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Effect of foliar spray of nano urea on growth parameters, quality attributes and yield of linseed

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Abstract
A field experiment was conducted during *rabi* season of 2021-2022 to study the effect of different doses and application methods of nitrogenous fertilizer on growth and quality parameter, economics and yield of linseed. The experiment was laid out in Split plot Design with main plot treatments consisting of soil application of 100% (N_1), 75% (N_2), 50% (N_3) and 25% (N_4) N in two splits 50% as basal application and 50% as top dressing and subplot treatments consisting of foliar application of different doses of nitrogenous fertilizers as follows, F_1 – Water spray, F_2 – One spray of nano-urea @ 3 ml/lit at flower initiation stage, F_3 – Two sprays of nano-urea @ 3 ml/lit at flower initiation and capsule development stage, F_4 – One spray of 2% Urea at flower initiation stage and F_5 – Two sprays of 2% Urea at flower initiation and capsule development stage as foliar application. Soil application of 100% N (N_1) and supplemental nitrogen management with foliar application of two sprays of nano-urea @ 3 ml/lit at flowering stage and capsule developmental stage (F_3) was found to record significantly highest seed and straw yield, BC ratio, plant height, dry matter accumulation, Oil yield compared to the rest of the treatments.

Keywords: Dry matter accumulation, foliar application, linseed, nano-urea, oil content

Introduction

India is one of the leading oilseeds growing country in the world and fourth largest vegetable oil economy next to USA, China and Brazil. Linseed (*Linum usitatissimum* L.) is India's most important oilseed crop, ranking second after to rapeseed-mustard in terms of acreage and production. It is important industrial, edible oil, and fibre crop on account of the oil derived from its seed and the stem fibre. It is high in oil (41%), protein (20%), and dietary fibre (28%). Linseed is an important Rabi crop chiefly grown under rainfed (63%), utera (25%) and irrigated (12%) conditions (Dash *et al*., 2017) [1]. Research evidences show that linseed yield is determined by the ability of plants to accumulate dry matter during the vegetative period (Aufhammer *et al*., 2000; Hassan and Leitch 2000) [2, 10].

Nitrogen is required for the synthesis of several growth promoting enzymes, proteins and so plays an important role in plant growth regulation, particularly during the vegetative phase (Iqbal, 2019) [11]. Agricultural use of inorganic fertilizers in 2019 was about 190 million tonnes of nutrients, of which 57% was nitrogen (FAO, 2021) [7]. So, optimum fertilizer management and application timing based on the crop need or when water is available to enhance nutrient uptake, can be a suitable strategy to improve crop growth and yield (Corbellini *et al*., 2006) [4]. Some studies have reported that, compared to single application, split application of nitrogen depending on initial soil status is beneficial for improving crop growth and yield as well as improving the efficiency of nitrogen utilization. The controlled release of nutrients provided by nanostructured fertilizers will allow for a longer effective duration of nutrient supply to the plant ensuring without any negative environmental consequences (Kopittke *et al*., 2019) [13].

Nanomaterials are defined as materials with a single unit in at least one dimension that is between 1 and 100 nm (Lal and Liu, 2014) [14] and had a dual positive and negative charge on the same particle, which enhanced the intake of additional nutrients by protecting them from various

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losses in the soil. In order to improve crop growth, yield, and quality metrics while lowering fertiliser waste and cultivation expenses, nano fertilisers are essential tools in agriculture. Nanotechnology can reduce soil and water pollution by slowing down the rate at which nutrients from fertilisers leach down and increasing their availability to plants. Present-day nano fertilisers begin to appear as a substitute for conventional fertilizers (Veronica *et al*., 2014) [23].

