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Assessment of foliar application of nano urea on growth and yield attributes of linseed (*Linum usitatissium* L.)

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Abstract
A field experiment was conducted during *Rabi* 2024 at the Experimental Farm of Oilseeds Research Station, Latur to study the influence of foliar application of Nano Urea on growth and yield of linseed (*Linum usitatissimum* L.). The experiment was laid out in a Randomized Block Design comprising eight treatments viz., T_1-Control, T_2-100% NPK, T_3-100% NPK + 1 F.A. of Nano Urea @0.4% at 40 DAS, T_4-75% RDN + 100% PK + 2 F.A. of Nano Urea @0.4% at 20 and 40 DAS, T_5-75% RDN + 100% PK + 2 F.A. of Nano Urea @0.5% at 20 and 40 DAS, T_6-50% RDN + 100% PK + 2 F.A. of Nano Urea @0.4% at 20 and 40 DAS, T_7-50% RDN + 100% PK + 2 F.A. of Nano Urea @0.5% at 20 and 40 DAS and T_8-100% PK + 3 F.A. of Nano Urea @0.5% at 15, 30 and 45 DAS, each replicated thrice. The results showed that the key growth attributes such as plant height (13.55 cm, 34.17 cm and 37.23 cm at 25, 50 DAS and at harvest), fresh weight (8.76 g at 25 DAS and 42.28 g at 50 DAS) and Dry weight (2.21 g at 25 DAS and 10.55 g at 50 DAS) plant^{-1}, improved with the application of 100% NPK + 1 F.A. of Nano Urea @0.4% at 40 DAS which was found at par with treatment T_4 (75% RDN + 100% PK + two foliar applications of Nano Urea @0.4% at 20 and 40 DAS), T_2 (100% NPK) and T_5 (75% RDN + 100% PK + two foliar applications of Nano Urea @0.5% at 20 and 40 DAS). In terms of productivity, significantly higher number of capsules plant^{-1} (34.93), number of seeds capsule^{-1} (9.18), seed yield (1090.53 kg ha^{-1}) and straw yield (2029.31 kg ha^{-1}) were observed with treatment 75% RDN + 100% PK + two foliar applications of Nano Urea @ 0.4% at 20 and 40 DAS. This performance was found statistically at par with T_3 (100% NPK + one foliar application of Nano Urea @0.4% at 40 DAS), T_2 (100% NPK) and T_5 (75% RDN + 100% PK + two foliar applications of Nano Urea @0.5% at 20 and 40 DAS).

Keywords: Growth, yield, nano urea, linseed, foliar application

Introduction
Linseed (*Linum usitatissimum* L.), commonly known as flaxseed or Alsi, is a significant Rabi oilseed crop cultivated for both oil and fiber. It thrives in temperate and cool climates and is valued for its nutritional richness, including omega-3 and omega-6 fatty acids, lignans, proteins and dietary fiber. Linseed oil comprises key fatty acids such as palmitic, stearic, oleic, linoleic, and linolenic acids, while the seeds also provide essential vitamins (A, B, D, E). Beyond nutrition, linseed has industrial applications in paints, varnishes, inks and biodegradable composites. India ranks third globally in linseed production, with major cultivation areas in Madhya Pradesh, Maharashtra and Uttar Pradesh.

The LSL-93 variety, developed at the Oilseeds Research Station in Latur, is high-yielding, early maturing and disease-resistant, containing 38-39% oil. Nutrient management is crucial for linseed productivity, with nitrogen (N) promoting vegetative growth and seed yield, phosphorus (P) aiding root and reproductive development, and potassium (K) enhancing stress tolerance. However, conventional fertilizers often suffer from nutrient losses due to leaching and volatilization.

Nanotechnology, especially Nano Urea, offers a sustainable alternative. Nano Urea (liquid), containing 4% N, enhances nitrogen use efficiency through better foliar absorption and controlled nutrient release, reducing the need for conventional urea by up to 50%. This results in economic benefits for farmers and lowers environmental impact. Recent studies in India affirm the potential of Nano Urea in boosting linseed yield and quality when applied at key growth stages, supporting its role in sustainable agriculture.

