Plant Archives Vol. 24, No. 2, 2024 pp. 1775-1781 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.255

EFFECTS OF NANO UREA ON GROWTH AND YIELD ATTRIBUTES OF PEA (*PISUM SATIVUM* L.)

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(Date of Receiving-22-05-2024; Date of Acceptance-03-08-2024)

ABSTRACT

This study investigates the effects of Nano Urea on the growth and yield attributes of pea (*Pisum sativum* L.) in a field study conducted in Gwalior, Madhya Pradesh, during the 2023-24, growing season. A randomized block design (RBD) was employed, comparing three treatments: Nano Urea, traditional urea and a control with no fertilizer. Parameters measured included germination percentage, flowering time, pod characteristics and yield components. Results indicated significant improvements in growth and yield with Nano Urea, highlighting its potential as a sustainable alternative to traditional urea. According to the study, yields of Arkel have increased dramatically (15.61 t/ha) when 100% nano urea is applied during vegetative growth stages, compared to farmers' practices or controls. The greater cost of cultivation in T_7, T_6 and T_4. The lowest cost of cultivation found in T_8 (210183.30 Rs/ha). The highest Gross income (Rs/ha) was recorded in T_2 (702600.00Rs/ha). The highest Net income (Rs/ha) was recorded in T_2 (447648.00 Rs/ha). The highest benefit cost-ratio was found in T_8 (1.90). The lowest benefit cost-ratio observed in T7 (0.98). Therefore, three treatments, T_8, T_2, T_3 can be recommended for commercial cultivation of Arkel variety of pea. Therefore, it can be suggested to apply nano urea foliar application to increase pea production and it is possible to do additional research to get more practical results in future.

Key words : Nano urea, Growth, Higher yield, Gross return, Benefit-cost ratio.

Introduction

The Garden pea (*Pisum sativum* L.) is a vital winter vegetable crop grown commercially worldwide, providing a rich source of protein, vitamins and minerals. As a critical economic and nutritive crop, the pea is often referred to as "poor man's meat" due to its affordability and high nutritional value (Sahu *et al*., 2022). However, the use of traditional urea fertilizers has raised concerns about their environmental impact and economic feasibility (Sathyan, 2022). In recent years, nanotechnology has emerged as a potential solution to address these concerns.

Nano Urea, a novel nanotechnology-enabled product, has been shown to outperform traditional urea fertilizers in several aspects. Research has demonstrated that smaller Nano Urea crystals can be better absorbed by plants, improving nitrogen usage and reducing loss (Guo *et al*., 2018). Additionally, Nano Urea has been found to improve nitrogen use efficiency (NUE), reducing nitrogen leakage and volatilization and promoting cleaner air and land (Jadon *et al*., 2018). Furthermore, Nano Urea has been shown to help plants cope with drought stress, making it a valuable resource for regions with unpredictable weather patterns (Sahu *et al*., 2022).

Several studies have investigated the effects of Nano Urea on pea growth and production in various locations, with promising results. For example, Verma *et al*. (2023) found that the application of 0.1% Nano Zinc and 0.2% Nano Urea at 30 DAS resulted in improved growth and production attributes of pea. Similarly, Kumar *et al*. (2020) reported that the use of 25% less conventional urea and two sprays of 0.4% Nano Urea on onion leaves resulted in improved growth and yield.

Materials and Methods

The field experiment was carried out at the Vegetable

Research Farm (CRC-3), Under the poly house, School of Agriculture, Department of Horticulture, ITM University, Gwalior (MP), during *rabi* season (2023-2024) from the last week of September to mid of April. Summer season is considered very hot, where the months of May and June are found to be the hottest months here with a maximum average temperature of 35^{0}C to 45^{0}C (95^{0}C to 113^{0}C). The place of investigation is situated in the ITM University, Gwalior district of Madhya Pradesh. It is geographically located in the Gird region of India 26 21, N latitude and 78 20' E longitudes and an altitude of 211.5 m above sea level. It is present in the southwest of the main city centre of Gwalior. These treatments are evaluated in Randomized block design (RBD) at spacing of 30 cm x 10 cm with three replications. The experiment was consisting of eight treatments (Table 1).

