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Enhancing Dragon Fruit Growth: The Efficacy of Nano Urea as an Alternative to Conventional Urea in Subtropical Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Among the recent technologies, nano fertilizers are an emerging innovation, which has the potential to offer sustainable solutions to enhance the efficient use of nutrients and growth of plants. Nano urea is one of them, increasing nitrogen availability to crops by more than 80%, leading to greater use of fertilizer efficiency and crop output. The present investigation was carried out to depict the

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best treatment combination of urea, and nano urea for vegetative growth of dragon fruit. There was a significant increase in vegetative growth by nano urea regarding various growth characteristics. Results suggested that nano urea was beneficial and resulted very close to the recommended dose of fertilizers (RDF). Among the treatments under study, the foliar application of Urea @ 2% combined with Nano urea @ 6ml/L may be recommended for dragon fruit growth, since it produced maximum vegetative growth of dragon fruit in terms of plant length, number of primary branches, number of segments of main stem, number of areoles, stem thickness, stem circumference, number of spines, distance between two areoles, arch height and chlorophyll content at subtropical Lucknow condition.

Keywords: Dragon fruit; nano urea; urea; vegetative growth.

1. INTRODUCTION

Dragon fruit (*Hylocereus spp*.) is a cactus plant belonging to the family Cactaceae, having a chromosome no. 2n=22 is emerging as a supercrop even for marginal land owing to its health and medicinal benefits worldwide. It is popular with various names in different areas (Pitaya, Night Blooming Cereus, Strawberry Pear, Queen of Night, Jesus in the Cradle, Honorable Queen, Belle of Night). It originated in Mexico and Central and South America (Britton and Rose, 1963; Morton, 1987) and is now cultivated in China, Australia, Hawaii, Indonesia, Guatemala, Israel, Taiwan, Malaysia, Vietnam and Thailand. In India, it is mainly grown in parts of Maharashtra, Karnataka and Gujarat, West Bengal, Uttar Pradesh (Maji et al., 2021). Following types are primarily popular in India, all with leathery, slightly leafy skin: *Hylocereus undatus*— white flesh with pink skin, *Hylocereus polyrhizus*– red flesh with pink skin, *Hylocereus costaricencis* – with violet red flesh and pink skin and *Hylocereus* (*Selenicerus*) *megalanthus* – white flesh with yellow skin (Hunt, 2006; Hamidah et al*.,* 2017). The taste of this fruit is delicately sweet but crispy, and it looks alluring with its green scales and pink skin. It is rich in nutrient content, especially vitamin C, phosphorus, calcium as well as its antioxidant properties (Morton, 1987). Consumers can make value-added goods from the pulp of dragon fruit, wine. Pectin is rich in fruit peel, and according to various methods, fruit peel can produce 7.5% of pectin (Thirugnanasambandham et al., 2014). It is a good source of minerals, glucose, fructose, dietary fiber and vitamins (Rao and Sasanka, 2015) and well-known for its rich vitamin C, phosphorus, calcium as well as anti-oxidant contents (Morton, 1987) along with B group vitamins (LeBellec et al., 2006). Whereas, seeds contain 50% of essential fatty acids namely, Linoleic acid and Linolenic acid (Sonawane, 2017). Regular consumption of dragon fruit greatly controls asthma, cough, cholesterol, helps in preventing cancer, boosts immune power (Subramani et al., 2023).

Although dragon fruit is well responsive to nutrient management. Judicious application of fertilizers and manures is necessary for higher fruit yield with better quality (Nangare et al*.,* 2020; Singh et al., 2022). Nano urea is bioavailable to plants because of its desirable particle size about 20-50 nm and more surface area about (10000 times over 1mm urea prill) and number of particles (55000, nitrogen particles over 1mm urea prill). Hence, nano urea increases its availability to crops by more than 80% resulting in higher nutrient use efficiency (Anon., 2005) as stated by IFFCO. Nano urea is responsible for influencing both qualitative as well as quantitative aspects of dragon fruit. Keeping these facts in view a field experiment was conducted to assess the efficiency of nano urea along with urea on the growth of dragon fruit plants.