Materials and Methods

The experiment was conducted at the research farm of Oilseeds Research Station, Latur, during *Rabi* season of the year 2024-2025, the variety of linseed used was LSL-93 and the topography of experimental field was uniform and levelled. The soil of the research farm was dark grey to brown in colour and clayey in texture (2:1 smectite type). The soil was moderately calcareous, slightly alkaline (pH 7.75), low in available nitrogen (136.85 kg ha^{-1}), low in phosphorus (10.45 kg ha^{-1}) and high in potassium (414.26 kg ha^{-1}). The experiment implemented in randomized block design (RBD) with a plot size of 3.6×3.6 m², and row-to-row and plant-to-plant distances of 30 cm and 5 cm, respectively. Fertilizers used in this experiment include Urea, SSP by soil application and Nano Urea by foliar application. The seed rate used was 30 kilograms per hectare. Sowing was done by dibbling method. The recommended cultural practices and plant protection measures were taken.

Five plants were randomly selected and tagged from each net plot to record biometric observations at various growth stages. These same plants were later harvested individually for post-harvest analysis. The data collected from various observations were organized into tables and analyzed using analysis of variance (ANOVA).

Results and discussion

Plant height (cm)

The maximum plant heights of 13.55 cm, 34.17 cm and 37.23 cm at 25, 50 DAS and at harvest, respectively, were observed with the application of 100% NPK along with one foliar application (F.A.) of Nano Urea @0.4% at 40 DAS (T_3). However, these plant height values found at par with treatments, T_4 (75% RDN + 100% PK with two foliar applications of Nano Urea @0.4% at 20 and 40 DAS), which recorded plant heights of 32.09 cm at 50 DAS and 35.15 cm at harvest, T_2 (100% NPK), which recorded 31.9 cm at 50 DAS and 34.34 cm at harvest and T_5 (75% RDN + 100% PK with two foliar applications of Nano Urea @0.5% at 20 and 40 DAS), showing 31.79 cm at 50 DAS and 34.2 cm height at harvest. T_1 (absolute control) recorded the lowest plant height, measuring 9.62 cm, 23.82 cm and 26.27 cm at 25 DAS, 50 DAS and at harvest, respectively.

The enhancement in plant height may be due to the soil application of 100% or 75% of the RDN, supplemented with a foliar application of Nano Urea. Nano Urea contains extremely small N particles that are readily absorbed by the plant leaves through stomata, particularly during critical growth stages. At these times, it enhances meristematic activity and promotes cell elongation, directly contributing to greater plant height. These findings align with the results reported by Bhedela *et al.* (2024) [1], Pandav *et al.* (2022) [6] in mustard and Khule *et al.* (2023) [4] in linseed.

Fresh and dry weight (g $plant^{-1}$)

The highest fresh (8.76 g at 25 DAS and 42.28 g at 50 DAS) and dry weight (2.21 g at 25 DAS and 10.55 g at 50 DAS) $plant^{-1}$ of linseed was observed in treatment T_3 (100% NPK + one foliar application of Nano Urea @0.4% at 40 DAS). It was found to be at par with treatments T_4 (75% RDN + 100% PK + two foliar applications of Nano Urea @0.4% at 20 and 40 DAS), T_2 (100% NPK) and T_5 (75% RDN + 100% PK + two foliar applications of Nano Urea @0.5% at 20 and 40 DAS), and all were significantly superior to the remaining treatments. The lowest fresh (4.09 g at 25 DAS and 24.17 g at 50 DAS) and dry weights (1.04 g at 25 DAS and 6.07 g at 50 DAS) were recorded in the control treatment (T_1).

The notable improvement in both fresh and dry weight of linseed plants with the use of Nano Urea in combination with various RDN levels, it enhances plant metabolism, boosts chlorophyll production and supports better photosynthesis. This results in improved vegetative growth and higher biomass accumulation. Similar results were also observed by Khule *et al.* (2023) [4], Ray *et al.* (2025) [8] and Magar *et al.* (2024) [5] in linseed, as well as by Srivastava *et al.* (2022) [10] in maize and Kalita *et al.* (2024) [3] in mustard.