Table 1 : List of treatments used in the experiment.

S. no.	Treatment notation	Treatments detail
1	T_1	Control
2	T_2	100% N through Nano Urea
3	T_3	90% RDN through Urea + 10% N through Nano Urea
4	T_4	80% RDN through Urea + 20% N through Nano Urea
5	T_5	70% RDN through Urea + 30% N through Nano Urea
6	T_6	60% RDN through Urea + 40% N through Nano Urea
7	T_7	50% RDN through Urea + 50% N through Nano Urea
8	T_8	40% RDN through Urea + 60% N through Nano Urea

The experimental site had a pH of 7.2 and was well-leveled, well-drained, and fertile sandy loam soil. The soil was prepared by 2-3 ploughing and tillage practices to make it into fine tilth. Farmyard manure (FYM) was evenly mixed into the soil during land preparation to ensure proper distribution of organic matter throughout the soil. The crop used in the study was garden pea (*Pisum sativum* L.) variety 'Arkel'. Seeds were sown on November 25, 2023. Growth and yield attributes of Pea observed during the study are **GPR**: Germination Percentage Rate, **DFF**: Days to First Flowering, **DFPF**: Days to 50% Flowering, **PDL**: Pod Length, **PDW**: Pod Width, **PDG**: Pod Girth, **NPP**: Number of Pods per Plant, **NSP**: Number of Seeds per Pod, **SWP**: Seed Weight per Pod, **APH**: Average Plant Height, Number of Primary Branches per Plant, **YPP**: Yield per Plot , **YTH**: Yield per Hectare, **SYP**: Seed Yield per Plant, **PYP**: Pod Yield per Plant, **WHS** (Weight of 100 seed), **SLP** (Shelling percentage of pea), **PIC** (Number of pickings).

The germination percentage was calculated using towel paper method as per the procedure of International Seed Testing Association (Anonymous, 2019). However, the seeds were germinated on the top of one layer paper enclosed with appropriate moisture level and kept at the room temperature. Data were taken after four days. The germination percentage of peas was calculated as:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds set for the test}} \times 100$$

To determine the cost of cultivation for each treatment, all inputs used in the study were priced at the current market rates. To calculate gross income, the pea yields were evaluated in accordance with the going market rates. Net income and the benefit-to-cost ratio were then computed to evaluate the profitability of various therapies. Benefit: Cost ratio was calculated by dividing net returns with the cost of cultivation for each treatment.

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ ha)}}$$

The analysis of variance for the design of experiment (RBD) was carried out according to the procedure outlined by Panse and Sukhatme (1967). The significance of differences among treatment means was tested by 'F' test. To test the hypothesis H_0: $t_1 = t_2 \ldots t_n$, the fixed effect model for analysis of variance for Randomized Block Design is given bellow:

$$Y_{ij} = \mu + t_i + b_i + e_{ij}$$

Where,

Y_{ij} = Yield of i^{th} entry in the j^{th} replication

μ = General mean

t_i = Effect of the i^{th} entry (i = 1,2….)

b_i = Effect of the j^{th} replication (j = 1,2…...)

e_{ij} = Environmental effect

Results and Discussion

Different parameters related to growth and productivity of pea (*Pisum sativum* L.) reflected a significant variation under different growing media.