2. MATERIALS AND METHODS

The experiment was carried out at dragon fruit orchard, Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow (Uttar Pradesh), India (26°55′N latitudes and 80°54′E, 123 m above MSL) in the subtropical climate of central Uttar Pradesh) during 2022-23. Soil was sandy loam with uniform fertility having pH of 8.1. There were 10 treatments- Control (T_0), RDF 100% (T_1), 2% N_2 through Urea (T_2), 1.5% N_2 through Urea (T_3), 6ml/l Nano Urea (T_4), 4 ml/l Nano Urea(T_5), 2% N_2 through Urea + 6 ml/l Nano Urea (T_6), 2% N_2 through Urea + 4 ml/l Nano Urea(T_7), 1.5% N_2 through Urea + 6 ml/l Nano Urea (T_8), 1.5% N_2 through Urea + 4 ml/l Nano Urea(T_9) which were laid out in Randomized Block Design with 3 replications. There were 30 poles each having 4 plants planted at 4 m x 2 m spacing. The base area of 1

m radius was cleaned for fertilizer and irrigation management. Plants along with new growth are tied up with pole regularly for better support.

Nano urea was collected from IFFCO Bhawan - 8, IFFCO State Office, Gokhle Marg, Lucknow (UP) which had a desirable particle size about 20-50 nm and more surface area (10000 times over 1 mm urea prill) and several particles (55000, nitrogen particles over 1 mm urea prill). Well-rotted FYM @ 16 kg/pole, Vermicompost @ 8 kg/pole and recommended dose of fertilizer @ 200g N_2, 225g P_2O_5, 137.5g K_2O/Pole (Nangare et al., 2020) were applied in two split doses first during November 2021 and second during February 2022 (end of winter). Chemical fertilizers, vermicompost and FYM were applied as soil application followed by irrigation whereas nano urea was applied twice as foliar spray as per treatment combination. Observations were recorded for its vegetative growth like plant length, number of primary branches, number of segments of main stem, number of areoles, stem thickness, stem circumference, number of spines, distance between two areoles, arch height and chlorophyll content using standard methods of biochemical analysis (Thimmaiah, 2004). To test the significance of variance in the data obtained from the various vegetative growth characters, the variance analysis technique was adopted as Panse and Sukhatme (1985) suggested for Randomized Block Design (RBD). Significance of difference in the treatment effect was tested through an 'F' test at a 5% level of significance and critical difference (CD) was calculated, wherever the result was significant or not.

3. RESULTS AND DISCUSSION

3.1 Plant Length

It was evident from Table 1 and Fig. 1 that there was a significant difference among the treatments at 30, 45, 60, 75, and 90 days after treatment (DAT). It was observed that an increase in plant length (7.09 cm) was recorded maximum at 45 days (from 30 DAT to 45 DAT) with T_6 treatment (2% N_2 through Urea + 6 ml/l Nano urea) followed by a 5.70cm increase in T_9 treatment (1.5% N_2 through Urea + 4 ml/l Nano urea). It was seen that a maximum increase (7.09 cm) in length at 45 DAT from 30 DAT was recorded under treatment T_6 (2% N_2 through Urea + 6 ml/l Nano urea) and at 60 DAT, it was maximum observed on T_6 (2% N_2 through urea + 6 ml/l Nano urea). Similarly, there was no specific pattern of increase since T_6 showed highest increase at 75 DAT from 60 DAT and continued to 90 DAT followed by T_2. It was also calculated that T_6 caused a maximum increase from 30 DAT to 90 DAT and control plants recorded minimum increase. However, at various stages of growth, the highest rate of increase in plant length was observed on increase at 75 DAT from 60 DAT. Overall, it was noticed that maximum total increase from 30 DAT to 90 DAT was recorded at T_6 and minimum increase was observed in untreated control. Kumar et al. (2020) also reported that nano fertilizers significantly increased plant growth and yield.

3.2 Number of Primary Branches/Plant

It was seen that maximum (2.67) increase in number of branches was noticed under treatment T_2 (2% N_2 through Urea) and At 60 DAT (from 45 DAT to 60 DAT), it was found that maximum (3.00) increase in number of branches was under treatment T_3 (1.5% N_2 through Urea). It was evident from the above results (Table 1 and Fig. 2) that change in a number of branches from 45 days to 60 days was non-significant (at 5% level of significance).

