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Response of Soil Applied Urea and Foliar Applied Nano Urea on the Growth, Yield and Quality of *Kharif* Sesame (*Sesamum indicum*) under the Central Plain Agro-climatic Zone of Punjab

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ABSTRACT

Background: In context of oilseeds like sesamum nitrogen is an important major or primary nutrient which is essential specifically for plant height, dry matter accumulation plant^{-1}, development of pod and seed. Deficiency of Nitrogen in sesame results in lower vegetative growth, yield and dry matter partitioning. Along with this it also increase the photosynthetic rate and total chlorophyll content and application of nitrogen fertilizers through nano urea increases nitrogen use efficiency. Nano Urea is low cost technology and required in small quantities. Nano urea produces less hazardous effect on environment. It will also help in decreasing the amount of greenhouse gasses production and their release into the atmosphere. Even though the several research works are already available on effect of foliar spray in Sesame, scope of spray nano urea with different nitrogen levels in sesame enabled us to take up this experiment.

Methods: The present field experiment was carried out during *Kharif* season of 2022 at Agronomy Research Fields, School of Agriculture, Lovely Professional University, Phagwara, Punjab. Nitrogen is applied to sesame through soil as mineral nitrogen and foliar spray. The data pertaining to growth characteristics, yield characteristics, gross monetary returns and net monetary returns of sesame (*kharif*) was collected at regular interval in 2022-23 which was analyzed statistically in SPD (Split Plot Design) with 12 treatment combinations replicated thrice.

Result: Significantly higher plant height (cm), no. of functional leaves plant^{-1}, stem girth (cm) and dry matter accumulation (g plant $^{-1}$) were registered with application F_3 - 100% RDN through soil application of mineral nitrogen to sesame over rest of treatments at 40 DAS, 60 DAS, 80 DAS and at harvest. Among the foliar application of nano-urea to sesame, treatment F_4- 25% N recorded significantly higher plant height (cm), no. of functional leaves plant^{-1}, stem girth (cm) and dry matter accumulation (g plant^{-1}) over lower levels of treatments and found at with treatment F_3-20% N at 40 DAS, 60 DAS, 80 DAS and at harvest. However at harvest higher number of dry capsules plant^{-1}, number of seeds capsules^{-1}, seed yield (q ha^{-1}), straw yield (q ha^{-1}) and oil content (%) were obtained by F_3 - 100% RDN through soil application of mineral nitrogen to sesame over all other treatments to sesame. Foliar application of F_4 - 25% N and F_3- 20% N to Sesame both being at par with each other and registered significantly higher number of dry capsules plant^{-1}, number of seeds capsules^{-1}, seed yield (q ha^{-1}), straw yield (q ha^{-1}) and oil content (%) over remaining levels of foliar applications of nano urea.

Key words: Climate action, Food, Life on land, Mineral urea, Nano technology, Nano urea, Nitrogen, Nutrient use efficiency, Sesame, Sustainable agriculture, Zero hunger.

INTRODUCTION

Seasame (*Sesamum indicum*) one of the important edible oilseeds cultivated in India placed in *Pedaliaceae* family. Sesame is called queen of oilseeds. Sesame is an important cooking oils in India it is in reality the poor man's option for butter oil. It is rich in oil content (50%) and protein content is in seed (18-20%) by Singh *et al.* (2020). About 78% sesame seed is produced in our country (India) is used for oil extraction and about 2.5% for planting as a seed. Nearly 73% oil is used for edible purpose, 8.3% for hydrogenation and 4.2% for manufacturing of paints, pharmaceutical, insecticides *i.e.* industrial purpose. Seeds of sesame are fried and mixed with sugar then eaten. Also, seeds are used for preparation of sweets.100 gms sesame seeds provide 592 calories. Lower grade of sesame oil is used for soap factories. Oil cake of sesame used for feeding of livestock cake which contains about 6.0 to 6.2% N, 2 to 2.2% P_2O_5 and 1.0 to 1.2% K_2O.

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Nitrogen is one of essential nutrient for plant growth and development. It plays an important role in improvement of seed quality and grading. It is found that N application increased vegetative growth of plant. Nutrients, when applied as a foliar spray, are taken up by the plants through its foliage and absorbed in the cell sap and circulated in the plant body. They activate several enzymes or biological reactions in plant tissue.

Urea is favourite source of nitrogen fertilizer that most of the Indian farmers are using for more than a decade now. Also its ease of application in the field and ease of availability is also associated with its unanimous choice among the farmers. Government is providing subsidies under various schemes therefore, farmers rely upon these sources of fertilizers, but the studies show that the conventional use of these kinds of fertilizers are resulting into eutrophication due to its overuse. However, accumulation of these fertilizers results into serious environmental pollution. Also, excessive use of such fertilizers will lead to the accumulation of ammonium and nitrate ions into the plant parts and consumption of such plants will cause detrimental health issues like met hemoglobinemia in human beings (Kumar *et al.,* 2021). Scientists around the world were searching for more sustainable and efficient than existing sources of nitrogen fertilizers. That's when nanotechnology came into the scenario. Nanofertilizers are actually nutrient carriers of nano size which usually ranges from 30-40 nm. They are capable of holding nutrient ions because of their high surface area and slow release ability, thus improving nutrient use efficiency and preventing the ions to get fixed or lost in the environment (Reddy, 2021).