Number of capsules $plant^{-1}$ and No. of seeds $capsule^{-1}$

Treatment T4 (75% RDN + 100% PK + two foliar sprays of Nano Urea @ 0.4% at 20 and 40 DAS) recorded the highest number of capsules per plant, with 8.44 at 50 DAS and 34.93 at harvest. Treatments T_3 (100% NPK + one Nano Urea spray at 40 DAS) and T_2 (100% NPK) also showed high no. of capsules 32.11 for T_3 and 31.46 for T_2 at harvest. Both statistically similar to T_4. The lowest capsule count was noted in the untreated control (T_1), with only 3.46 at 50 DAS and 15.80 at harvest. Similarly, seed count per capsule was highest in T_4 (9.18), followed closely by T_3 (8.75) and T_2 (8.55), with all three statistically at par. The control (T_1) again showed the lowest seed count (6.31). This highlights the positive impact of integrated nutrient management, particularly with Nano Urea foliar applications.

The enhancement in the number of capsules $plant^{-1}$ and seeds $capsule^{-1}$ is largely due to the synergistic effects of balanced nutrient management. Foliar application of N at critical growth stages ensures its timely availability during floral initiation and the development of reproductive structures, promotes better flowering, increased capsule formation and improved seed development**.** Similar results were also obtained by Reddy *et al.* (2023) [9], Khule *et al.* (2023) [4] in linseed crop and Kalita *et al.* (2024) [3], Pandav *et al.* (2022) [6], Parmar *et al.* (2020) [7] in mustard crop.

Seed and Straw yield

Treatment T4 (75% RDN + 100% PK + two foliar sprays of Nano Urea @ 0.4%) recorded the highest seed (1090.53 kg ha^{-1}) and straw yield (2029.31 kg ha^{-1}) of linseed. However, these yields were statistically at par with T_3, T_2 and T_5, which also showed comparable performance. The lowest seed (681.58 kg ha^{-1}) and straw yield (1234.56 kg ha^{-1}) were observed in the control treatment (T_1), which received no nutrient application. This demonstrates the positive impact of integrated nutrient management with Nano Urea on both seed and straw productivity. The significant increase in seed yield and straw yield of linseed through the combined application of RDF and Nano Urea can be attributed to improved N availability, enhanced N use efficiency and better synchronization of vegetative and reproductive growth stages. RDF ensures a strong nutritional foundation, while foliar application of Nano Urea provides timely and efficient N supplementation during critical growth phases and its small particle size ensures quicker absorption and targeted delivery, reducing nutrient loss and promoting higher productivity. The results explained above are in close conformity with the findings of Reddy *et al.* (2023) [9], Harode *et al.* (2024) [2] and Magar *et al.* (2024) [5] in linseed crop.

Table 1: Effect of RDN and foliar application of Nano urea on plant height at 25, 50 DAS and at harvest stage of linseed

Sr. No.	Treatment Details	Plant height (cm)		
		25 DAS	50 DAS	At Harvest
T_1	Control	9.62	23.82	26.27
T_2	100% NPK (RDF)	13.21	31.9	34.34
T_3	100% NPK + 1 F.A. of Nano Urea @ 0.4% at 40 DAS	13.55	34.17	37.23
T_4	75% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	13.27	32.09	35.15
T_5	75% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS	13.15	31.79	34.2
T_6	50% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	12.8	30.99	33.54
T_7	50% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS.	12.29	30.08	32.71
T_8	100% PK + 3 F.A. of Nano Urea @0.5% at 15, 30 and 45 DAS	11.53	27.3	29.37
S.E m±		1.03	0.86	1.12
CD at 5%		NS	2.59	3.35

Table 2: Effect of RDN and foliar application of Nano Urea on fresh and dry weight at 25 and 50 DAS of linseed

Sr. No.	Treatment Details	Fresh weight (g)		Dry weight (g)	
		25 DAS	50 DAS	25 DAS	50 DAS
T_1	Control	4.09	24.17	1.04	6.07
T_2	100% NPK (RDF)	8.25	39.30	2.09	9.85
T_3	100% NPK + 1 F.A. of Nano Urea @ 0.4% at 40 DAS	8.76	42.28	2.21	10.55
T_4	75% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	8.42	40.38	2.13	10.07
T_5	75% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS	8.15	38.57	2.06	9.51
T_6	50% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	7.85	36.27	1.98	9.11
T_7	50% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS.	7.29	33.99	1.85	8.51
T_8	100% PK + 3 F.A. of Nano Urea @0.5% at 15, 30 and 45 DAS	5.78	30.27	1.48	7.61
S.E m±		0.24	1.31	0.05	0.37
CD at 5%		0.72	3.91	0.15	1.10