Germination percentage ranged from 66.78 percent to 71.40 highest percentage. The overall mean was 69.27 percentage. The highest germination percentage was found in 40% RDN through Urea + 60% N through Nano Urea (71.40) followed by 100% N through Nano Urea (70.56), 70% RDN through Urea + 30% N through Nano Urea (70.29). The lowest germination percentage

observed in Control (66.78). Days to first flowering ranged from 42.78 to 46.48 highest. The overall mean was 44.39. The earliest days to first flowering was found in 100% N through Nano Urea (42.78) followed by 50% RDN through Urea + 50% N through Nano Urea (43.17), 80% RDN through Urea + 20% N through Nano Urea (43.86). The maximum days to first flowering was observed in 70% RDN through Urea + 30% N through Nano Urea (46.48). Days to 50% flowering ranged from 43.00 to 45.67 days. The overall mean was 44.41 days. Three treatment, 80% RDN through Urea + 20% N through Nano Urea (43.00 days), 100% N through Nano Urea (43.33 days), 60% RDN through Urea + 40% N through Nano Urea T_6 (44.00 days) were significantly earlier than others for number of days taken to 50% flowering. While, the maximum number of days taken to 50% flowering were found in the treatment 50% RDN through Urea + 50% N through Nano Urea (45.67 days) followed by 70% RDN through Urea + 30% N through Nano Urea (45.33 days) and Control T_1 (45.00 days). The pod length shall be noted in ascending order from 60.33 mm to 66.00 mm. The overall mean was 63.62 mm. The minimum pod length was found in 40% RDN through Urea + 60% N through Nano Urea (60.33 mm) followed by Control (61.67 mm) and 60% RDN through Urea + 40% N through Nano Urea (62.33 mm). While the maximum pod length was found in 50% RDN through Urea + 50% N through Nano Urea (66.00 mm). The pod width shall be noted in ascending order from 17.33 mm to 21.67 mm. The overall mean was 19.16 mm. The minimum pod length was found in Control (17.33 mm) and 90% RDN through Urea + 10% N through Nano Urea (17.33 mm) followed by 80% RDN through Urea + 20% N through Nano Urea (19.00 mm) and 70% RDN through Urea + 30% N through Nano Urea (19.00 mm). While, the maximum pod length was found in 100% N through Nano Urea (21.67 mm). The Pod girth ranged from 26.77 to 29.03. The overall mean was 28.05. The highest pod girth was found control (29.03 mm) followed by 60% RDN through Urea + 40% N through Nano Urea (28.68 mm) and 100% N through Nano Urea (28.67 mm)). The lowest pod girth was found in 50% RDN through Urea + 50% N through Nano Urea (26.77 mm). The number of pod/plants ranged from 21.49to 24.00 highest. The overall mean was 22.39. The highest number of pod/ plants was found in 40% RDN through Urea + 60% N through Nano Urea (24.00) followed by 90% RDN through Urea + 10% N through Nano Urea (23.17) and 60% RDN through Urea + 40% N through Nano Urea (23.10). The lowest number of pod/ plants found in 70% RDN through Urea + 30% N through Nano Urea (21.49).

Table 2 : Mean performance of pea (*Pisum sativum* L.).

S. no.	Treatments notation	GPR	DFF	DFPF	PDL	PDW	PDG	NPP	NSP	SWP	APH	NPB	YPP	YTH	SYP	PYP	WHS	SLP	PIC
1	T1	66.78	44.22	45.00	61.67	17.33	29.03	22.08	4.34	3.65	62.01	3.64	6.13	12.28	180.67	297.00	23.33	50.33	3.17
2	T2	70.56	42.78	43.33	65.67	21.67	28.67	21.75	4.67	4.20	60.10	3.40	7.24	15.61	189.67	345.33	25.00	50.33	3.37
3	T3	69.56	44.56	44.67	64.33	17.33	26.82	23.17	4.25	3.81	59.57	3.43	5.70	15.28	178.33	346.33	25.33	48.33	3.57
4	T4	69.22	43.86	43.00	63.67	19.00	27.53	21.80	4.26	4.62	57.76	3.75	5.60	13.19	179.00	342.67	27.67	50.33	3.17
5	T5	70.29	45.68	45.33	65.00	19.00	28.47	21.49	4.28	4.38	58.53	2.98	5.40	11.56	176.00	351.39	28.33	47.67	3.27
6	T6	68.84	46.48	44.00	62.33	19.33	28.68	23.10	4.68	4.05	56.67	3.96	5.85	15.08	179.67	352.67	25.00	50.00	3.04
7	T7	67.56	43.17	45.67	66.00	19.67	26.77	21.80	4.12	3.90	62.98	3.64	5.99	12.93	185.33	348.05	29.33	51.00	3.17
8	T8	71.40	44.44	44.33	60.33	20.00	28.47	24.00	4.29	3.72	66.77	2.98	5.97	13.62	193.00	347.72	27.67	50.00	3.27
	Mean	69.27	44.39	44.41	63.62	19.16	**28.05**	**22.39**	**4.36**	**4.04**	**60.54**	**3.47**	**5.98**	**13.69**	**182.70**	**341.39**	**26.45**	**49.74**	**3.25**
	SEm	0.93	1.20	1.69	1.80	1.04	0.99	1.08	0.32	0.39	1.95	0.28	0.43	0.77	4.02	2.35	1.26	1.15	0.24
	CD at 5%	2.83	3.64	5.12	5.47	3.16	3.00	3.27	0.98	1.19	5.94	0.85	1.30	2.33	12.21	7.15	3.82	3.50	0.75