Materials and Methods

A field experiment was conducted at Western Section of Research Farm of Birsa Agricultural University, Kanke, Ranchi (23º317'N, 85º19'E, 625 m above mean sea-level) during the *rabi* seasons of 2021–22 and 2022-23. The climate of site is sub-humid with hot summer and cold winter. Mean monthly maximum temperature and pan-evaporation was recorded highest in April during the year, whereas, the mean monthly minimum temperature was the lowest in December. An average amount of 23 mm rainfall received during cropping period. Initial status of soil (0–15 cm) of experimental field was sandy loam (61.3% sand, 22.5% silt and 16.2% clay) in nature, low in organic carbon (0.42%) and available nitrogen (227 kg N/ha), high in available phosphorus (36 kg P/ha), medium in available potassium (160.2 kg K/ ha) and neutral in soil reaction (pH 5.80). The experiment was laid out in a Split Plot design with 2 replications. In the main plot, 4 Nitrogen management practices (50%N as basal+50% as top dressing at 20 DAS), viz. 100% N (N_1); 75% N(N_2); 50% N(N_3) and 25% (N_4) while five nitrogen management through nano-urea, viz. water spray (F_1); One spray of nano-urea @ 3 ml /litre of water at flower initiation stage (F_2), Two sprays of nano-urea @ 3 ml /litre of water at flower initiation and and capsule development stage (F_3),One spray of 2% urea at flower initiation stage (F_4) and Two sprays of 2% urea at flower initiation and capsule development stage (F_5) were taken in sub-plots. Linseed variety "Priyam" was seeded directly using 25 kg seed per ha in rows spaced at 30 cm on 18th November 2021 after basal application of fertilizer. Recommended dose of chemical fertilizer 30 kg N + 20 kg P_2O_5 + 20 kg K_2O/ha was applied through urea, diammonium phosphate and muriate of potash respectively.

Oil content in seed (%)

Oil content in seed was estimated by Granolyser (manufactured by pfeuffer GmbH, Flugplatzstraβe 70,97318 Kitzingen, Germany).

Oil yield (kg/ha)

Oil yield was obtained from oil content multiplied by seed yield and expressed in kg per hectare.

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil content (\%) in seed x seed yield (kg/ha)}}{100}$$

Statistical analysis

The data recorded for different characteristics were subjected to statistical analysis by adopting the method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984) [8]. The significance of comparison was tested. The significant difference values were computed for a 5 percent probability of error. Wherever the variance ratio (F value) was found significant, critical difference (CD) values were computed for the comparison among the treatment means.

Results and Discussion

Plant population

The initial plant population recorded at 20 DAS and maturity recorded maximum plant population with the application of 100% Nitrogen *viz.* 128/m^2 and 117/m^2, respectively. Slightly more number of plant/m^2 was recorded with the F_3 application i.e., two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage at initial (126/m^2) and at maturity (115/m^2). As there was no application of fertilizer before sowing that would be the reason for no variation in any treatment. These results confirm the prior observation made by Gudeta (2015) [9] and Patel *et al.* (2017) [19].

Plant height

Plant height gradually increased with each stage of crop development. Data analysis revealed that plant height increased with crop age, but notable increases were only seen between 30 and 60 DAS and peaked at harvest. There was no significant difference in the plant's height at 30 DAS. It was found that several treatments had a significant impact on plant height at 60, 90 DAS, and during harvest.

Plant height was found maximum with the application of 100% of the recommended Nitrogen dose (N_1) followed by the application of 75% Nitrogen (N_2) and 50% of N. The plant height was found to be lowest with 25% of Nitrogen at 30, 60, 90 DAS and at maturity. Meena *et al.* (2023) [15] concluded a notable residual effect on the growth indices of mustard when grown under 100% RDN. Similar conclusion was also drawn by Sujatha and GangadharaRao (2019) [21].

Among different foliar applications two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage (F_3) resulted in maximum plant height and the minimum plant height was observed with the application of water spray(F_1).The probable reason may be due to the use of nano nitrogenous fertilizer could contribute to the growth of plants by reducing Nitrogen losses, enhancing nutrient use efficiency, and providing balanced crop nutrition tailored to the crop's growth period, which increase plant height. Recent studies conducted by Midde *et al.* (2022) [16] have suggested that when applied as a foliar spray, nano-Nitrogen fertilizer can be rapidly absorbed by plants.

Dry matter accumulation (g/plant)

As the crop grew, the dry matter increased and reached it's peak at harvest. Plant dry matter accumulation was significantly affected by various Nitrogen levels and foliar sprays. Highest dry matter accumulation was found in 100% RDN (N_1) succeeded by 75% RDN (N_2) and 50% RDN (N_3). Least dry matter was found with the application of 25% RDN. These findings confirm with the findings of Navya *et al.* (2022) [18] and Meena *et al.* (2023) [15].

The highest dry matter accumulation was observed when the plants were treated with two sprays of Nano-urea at a rate of 3 ml per litre of water for each application at 30, 60, 90 DAS (Days After Sowing) and at maturity. These sprays were administered during the flower initiation stage and the capsule development stage (F_3), followed by one spray of Nano-urea @ 3 ml /litre of water at flower initiation stage (F_2) and two sprays of 2% urea at flower initiation and capsule development stage (F_5), while the lowest dry matter accumulation was observed with treatment F_1 i.e., water spray. The application of nano-Nitrogen through foliar spraying may have led to an increase in the dry weight of the plant, possibly due to improved growth and increased branch development. This could have resulted in higher levels of photosynthetic activity and the production of more photosynthate. Nitrogen is essential for the metabolic processes that led to the accumulation of dry matter in plants. These results were consistent with previous studies conducted by Nathan *et al.* (2018) [17] and Varsha *et al.* (2020) [22].