It was noticed that treatment T_6 (2% N_2 through Urea + 6 ml/l Nano urea) showed highest number of branches increase (3.66) followed by treatment T_1 (2.66) was recorded under treatment T_3 (from 60 DAT to 75 DAT) similarly, overall increase in number of branches from 30 to 90 DAT, maximum number of branches (10.33) was obtained with treatment T_6 (2% N_2 through Urea + 6 ml/l Nano urea).

3.3 Number of Areoles/Segments (Three Sides)

The number of areoles was counted on three sides of a segment and increase in a number of areoles was presented in Table 2. It showed that maximum increase in a number of areoles per segment was measured (6.67) under treatment T_2 (2% N_2 through Urea) at 45 DAT (from 30 DAT to 45 DAT). However at 60 DAT (from 45 DAT to 60 DAT), it was found that maximum increase (5.33) in number of areoles per segment was noticed under treatment T_1 (RDF).

At 90 DAT (from 75 DAT to 90 DAT), it was seen that treatment T_1 (RDF) caused highest increase in number of areoles/segment (5.33) data observed (Fig. 3) in total overall increase in number of areoles (Table 3) from 30 to 90 DAT,

revealed that maximum increase in number of areoles/segment (18.00) was in treatment T_1 (RDF) and minimum increase was found in T_5 treatment (4 ml/l Nano urea).

3.4 Stem Thickness

It was also observed (Table 2) that T_6 (2% N_2 through Urea + 6 ml/l Nano urea) caused maximum increase in stem thickness at 45 DAT and At 60 DAT (from 45 DAT to 60 DAT), it was found (Fig. 2) that maximum (0.26 cm) increase in stem thickness under treatment T_7 (2% N_2 through Urea + 4 ml/l Nano urea) and treatment T_5 (4 ml/l Nano urea) showed highest increase (0.34 cm) in stem thickness from 60 to 90 DAT. The maximum stem thickness was recorded at 90 DAT (4.55 cm) under T_2 (2% N_2 through urea), which also showed the maximum increase in stem thickness. Law-Ogbomo and Law-Ogbomo (2009) reported that NPK fertilizer applications significantly increase plant stem girth in maize.

3.5 Number of Spines Per Areoles

An increase in number of spines per areoles (0.16) was recorded maximum at 45 days (from 30 DAT to 60 DAT) with treatment T_4 (6 ml/l Nano urea) (Table 3). Similarly, T_4 also showed.

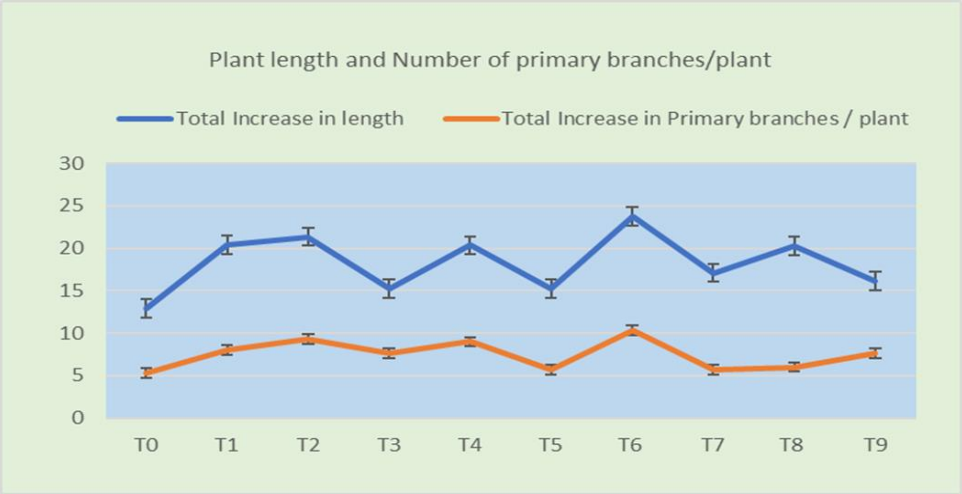

Fig. 1. Effect of Urea and Nano-urea on increase of plant length and Number of primary branches / plant from 90 DAT