Characters: GPR: Germination Percentage Rate, **DFF**: Days to First Flowering, **DFPF**: Days to 50% Flowering, **PDL**: Pod Length, **PDW**: Pod Width, **PDG**: Pod Girth, **NPP**: Number of Pods per Plant, **NSP**: Number of Seeds per Pod, **SWP**: Seed Weight per Pod, **APH**: Average Plant Height, Number of Primary Branches per Plant, **YPP**: Yield per Plot , **YTH**: Yield per Hectare, **SYP**: Seed Yield per Plant, **PYP**: Pod Yield per Plant, **WHS** (Weight of 100 seed), **SLP** (Shelling percentage of pea), **PIC** (Number of pickings).

The Number of seeds/Pod ranged from 4.12mm to 4.68mm highest. The overall mean was 4.36 mm. The highest number of seeds/ Pod was found in 60% RDN through Urea + 40% N through Nano Urea (4.68 mm) followed by 100% N through Nano Urea (4.67 mm) and Control (4.34 mm). The lowest number of seeds/Pod was found in 50% RDN through Urea + 50% N through Nano Urea (4.12 mm). Seed weight ranged from 3.65g to 4.62g. The maximum seed weight/ pod found in 80% RDN through Urea + 20% N through Nano Urea (4.62g) followed by 70% RDN through Urea + 30% N through Nano Urea (4.38g) and 100% N through Nano Urea (4.20g). The minimum seed weight/ pod found in Control (3.65g). Plant height ranged from 56.67cm to 66.77cm. The highest plant height found in 40% RDN through Urea + 60% N through Nano Urea (66.77cm) followed by 50% RDN through Urea + 50% N through Nano Urea (62.98 cm) and Control (60.01cm). The lowest plant height found in 60% RDN through Urea + 40% N through Nano Urea (56.67cm). The number of primary branches/ plants ranged from 2.98 to 3.96 highest. The overall mean was 3.47. The highest number of primary branches/ plants was found in 60% RDN through Urea + 40% N through Nano Urea (3.96) followed by 80% RDN through Urea + 20% N through Nano Urea (3.75), Control (3.64) and 50% RDN through Urea + 50% N through Nano Urea (3.64). The lowest number of primary branches/ plants was observed in both 70% RDN through Urea + 30% N through Nano Urea (2.98) and 40% RDN through Urea + 60% N through Nano Urea (2.98). Yield/plot ranged from 5.40 kg to 7.24 kg highest. Over all mean was 5.98 kg. The highest yield/plot was found in 100% N through Nano Urea (7.24 kg) followed by Control (6.28 kg), 50% RDN through Urea + 50% N through Nano Urea (5.99 kg)). The lowest value of yield/plot was observed in 70% RDN through Urea + 30% N through Nano Urea (5.40 kg). Yield (t/ha) ranged from 11.56 t to 15.61 t highest. Overall mean was 13.69. The highest yield (t/ha) was found in 100% N through Nano Urea (15.61 t) followed by 90% RDN through Urea + 10% N through Nano Urea (15.28 t), 60% RDN through Urea + 40% N through Nano Urea (15.08 t). The lowest yield (t/ha) observed in 70% RDN through Urea + 30% N through Nano Urea (11.56 t). Seed yield / plant ranged from 176.00g to 193.00 g highest. Overall mean was 182.70 g. The highest seed yield/plant was found in 40% RDN through Urea + 60% N through Nano Urea (193.00 g) followed by 100% N through Nano Urea (189.67 g) and 50% RDN through Urea + 50% N through Nano Urea (185.33 g). The lowest seed yield observed in 70% RDN through Urea + 30% N through Nano Urea (176.00 g). Pod yield /plant ranged from 297.00 g to 352.67 g highest. Overall mean was