Seed yield and economics
A perusal of data presented in Table 4 revealed that application of 100% nitrogen resulted in the highest seed yield (1442.21 kg/ha), straw yield (2652.06 Kg/ha) and BC ratio (1.71) among the various nitrogen levels tested, which were comparable to treatment applied with 75%N. The lowest seed yield (880.12 Kg/ha), straw yield (1810.52 Kg/ha) and BC ratio (0.04) was observed with application of 25% nitrogen. However, harvest index was found to be non-significant. There are several factors that directly or indirectly influence yield and BC ratio. Directly, the main factors are the number of capsules per plant, the number of seeds per capsule, test weight in grams, and test weight per plant in grams. Indirectly, growth attributes such as dry matter production per plant and its distribution to various plant parts can also influence yield and ultimately BC ratio. This observation is consistent with studies conducted by Sujatha and GangadharaRao (2019) [21] and Navya *et al.* (2022) [18].

Quality analysis
Nutrient management practices through soil application showed significant impact on oil yield. Treatment N_1 i.e., application of 100% Nitrogen recorded significantly highest oil yield. These findings are in line with Singh *et al.* (2010) [20] and khule (2022) [12].

The highest oil yield was obtained with F_3 i.e., two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage followed by F_2- one spray of Nano-urea @ 3 ml /litre of water at flower initiation stage and F_5- two sprays of 2% urea at flower initiation and capsule development stage. The increase in oil content and oil output was caused by the creation of amino acids like methionine and the conversion of carbohydrates into oil, which eventually boosted oil production. This might be the cause of the rise in output of linseed oil and content. The findings of Dohat *et al.* (2017) [6] and Bonde and Gawande (2017) [3] were in line with the above discussed results.

Table 1: Effect of Nitrogen management practices on Plant population/m^2 of linseed (2021-2022)

Treatments	Plant population/m^2	
	20 DAS	At harvest
A. Nitrogen management (50%N as basal+50% as top dressing at 20 DAS)		
N_1:100%N	128	117
N_2:75%N	126	117
N_3:50%N	124	112
N_4:25%N	121	112
SEm±	2.08	1.22
CD(P=0.05)	NS	NS
B. Nitrogen management through Nano-urea		
F_1: Water spray	124	114
F_2: One spray of Nano-urea @ 3 ml /litre of water at flower initiation stage	125	115
F_3: Two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage	126	115
F_4: One spray of 2% urea at flower initiation stage	124	114
F_5: Two sprays of 2% urea at flower initiation and capsule development stage	124	114
SEm±	5.99	3.53
CD (P=0.05)	NS	NS
CV (%)	13.59	8.71
C. Interaction (AXB)	NS	NS

Table 2: Effect of Nitrogen management practices on Plant height of linseed (2021-2022)

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Maturity
A. Nitrogen management (50%N as basal+50% as top dressing at 20 DAS)				
N1:100%N	13.95	41.88	49.43	50.26
N2:75%N	13.43	39.88	46.58	47.26
N3:50%N	12.39	35.85	40.86	41.25
N4:25%N	10.85	29.83	32.29	33.23
SEm±	0.57	0.43	0.43	0.43
CD(P=0.05)	NS	1.94	1.92	1.91
B. Nitrogen management through Nano-Urea				
F1: Water spray	11.89	35.90	40.15	40.70
F2: One spray of Nano-urea @ 3 ml /litre of water at flower initiation stage	13.06	37.02	44.58	45.16
F3: Two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage	13.10	38.14	44.77	45.82
F4: One spray of 2% urea at flower initiation stage	12.32	36.29	40.81	41.37
F5: Two sprays of 2% urea at flower initiation and capsule development stage	12.92	36.93	41.15	41.95
SEm±	0.46	1.21	1.19	1.21
CD (P=0.05)	NS	NS	3.56	3.64
CV (%)	10.26	9.27	7.95	7.98
C. Interaction (AXB)	NS	NS	NS	NS

Table 3: Effect of Nitrogen management practices on dry matter accumulation of linseed (2021-2022)