Table 3: Effect of RDN and foliar application of Nano urea on number of capsule plant^{-1} at 50 DAS and at harvest stage of linseed

Sr. No.	Treatment Details	No of capsules plant^{-1}		No of seeds capsules^{-1}
		50 DAS	At harvest	
T_1	Control	3.46	15.8	6.31
T_2	100% NPK (RDF)	7.77	31.46	8.55
T_3	100% NPK + 1 F.A. of Nano Urea @ 0.4% at 40 DAS	7.81	32.11	8.75
T_4	75% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	8.44	34.93	9.18
T_5	75% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS	7.36	30.07	8.52
T_6	50% RDN +100% PK + 2 F.A. of Nano Urea @ 0.4% at 20 and 40 DAS	5.31	25.06	7.33
T_7	50% RDN + 100% PK + 2 F.A. of Nano Urea @ 0.5% at 20 and 40 DAS.	4.75	23.57	7.12
T_8	100% PK + 3 F.A. of Nano Urea @0.5% at 15, 30 and 45 DAS	4.18	19.95	6.69
S.E m±		0.27	1.29	0.28
CD at 5%		0.81	3.88	0.85

Table 4: Effect of RDN and foliar application of Nano urea on seed yield of linseed crop

Sr. No.	Treatment Details	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	Control	681.58	1234.56
T_2	100% NPK (RDF)	1023.66	1936.72
T_3	100% NPK + 1 F.A. of Nano Urea @0.4% at 40 DAS	1046.8	1998.44
T_4	75% RDN +100% PK + 2 F.A. of Nano Urea @0.4% at 20 and 40 DAS	1090.53	2029.31
T_5	75% RDN + 100% PK + 2 F.A. of Nano Urea @0.5% at 20 and 40 DAS	1013.37	1926.43
T_6	50% RDN +100% PK + 2 F.A. of Nano Urea @0.4% at 20 and 40 DAS	949.07	1831.26
T_7	50% RDN + 100% PK + 2 F.A. of Nano Urea @0.5% at 20 and 40 DAS.	905.34	1754.11
T_8	100% PK + 3 F.A. of Nano Urea @0.5% at 15, 30 and 45 DAS	874.48	1694.95
S.E m±		31.09	49.99
CD at 5%		93.20	149.85

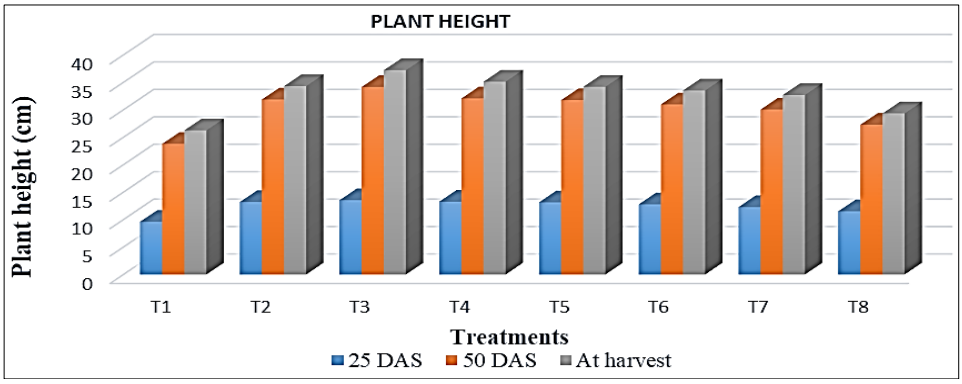

Fig 1: Effect of different levels of nitrogen and foliar application of Nano Urea on plant height (cm) at 25, 50 DAS and at harvest stage of linseed