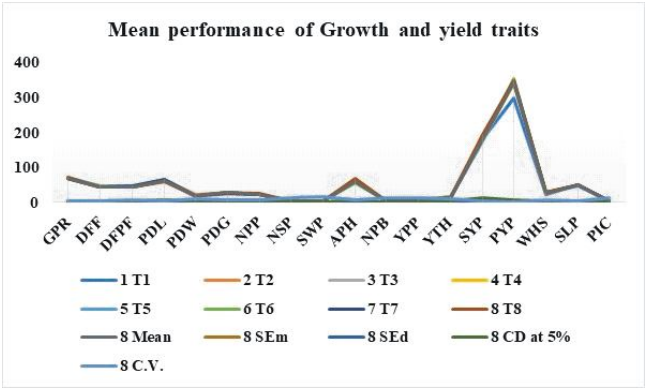

Fig. 1 : Graphical representation of growth and yield traits of pea (*Pisum sativum* L).

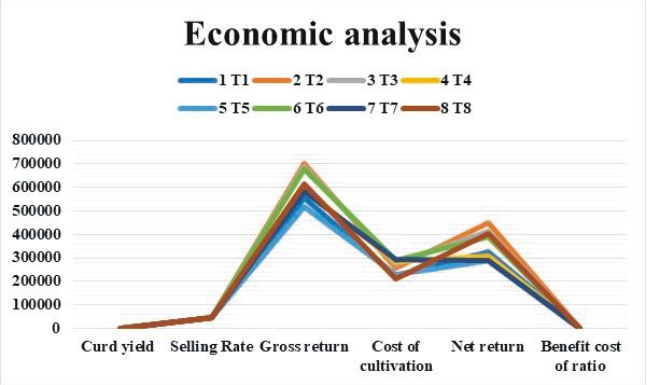

Fig. 2 : Graphical representation of economic analysis of pea (*Pisum sativum* L).

341.39 g. The highest pod yield/plant was found in 60% RDN through Urea + 40% N through Nano Urea (352.67 g) followed by 70% RDN through Urea + 30% N through Nano Urea (351.39 g) and 50% RDN through Urea + 50% N through Nano Urea (348.05 g). The lowest pod yield observed in control (297.00 g). Weight of 100 seed ranged from 23.33 g to 29.33 g. The mean was 26.45 g. The maximum weight of 100 seed found in 50% RDN through Urea + 50% N through Nano Urea (29.33 g) followed by 70% RDN through Urea + 30% N through Nano Urea (28.33g) and both 80% RDN through Urea + 20% N through Nano Urea (27.67 g), 40% RDN through Urea + 60% N through Nano Urea. The minimum weight of 100 seed found in Control (23.33g). Shelling percentage ranged from 51.00 to 47.67. Overall mean was 49.74. The maximum shelling percentage was found in 50% RDN through Urea + 50% N through Nano Urea (51.00) followed by Control (50.33), 100% N through Nano Urea (50.33) and 80% RDN through Urea + 20% N through Nano Urea (50.33). The minimum shelling percentage was found in 70% RDN through Urea + 30% N through Nano Urea (47.67). Number of pickings ranged from 3.04 to 3.57. Overall mean was 3.25. The maximum number of pickings found in 90% RDN through Urea +

Table 3 : Mean performance of economic cultivation of pea (*Pisum sativum* L.).