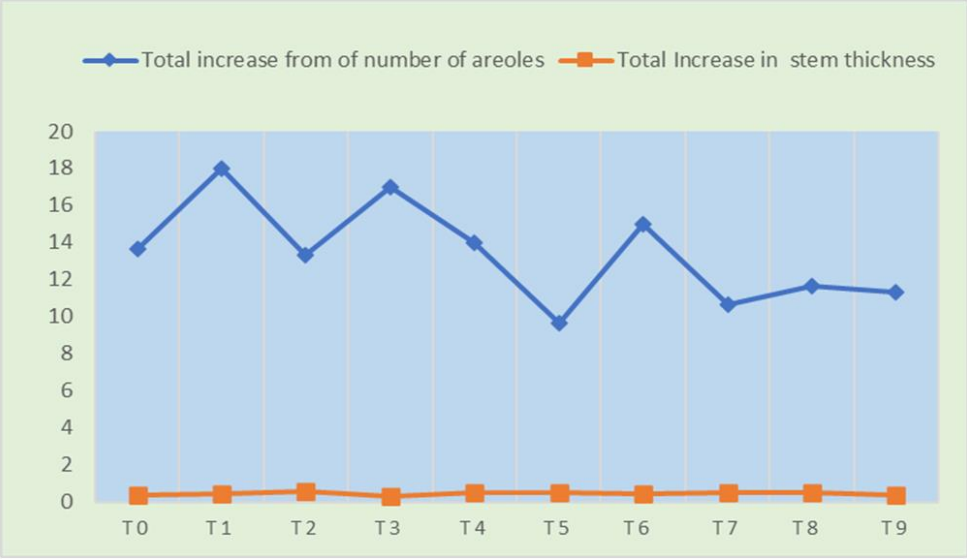

Fig. 2. Effect of Urea and Nano-urea on increase of number of areoles per segment. and stem thickness

Table 1. Effect of Urea and Nano-urea on Increase of plant length,Number of primary branchesof dragon fruit

Treatment	Plant length (cm) at 30 DAT	Increase in length (cm) at (30-45 DAT)	Increase in length (cm) at (45-60DAT)	Increase in length (cm) at (60-75 DAT)	Increase in length (cm) at (75-90 DAT)	Plant length (cm) at 90 DAT	Total Increase (cm) (from 30 days to 90 days)	Number of primary branches/ plant at 30 DAT	Increase in Primary branches / plant at (30-45 DAT)	Increase in Primary branches / plant at (45-60 DAT)	Increase in Primary branches / plant at (60- 75 DAT)	Number of primary branches/ plant at 75-90 DAT	Increase in Primary branches / plant 90 DAT)	Total Increase (cm)(from 30 days to 90 days)
T_0	187.67	2.66	3.29	10.70	2.23	200.6	12.93	6.00	1.33	1.00	2.00	1.00	11.33	5.33
T_1	183.33	4.90	5.76	16.47	3.93	203.73	20.40	8.00	1.00	2.67	2.66	1.67	16.00	8.00
T_2	201.67	4.80	6.64	17.53	3.84	222.04	21.37	9.33	2.67	2.67	1.66	2.34	18.67	9.34
T_3	193.70	4.63	3.30	11.69	3.58	208.97	15.27	8.67	2.00	3.00	1.33	1.33	16.33	7.67
T_4	189.17	4.16	5.50	12.35	7.99	209.51	20.34	10.00	2.33	2.67	2.33	1.67	19.00	9.00
T_5	193.70	4.63	3.30	11.69	3.58	208.97	15.27	10.33	1.33	2.00	1.66	0.67	16.00	5.67
T_6	195.67	7.09	8.47	18.46	5.29	219.42	23.75	9.00	1.67	2.00	3.66	3.00	19.33	10.33
T_7	193.62	5.32	4.38	13.80	3.30	210.72	17.10	11.00	1.33	2.00	1.66	0.67	16.00	5.67
T_8	183.00	4.14	6.43	15.60	4.68	203.28	20.28	8.00	1.33	2.33	0.66	1.67	17.00	6.00
T_9	183.67	5.70	5.06	11.04	5.12	199.83	16.16	7.67	1.67	1.66	2.34	2.00	15.67	7.67
SEm (±)		**0.459**	**0.075**	**0.140**	**0.060**		**0.204**		**0.014**	**0.023**	**0.258**	**0.015**		**0.324**
CD(P=0.05)		**1.374**	**0.226**	**0.419**	**0.180**		**0.610**		**0.042**	**0.069**	**0.772**	**0.045**		**0.969**