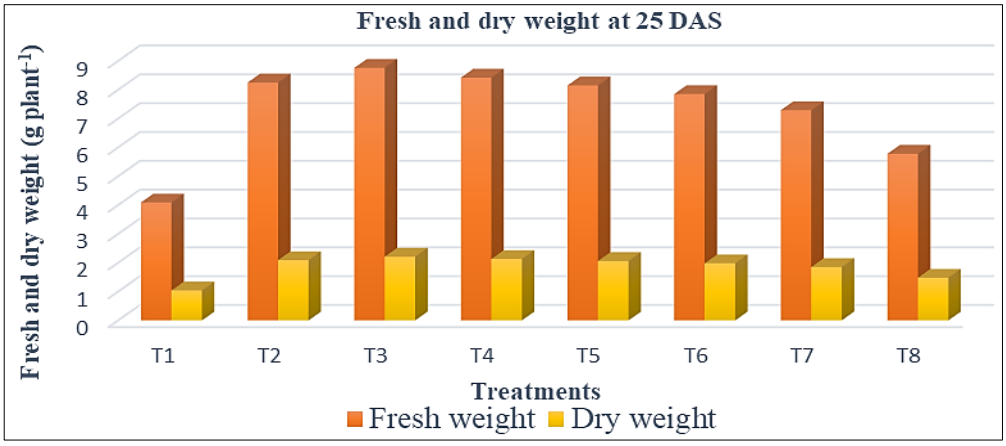

Fig 2: Effect of different levels of nitrogen and F.A. of Nano urea on fresh and dry weight of linseed plants at 25 DAS

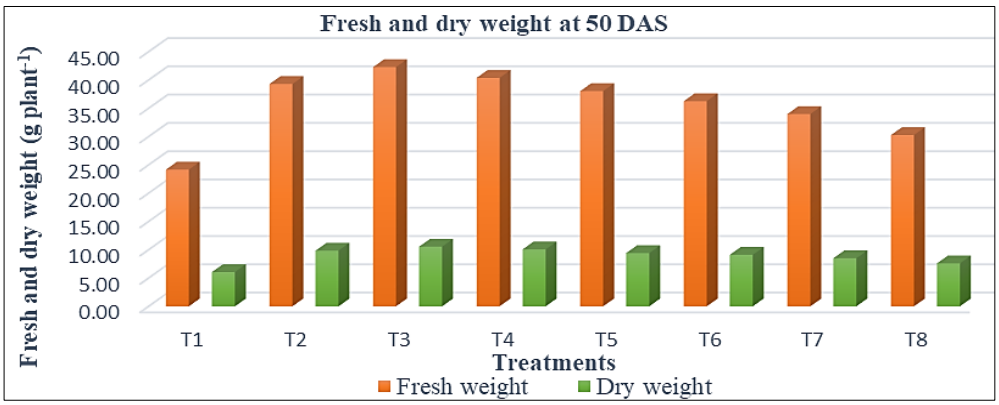

Fig 3: Effect of different levels of nitrogen and F.A. of Nano urea on fresh and dry weight of linseed plants at 50 DAS

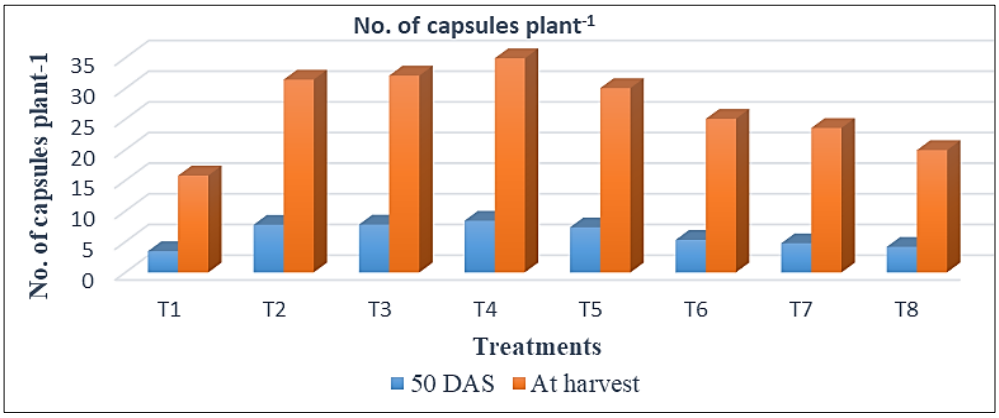

Fig 4: Effect of different levels of nitrogen and F.A. of Nano urea on no of capsules plant^{-1} at 50 DAS and at harvest stage of linseed