Treatment	Curd yield	Selling Rate	Gross return	Cost of cultivation	Net return	Benefit cost of ratio
	t/ha	Rs/ton	Rs/ha	Rs/ha	Rs/ha	
T_1	12.28	45000	552450.00	226561.00	325889.00	1.44
T_2	15.61	45000	702600.00	254952.00	447648.00	1.76
T_3	15.28	45000	687450.00	274565.30	412884.70	1.50
T_4	13.19	45000	593550.00	284648.00	308902.00	1.08
T_5	11.56	45000	520050.00	230183.30	289866.70	1.27
T_6	15.08	45000	678600.00	287489.30	391110.70	1.36
T_7	12.93	45000	582000.00	293856.70	288143.30	0.98
T_8	13.62	45000	612750.00	210183.30	402566.70	1.90

10% N through Nano Urea (3.57) followed by 100% N through Nano Urea (3.37), 70% RDN through Urea + 30% N through Nano Urea (3.27) and 40% RDN through Urea + 60% N through Nano Urea (3.27). The minimum number of pickings found in 60% RDN through Urea + 40% N through Nano Urea (3.04) (Table 2).

Economic studies on treatment applications are crucial for farmers, as they prioritize monetary returns and profitability when choosing crop recommendations and adopting specific agricultural practices. Therefore, assessing the economic viability of various treatments is essential to determine the best approach. Desired traits include higher gross returns, lower cultivation costs, and favorable benefit-cost ratios. In this study, the economics of different treatments for pea cultivation were evaluated based on the cost of cultivation (` per hectare), gross returns (` per hectare), net returns (` per hectare), and benefit-cost ratio (B). The relative economic performance of each treatment is summarized in Table 3. Cost of cultivation ranged from 210183.30 Rs/ha 293856.70 Rs/ha. The overall mean was 257804.90 Rs/ha. The highest cost of cultivation was recorded in 50% RDN through Urea + 50% N through Nano Urea (293856.70 Rs/ha). However, the lowest cost of cultivation was observed in 40% RDN through Urea + 60% N through Nano Urea (210183.30 Rs/ha). Gross income (Rs/ha) ranged from 520050.00 Rs/ha to 702600.00 Rs/ha highest. The overall mean was 616181.30 Rs/ha. The highest gross income (Rs/ha) was recorded in 100% N through Nano Urea (702600.00 Rs/ha). The lowest gross income (Rs/h) observed in 70% RDN through Urea + 30% N through Nano Urea (520050.00 Rs/ha). Net returns (Rs/ha) ranged from 288143.30 Rs/ha to 447648.00 Rs/ha. The overall mean was 358376.40 Rs/ha. The highest net returns (Rs/ha) was recorded in 100% N through Nano Urea (447648.00 Rs/ha). The lowest net returns (Rs/ha) observed in 70% RDN through Urea + 30% N through Nano Urea (289866.70 Rs/ha). Benefit cost-ratio ranged from 0.98 to 1.90 highest. The overall mean was 1.41. The highest benefit cost-ratio was found in 40% RDN through Urea + 60% N through Nano Urea (1.90) followed by 100% N through Nano Urea (1.76) and 90% RDN through Urea + 10% N through Nano Urea (1.50). The lowest benefit cost-ratio observed in 50% RDN through Urea + 50% N through Nano Urea (0.98).

Discussion

This study's findings align with previous research highlighting the advantages of Nano Urea in enhancing crop growth and yield. Verma *et al*. (2023) observed that Nano Urea positively influenced pea growth and production qualities during the Rabi season. Kumar *et al*. (2020) also reported improvements in onion growth and production due to Nano Urea. These studies support the notion that Nano Urea can be a beneficial alternative to traditional urea.