Treatments	Dry matter accumulation (g/plant)			
	30 DAS	60 DAS	90 DAS	Maturity
A. Nitrogen management (50%N as basal+50% as top dressing at 20 DAS)				
N1:100%N	0.81	1.59	3.59	3.74
N2:75%N	0.75	1.55	3.43	3.59
N3:50%N	0.62	1.25	2.99	3.28
N4:25%N	0.44	0.94	2.31	2.56
SEm±	0.03	0.05	0.11	0.14
CD (P=0.05)	0.14	0.24	0.50	0.61
B. Nitrogen management through Nano-urea				
F1: Water spray	0.63	1.27	2.78	2.92
F2: One spray of Nano-urea @ 3 ml /litre of water at flower initiation stage	0.67	1.37	3.28	3.42
F3: Two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage	0.69	1.39	3.23	3.62
F4: One spray of 2% urea at flower initiation stage	0.64	1.28	3.08	3.23
F5: Two sprays of 2% urea at flower initiation and capsule development stage	0.65	1.34	3.01	3.28
SEm±	0.02	0.04	0.10	0.11
CD (P=0.05)	NS	NS	0.29	0.32
CV (%)	8.36	7.88	8.90	9.16
C. Interaction (AXB)	NS	NS	NS	NS

Table 4: Effect of different doses of nitrogenous fertilizer and application methods on seed, straw yield, harvest index, BC ratio and NUE of linseed during *rabi* 2021-2022

Treatments	Yield (kg/ha)		Harvest Index (%)	BC ratio
	Seed	Straw		
A. Nitrogen level				
N1:100%N	1442.21	2652.06	35.24	1.71
N2:75%N	1365.88	2571.70	34.59	1.58
N3:50%N	1167.79	2277.72	33.96	1.23
N4:25%N	880.12	1810.52	32.63	0.70
SEm±	22.48	46.46	0.81	0.04
CD (P=0.05)	101.17	209.08	3.65	0.17
B. Foliar nitrogen management practices				
F1: Water spray	1083.83	2160.61	33.07	1.10
F2: One spray of nano-urea @ 3 ml /litre of water at flower initiation stage	1269.58	2401.09	34.58	1.39
F3: Two sprays of nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage	1364.86	2507.44	35.16	491.
F4: One spray of 2% urea at flower initiation stage	1156.54	2260.45	33.68	1.24
F5: Two sprays of 2% urea at flower initiation and capsule development stage	1195.17	2310.43	34.04	1.30
SEm±	32.78	65.99	0.86	0.06
CD (P=0.05)	98.27	197.85	2.59	0.17

Table 5: Effect of Nitrogen management practices on Oil content (%) and Oil yield (Kg/ha) of linseed (2021-2022)

Treatments	Oil content (%)	Oil yield (Kg/ha)
A. Nitrogen management (50%N as basal+50% as top dressing at 20 DAS)		
N_1:100%N	38.23	577.54
N_2:75%N	37.91	545.46
N_3:50%N	36.70	463.64
N_4:25%N	35.72	344.67
SEm±	1.91	32.04
CD(P=0.05)	NS	144.17
B. Nitrogen management through Nano-urea		
F_1: Water spray	36.93	418.28
F_2: One spray of Nano-urea @ 3 ml /litre of water at flower initiation stage	37.37	516.68
F_3: Two sprays of Nano-urea @ 3 ml /litre of water each at flower initiation stage and capsule development stage	37.40	556.13
F_4: One spray of 2% urea at flower initiation stage	36.98	448.29
F_5: Two sprays of 2% urea at flower initiation and capsule development stage	37.02	474.78
SEm±	1.11	19.09
CD (P=0.05)	NS	57.23
CV%	8.42	11.18
C. Interaction (AXB)	NS	NS

Conclusion

In conclusion, the study evaluated the effects of different nitrogen management practices and foliar applications on various growth parameters and yield components of linseed. It was observed that higher nitrogen application levels, particularly 100% of the recommended dose, resulted in increased plant population, height, dry matter accumulation, seed yield, straw yield, and beneficial cost ratio (BC ratio). This treatment also significantly influenced oil yield and quality parameters, indicating its positive impact on overall crop productivity and economic returns. Conversely, lower nitrogen levels showed reduced performance across these parameters. Additionally, foliar applications, especially F3 with nano-urea, demonstrated promising results in enhancing plant growth and oil yield, likely due to improved nutrient uptake efficiency and metabolic processes. These findings underscore the importance of strategic nutrient management practices in optimizing linseed production and quality, aligning with previous research in the field. Future studies could further explore the specific mechanisms through which nano-urea applications enhance crop performance, thereby refining agricultural practices for sustainable linseed cultivation.

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