.10	0.20	0.32
CD (5%)	0.71	0.24	1.71	2.21	0.41	0.62

RDF - Recommended dose of fertilizers, Basal - 25:100:50 Kg NPK ha^{-1}, FS – Foliar spray

Table 4. Effect of nano urea and zinc on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki (Season-2)

Treatments	Root length (cm)	Ascorbic acid (mg 100 g^{-1})	Nutrient uptake			
			N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (g ha^{-1})
T_1 - Control (FYM alone)	12.13	18.19	26.23	5.74	30.36	11.86
T_2 - RDF (50:100:50 kg NPK ha^{-1})	14.32	21.99	39.90	8.25	39.36	14.48
T_3 - Basal RDF + FS of 0.2% nano urea	14.78	22.75	41.64	8.61	51.43	17.10
T_4 - Basal RDF + FS of 0.3% nano urea	15.55	24.26	45.12	9.33	57.01	22.34
T_5 - Basal RDF + FS of 0.4% nano urea	16.15	25.77	48.60	10.05	60.73	27.58
T_6 - Basal RDF + FS of 0.2% nano urea + 0.05% nano Zn	15.21	23.81	44.09	9.16	55.98	21.82
T_7 - Basal RDF + FS of 0.2% nano urea + 0.1% nano Zn	15.97	25.20	47.48	9.89	59.87	26.97
T_8 - Basal RDF + FS of 0.3% nano urea + 0.05% nano Zn	16.58	26.53	50.34	10.41	62.59	30.20
T_9 - Basal RDF + FS of 0.3% nano urea + 0.1% nano Zn	17.01	27.28	52.08	10.77	64.45	32.82
T_{10} - Basal RDF + FS of 0.4% nano urea + 0.05% nano Zn	17.42	28.04	53.82	11.13	66.31	35.44
T_{11} - Basal RDF + FS of 0.4% nano urea+ 0.1 % nano Zn	17.86	28.80	55.56	11.49	68.17	38.06
S.Ed	0.20	0.31	0.56	0.12	0.69	0.32
CD (5%)	0.42	0.63	1.17	0.24	1.44	0.68

RDF - Recommended dose of fertilizers, Basal - 25:100:50 Kg NPK ha^{-1}, FS – Foliar spray

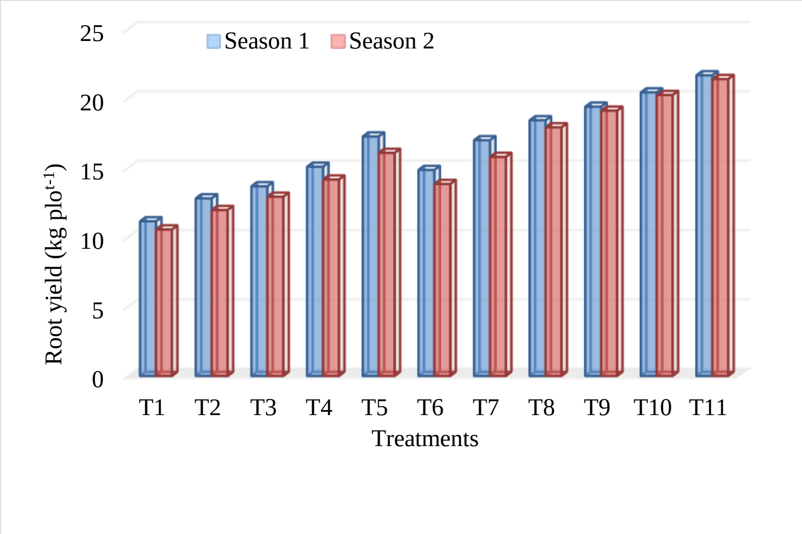

Fig. 9. Effect of nano urea and zinc on root yield plot^{-1} in Radish

In the present research work, application of Basal RDF dose of NPK and foliar application of nano urea and zinc nutrients significantly influenced the uptake of N, P and K in radish. Application of Basal RDF dose of NPK + FS of 0.4 per cent nano urea + 0.1 per cent nano Zn (T_{11}), registered the highest uptake of N, P_2O_5, K_2O and zinc (Tables 2 & 4). Increase in nutrient uptake might be due to more availability of macronutrients and also due to synergistic effect of micronutrients, which exerted an increase in uptake of nutrients. The increased accumulation of nutrients in the plants may be due to steady and sustained effect of Basal RDF dose of NPK and foliar nano urea and zinc fertilizers in supplying proportionate nutrients at right time which resulted in uniform and higher growth rate throughout the crop period as suggested by Manjunatha (2004). The increased accumulation of NPK in the plant may be attributed to more availability of the respective nutrients and more absorptive area which resulted in the highest nutrient accumulation (Deshpande and Lakdive, 1994 and Naik et al*.,* 1996) Application of zinc also promotes nutrient uptake that ultimately increase vegetative growth (Cakmak et al*.,* 1999).

4. CONCLUSION

Based on the results of the present investigation, it is evident that there is a visible progress with the treatment application of basal RDF + FS of 0.4 per cent nano urea + 0.1 per cent nano Zn (T_{11}) in growth and yield characters in radish (*Raphanus sativus* L.) cv. Pusa Chetki. Therefore, it can be concluded that the application of basal RDF + FS of 0.4 per cent nano urea + 0.1 per cent nano Zn (T_{11}) was found to be beneficial in improving the growth and yield of radish.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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