The observed improvements in pea growth and yield attributes in our study can be attributed to Nano Urea's superior nutrient use efficiency. Nano Urea's smaller crystal size facilitates better nutrient absorption by plants, leading to enhanced nitrogen utilization and minimized loss (Guo *et al*., 2018). Additionally, Nano Urea has been shown to bolster stress management in plants, which is particularly valuable in areas like Gwalior where weather conditions can be unpredictable (Jadon *et al*., 2018).

The results application of 100% nitrogen in the form of urea top dressing at vegetative stage and foliar spray of nano urea twice at flowering and seed filling stages significantly improved the physiological parameters viz. plant height (cm), primary branches of safflower (Gayathri *et al*., 2023). Same findings were observed according to Hossain *et al*. (2023), about the effects of various forms

of nitrogen (urea) on yield and characteristics that contribute to yield are significant. The highest grain yield was produced. It was evident that nano urea as a foliar spray during rapid growth stages could greatly increase seed yield and potentially aid other legume crops in increasing their yield as well. Similarly, Subramani *et al*. (2023) revealed that nano spray resulted in higher okra yield (9.6%) than NPK addition through chemical fertilizers. While increased concentration of nano spray (4%) had significant impact on the growth and yield parameters due to increased availability of N within the plant system.

Our study also identified that combining Urea with Nano Urea significantly impacted pea growth and yield attributes. Specifically, an optimal blend of 40% Urea and 60% Nano Urea resulted in the most favorable yield and growth attributes. This suggests that partial substitution of traditional urea with Nano Urea could effectively boost pea production in Gwalior.

The cost of cultivation is function of all input cost used during production of Arkel variety of Pea. It is sum of fixed and variable cost. The selling rate was 45000 Rs/ton. The greater cost of cultivation in T_7, T_6 and T_4. The highest Gross income (Rs/ha) was recorded in T_2 (702600.00 Rs/ha). The highest Net income (Rs/ha) was recorded in T_2 (447648.00 Rs/ha). The highest benefit cost-ratio was found in T_8 (1.90). The lowest benefit cost-ratio observed in T_7 (0.98). Therefore, three treatments, T_8, T_2, T_3 can be recommended for commercial cultivation of Arkel variety of pea. Urea as a supplementary dose with RDF is highly remunerative for Arkel variety of pea cultivation.

Previous research also supports our results. Sathyan (2022) found the significant impact on yield and its attributes while higher number of pods/plants, pod length, number of seeds/pod, fresh weight/ plant, pod yield, stover yield and harvest index was noticed. Economics like higher gross returns, net returns and B:C ratio was observed in sesame.

Conclusion

Based on the findings of the present investigation, it can be concluded that the combined application of 100% N through Nano urea can be considered as best growing media of all treatments obtain maximum yield good quality pea (*Pisum sativum* L.) in economically profitable manner. However, application of 100% N through Nano Urea increases the growth of the plant, maintain the quality of plant.

The cost of cultivation is function of all input cost used during production of Arkel variety of Pea. It is sum of fixed and variable cost. The selling rate was 45000 Rs/ton. The greater cost of cultivation in T_7, T_6 and T_4. The highest Gross income (Rs/ha) was recorded in T_2 (702600.00 Rs/ha). The highest Net income (Rs/ha) was recorded in T2 (447648.00 Rs/ha). The highest benefit cost-ratio was found in T_8 (1.90). The lowest benefit cost-ratio observed in T_7 (0.98). Therefore, three treatments, T_8, T_2, T_3 can be recommended for commercial cultivation of Arkel variety of pea. Urea as a supplementary dose with RDF is highly remunerative for Arkel variety of pea cultivation. According to the study, yields of Arkel have increased dramatically (15.61 t/ha) when 100% nano urea is applied during vegetative growth stages, compared to farmers' practices or controls. Therefore, it can be suggested to apply nano urea foliar application to increase pea production and it is possible to do additional research to get more practical results in future.