Control (T_0), RDF 100% (T_1), 2% N_2 through Urea (T_2), 1.5% N_2 through Urea (T_3), 6ml/l Nano Urea (T_4), 4 ml/l Nano Urea(T_5), 2% N_2 through Urea + 6 ml/l Nano Urea (T_6), 2% N_2 through Urea + 4 ml/l Nano Urea(T_7), 1.5% N_2 through Urea + 6 ml/l Nano Urea (T_8), 1.5% N_2 through Urea + 4 ml/l Nano Urea(T_9) respectively

Table 2. Effect of Urea and Nano urea on increase of number of areoles per segment and stem thickness of dragon fruit

Treatment	Increase of number of areoles at 30 DAT	Increase of number of areoles at (30-45 DAT)	Increase of number of areoles at (45-60DAT)	Increase of number of areoles at(60-75 DAT)	Increase of number of areoles at (75-90 DAT)	Increase of number of areoles at 90 DAT	Total increase from 30 days to 90 days)	Number of stem thickness at 30 DAT	Increase in stem thickness at (30-45 DAT)	Increase in stem thickness at(45-60 DAT)	Increase in stem thickness at (60- 75 DAT)	Number of stem thickness at 75-90 DAT	Increase in stem thickness 90 DAT)	Total Increase (cm)(from 30 days to 90 days)
T_0	45.00	3.33	3.34	4.66	2.34	58.67	13.67	3.83	0.04	0.10	0.13	0.07	4.17	0.34
T_1	44.33	3.67	5.33	3.67	5.33	62.33	18.00	3.90	0.10	0.10	0.20	0.03	4.33	0.43
T_2	39.33	6.67	3.33	2.34	1.00	52.67	13.34	3.97	0.06	0.20	0.20	0.09	4.52	0.55
T_3	40.00	5.67	5.33	3.33	2.67	57.00	17.00	4.60	0.07	0.07	0.13	0.07	4.93	0.33
T_4	45.00	3.00	4.00	5.00	2.00	59.00	14.00	3.90	0.07	0.17	0.17	0.10	4.40	0.50
T_5	44.67	0.33	2.00	4.33	3.00	54.33	9.66	3.43	0.03	0.13	0.23	0.07	3.90	0.47
T_6	34.00	2.00	3.00	6.00	4.00	49.00	15.00	4.33	0.20	0.07	0.10	0.06	4.76	0.43
T_7	40.33	3.67	3.00	2.00	2.00	51.00	10.67	4.20	0.01	0.26	0.17	0.05	4.68	0.48
T_8	57.00	0.33	2.67	5.00	3.67	68.67	11.67	3.67	0.07	0.10	0.20	0.10	4.13	0.47
T_9	44.00	2.00	2.67	4.33	2.33	55.33	11.33	3.90	0.13	0.07	0.10	0.07	4.27	0.37
SEm(±)		**0.028**	**0.050**	**0.043**	**0.044**		**0.152**		**0.002**	**0.003**	**0.003**	**0.001**		**0.007**
CD(P=0.05)		**0.083**	**0.149**	**0.128**	**0.130**		**0.456**		**0.005**	**0.009**	**0.009**	**0.003**		**0.021**

Control (T_0), RDF 100% (T_1), 2% N_2 through Urea (T_2), 1.5% N_2 through Urea (T_3), 6ml/l Nano Urea (T_4), 4 ml/l Nano Urea(T_5), 2% N_2 through Urea + 6 ml/l Nano Urea (T_6), 2% N_2 through Urea + 4 ml/l NanoUrea(T_7), 1.5% N_2 through Urea + 6 ml/l Nano Urea (T_8), 1.5% N_2 through Urea + 4 ml/l Nano Urea(T_9) respectively

Table 3. Effect of Urea and Nano urea on increase of number of spines per areoles and distance between areoles in dragon fruit