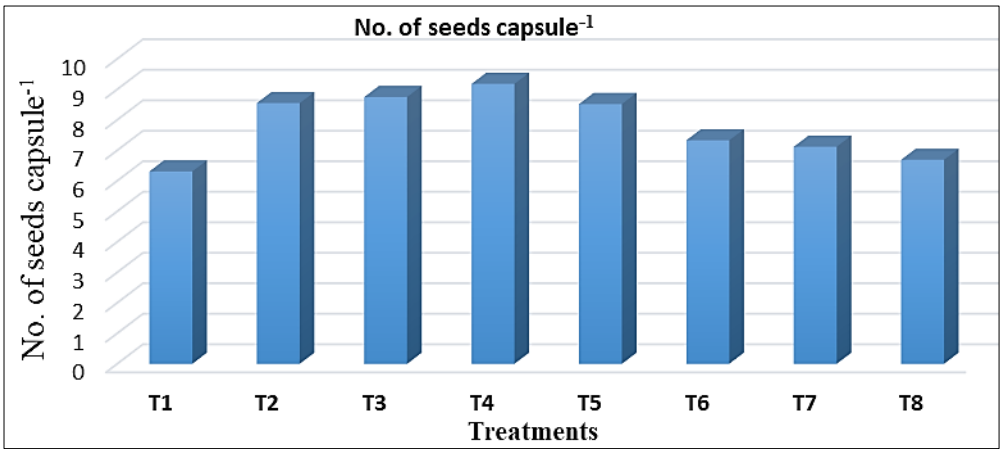

Fig 5: Effect of different levels of nitrogen and F.A. of Nano Urea on no. of seeds capsule^{-1} at harvest stage of linseed.

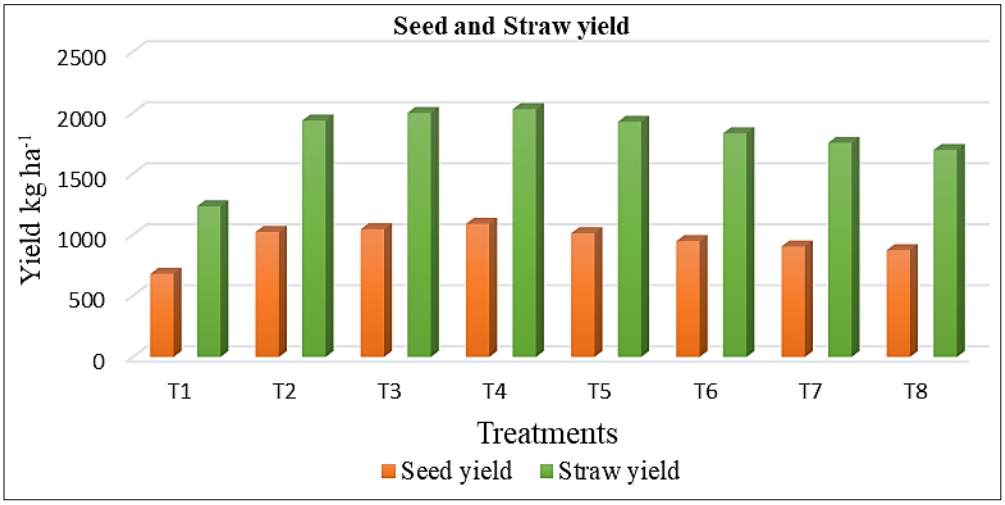

Fig 6: Effect of different levels of nitrogen and F.A. of Nano Urea on Seed and Straw yield of linseed

Conclusion

Plant height as well as fresh and dry weighta, were significantly enhanced with the combined application of 100% NPK + one foliar spray of Nano Urea @ 0.4% at 40 DAS. However, these values were statistically at par with the treatment receiving 75% RDN + 100% PK + two foliar applications of Nano Urea @0.4% at 20 and 40 DAS. The application of 75% RDN + 100% PK combined with two foliar sprays of Nano Urea @0.4% at 20 and 40 DAS resulted in a significant increase in number of capsules plant^{-1}, seed yield and straw yield, outperforming all other treatments.

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