The results from this study demonstrate that Nano Urea significantly improves the growth and yield parameters of pea plants compared to traditional urea and no fertilizer treatments. The enhanced efficiency of nutrient delivery in Nano Urea likely contributed to these improvements. This aligns with previous findings on the benefits of nano-fertilizers in enhancing crop performance and sustainability in agricultural practices. Nano Urea has shown considerable promise in improving the growth and yield of pea plants. The findings suggest that Nano Urea could be a viable, sustainable alternative to traditional urea, offering benefits in terms of both productivity and environmental impact. Further research should focus on optimizing application rates and assessing long-term soil health impacts.

Acknowledgement

The authors thank Department of Horticulture, School of Agriculture, ITM University, Gwalior (MP) for providing the required materials and research lab/field for the conduct of research trial. Authors thank Prof. (Dr.) Chandra Kant Sharma for technical support and providing vital resources during the development of this MS.

References

Anonymous (2019). *International Rules for Seed Testing*. ISTA (International Seed Testing Association), Geneva, Switzerland.

Ditta, A. (2012). Nano fertilizers in sustainable agriculture: Advantages and limitations. *Environ. Sci. Poll. Res.*, **19(4)**, 2012-2021.

Gayathri, P.A., Ghuge S.B., Shinde S.A., Mahesh S. and Pawar A.V. (2023). Study of Nitrogen Rates and Nano Urea Effects on Physiological Parameters and Yield of Safflower

(*Carthamus tinctorius* L.). *Int. J. Environ. Climate Change*, **13(10)**, 3974-3981.

Guo, J., Zhang W., Li H. and Wang X. (2018). Nano-urea: A novel fertilizer for improving nitrogen use efficiency. *J. Agricult. Sci.*, **156(3)**, 431-441.

Hossain, M.E., Begum S., Hoque M.M., Islam M.M. and Shahed M. (2023). Foliar Application of Nano Urea on Growth and Yield of Binamash-3 (*Vigna mungo* L). *J. Agroforest. Environ.*, **16(2)**, 131-133.

Jadon, S., Verma P., Sharma A. and Singh R. (2018). Nano-urea: A potential fertilizer for reducing nitrogen pollution. *J. Environ. Sci. Hlth.*, Part B, **53**, 439-447.

Kumar, R., Sharma V., Gupta S. and Chauhan R. (2020). Effect of nano-urea on growth and yield of onion (*Allium cepa* L.). *J. Agricult. Sci.*, **158(2)**, 241-248.

Moaveni, P. and Kheiri S. (2011). Effects of nano-iron and nano-zinc on growth and yield of wheat. *J. Agricult. Sci.*, **149(2)**, 231-238.

Naderi, Mohammad Reza and Danesh-Shahraki Akbar (2013). Effects of nano-fertilizers on growth and yield of crops. *J. Agricult. Sci.*, **151(2)**, 239-247

Sahu, S.K., Patel R., Choudhary A. and Yadav D. (2022). Nano-urea: A novel fertilizer for improving crop productivity and reducing environmental pollution. *J. Agricult. Sci.*, **160(1)**, 1-9.

Salama, Diaa M., El-Ghamry Ayman M., Dawood Mahmoud G. and El-Awadi Mohamed E. (2021). Effect of nano-urea on growth and yield of pea (*Pisum sativum* L.). *J. Agricult. Sci.*, **159(2)**, 241-248.

Sathyan, Thiruvenkatam (2022). Environmental impact of conventional urea fertilizers: A review. *J. Environ. Sci. Hlth.*, Part B, **57**, 1-11.

Subramani, T., Velmurugan A., Bommayasamy N., Swarnam T.P., Ramakrishna Y., Jaisankar I. and Singh L. (2023). Effect of Nano Urea on growth, yield and nutrient use efficiency of Okra under tropical island ecosystem. *Int. J. Agric. Sci.*, **19**, 134-139.

Verma, Sanjay Kumar, Singh Praveen, Mishra Abhishek and Yadav Jitendra (2023). Effect of nano-zinc and nano-urea on growth and yield of pea (*Pisum sativum* L.). *JJ. Agricult. Sci.*, **161(1)**, 1-8.

V, Panes, V.G. and Sukhatme P.V. (1967). *Statistical methods for Agricultural workers*. I.C.A.R., New Delhi.