Treatment	Increase Number of spines/areoles at 30 DAT	Increase Number of spines /areoles at (30-45 DAT)	Increase of Number of spines /areoles at (45-60DAT)	Increase of Number of spines /areoles at (60-75 DAT)	Increase of Number of spines /areoles at (75-90 DAT)	Increase of Number of spines /areoles at 90 DAT	Increase in Number of spines /areoles (from 30 - 90 days)	Distance between areoles at 30 DAT	Distance between areoles at (30-45 DAT)	Distance between areoles at (45-60 DAT)	Distance between areoles at (60- 75 DAT)	Distance between areoles at 75-90 DAT	Distance between areoles 90 DAT)	Distance between areoles) (from 30 days to 90 days)
T_0	3.34	0.01	0.01	0.03	0.01	3.38	0.04	3.02	0.04	0.01	0.03	0.01	3.10	0.04
T_1	3.02	0.02	0.03	0.07	0.03	3.12	0.10	2.84	0.02	0.03	0.01	0.03	2.94	0.10
T_2	4.23	0.11	0.22	0.25	0.11	4.59	0.36	3.07	0.04	0.02	0.05	0.07	3.24	0.36
T_3	3.88	0.04	0.09	0.18	0.00	4.06	0.18	3.55	0.02	0.01	0.05	0.01	3.63	0.18
T_4	3.43	0.16	0.26	0.31	0.01	3.75	0.32	2.78	0.10	0.02	0.02	0.01	2.94	0.32
T_5	4.16	0.10	0.13	0.19	0.01	4.36	0.20	2.37	0.04	0.02	0.01	0.02	2.46	0.20
T_6	3.61	0.05	0.10	0.02	0.11	3.74	0.13	2.90	0.13	0.07	0.01	0.01	3.13	0.13
T_7	4.09	0.08	0.11	0.12	0.03	4.24	0.15	3.02	0.04	0.01	0.07	0.04	3.18	0.15
T_8	3.37	0.12	0.17	0.14	0.21	3.72	0.35	2.40	0.07	0.02	0.04	0.00	2.53	0.35
T_9	3.77	0.04	0.14	0.24	0.02	4.03	0.26	2.52	0.04	0.01	0.05	0.02	2.64	0.26
SEm(±)		**0.002**	**0.002**	**0.002**	**0.001**		**0.003**		**0.001**	**0.000**	**0.001**	**0.000**		**0.002**
CD(P=0.05)		**0.005**	**0.006**	**0.007**	**0.003**		**0.009**		**0.003**	**0.001**	**0.002**	**0.001**		**0.007**

Control (T_0), RDF 100% (T_1), 2% N_2 through Urea (T_2), 1.5% N_2 through Urea (T_3), 6ml/l Nano Urea (T_4), 4 ml/l Nano Urea(T_5), 2% N_2 through Urea + 6 ml/l Nano Urea (T_6), 2% N_2 through Urea + 4 ml/l Nano Urea(T_7), 1.5% N_2 through Urea + 6 ml/l Nano Urea (T_8), 1.5% N_2 through Urea + 4 ml/l Nano Urea(T_9) respectively

Fig. 3. Effect of Urea and Nano-urea on distance of areole and number of spines per areole

3.6 Distance between Areoles (cm)

The variation in distance between areoles is presented in Table 3 and it showed that maximum increase in distance between areoles was measured (0.13cm) under treatment T_6 (2% N_2 through Urea + 6ml/l Nano urea) at 30 DAT to 60 DAT and at 75 DAT 90 DAT Maximum (0.07 cm) increase in distance between areoles was recorded under treatment T_7 (2% N_2 through Urea + 4ml/l Nano urea). The maximum distance between areoles was recorded at 90 DAT (3.63cm) under T_3 (1.5% N_2 through urea), however, T_6 (2% N_2 through Urea + 6ml/l Nano urea) showed the greatest increase in distance between areoles from 30 DAT to 90 DAT. Over-vegetative growth promotion was also reported by Maurya et al. (2023).

4. CONCLUSION

The study successfully demonstrated the potential of nano urea as a superior alternative to conventional urea in enhancing the vegetative growth of dragon fruit under subtropical conditions with slightly alkaline soil. The application of nano urea significantly improved various growth parameters, reflecting its efficacy in increasing nitrogen availability and fertilizer use efficiency. Among the different treatments evaluated, the combination of foliar application of Urea at 2% and Nano urea at 6ml/L was found to be the most effective, yielding the maximum vegetative growth. These findings suggest that nano urea, in conjunction with a reduced rate of conventional urea, can be recommended as an optimal fertilization strategy for dragon fruit cultivation, contributing to higher crop productivity and better soil health.

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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