Nano urea comprises nitrogen particles with a surface area of 10,000 times that of a 1 mm urea prill and a higher number of particles. Nano nitrogen particles having a pore size of 20 nanometers may readily pass through the cell wall and reach the plasma membrane. Large particles (30-50 nm) can pass through stomatal holes. They attach to carrier proteins through aquaporin, ion channels and endocytosis before getting digested inside the plant cell. As a result, foliar application of nanoscale particles such as nano nitrogen leads to better nitrogen absorption and penetration in seed formation. Nano nitrogen, based on nanotechnology principles, presents a new option for weaning farmers away from urea. Precision and targeted nitrogen delivery by foliar nano nitrogen spray decreases urea losses, improves nutrient absorption efficiency and resolve the pollution problems. It is translocated to respective plant parts *via* phloem and biologically absorbed into proteins, amino acids and other nutrients needed by the plant (Kumar *et al.,* 2021). Pourjafar *et al.* (2016) stated that low concentration levels of iron and manganese foliar application was more effective on plants for reduction harmful effect of water deficit levels than high micronutrient concentrations. Kumar *et al.* (2023) quoted that nano-urea is an indigenous fertilizer manufactured by IFFCO and its promotion can help reduce the financial burden associated with conventional urea imports. Research has demonstrated that utilizing 75% nitrogen with conventional urea, in combination with either one or two sprays of nano-urea, yields results on par with those achieved through the application of 100% nitrogen supplied via conventional urea. This suggests the potential of nano-urea in optimizing agricultural productivity while minimizing reliance on imported conventional urea. Its application significantly increases nitrogen availability to crops by more than 80%, leading to higher nutrient use efficiency. Additionally, nano urea helps in reducing the environmental footprint by minimizing nutrient loss through leaching and gaseous emissions, which were causing environmental pollution and climate change. This new form of urea would be advantageous for the agriculture sector, as it enables farmers to achieve comparable yields at a reduced cost of fertilizers. Nano urea is an environmentally sustainable option for farmers, promoting smart agriculture and contributing to climate change mitigation.

Acharya *et al.* (2023) observed that application of nanotechnology in agriculture is still in its budding stage. However, it has the potential to revolutionize agricultural systems particularly where the issues on fertilizer applications are concerned. Application of different nano fertilizers have greater role in enhancing crop production. This will reduce the cost of fertilizer for crop production and also minimize the pollution hazard. Nano fertilizers are more soluble or more reactive and it can improve penetration through cuticle, which also performs controlled release and targeted delivery. Nano fertilizers improve crop growth, yield, quality and increased NUE. Meanwhile, there is awareness created on the risks of consuming and performing few operations rather than the benefits and effectiveness of the technology.

Direct soil application N fertilizers leads to loss of major part of applied N fertilizers through volitization, leaching, denitrification and only 20 to 50% applied N is utilized by the plants that is why some extra efforts are required to minimize these losses of N. Foliar application of nitrogen through nano fertilizer increases the readily available nutrients. Foliar application of nitrogen through nano urea at vegetative stage of crop, promotes growth attributes which is reflected in increased yield. The objectives of the experiments were to assess the effect of foliar application of nano urea on growth, yield and yield attributes of sesame.

MATERIALS AND METHODS

A field experiment was conducted at the Agronomy Fields of Lovely Professional University, Phagwara, Punjab, during the *kharif* season of 2022-23. The chemical properties of soil of the experimental site were analyzed by taking the soil sample at a depth of 30 cm randomly from the field representing entire area of the experimental field. A composite soil sample of about half kg was taken and analyzed for the determination of various physical and chemical properties of soil. The soil of experimental plot was clayey in texture with chemical composition such as low in available nitrogen (125.44 kg ha^{-1}), medium in available phosphorous (17.42 kg ha^{-1}) and very high in available potassium (171.25 kg ha^{-1}). The soil was moderately alkaline in reaction having pH (8.27). The experiment consisted of twelve treatment combinations arranged in Split Plot Design (SPD) replicated thrice with net plot size of 4.0 m × 4.8 m and gross pot size 4.0 m × 6 m. The main plot consisted of three mineral nitrogen levels (urea) *viz.* F_1- 0% (0 kg N ha^{-1}) , F_2- 50% (25 kg N ha^{-1}), F_3- 100% (50 kg N ha^{-1}) and subplot consisted of four levels of nano urea form of nitrogen *viz.* N_1- 0% (0 ml ha^{-1}), N_2- 10% (109 ml ha^{-1}), N_3- 20% (218 ml ha^{-1}), N_4- 25% (272 ml ha^{-1}). The sowing of Sesame variety Punjab Til no.2 was done by dibbling method keeping 30 cm distance between the rows. Recommended dose of phosphorus and potassium was applied to all treatments. Foliar spray of nano urea is applied to sesame at 30 and 60 DAS.

RESULTS AND DISCUSSION

Growth attributes

All the growth attributes of the crop were non significantly influenced by various treatments applied to sesame at 20 DAS. However, application of mineral nitrogen through soil and nano urea through foliar spray at 40 DAS, 60 DAS, 80 DAS and at harvest significantly influenced on growth attributes of sesame like plant height (cm), no. of leaves $plant^{-1}$, stem girth (cm), dry matter production (g $plant^{-1}$) as shown in Table 1.

Effect of mineral nitrogen

Significantly higher plant height (cm), no. of functional leaves $plant^{-1}$, stem girth (cm) and dry matter accumulation ($plant^{-1}$ g) were registered with application F_3 - 100% RDN through soil application of mineral nitrogen to sesame over rest of treatments at at 40 DAS, 60 DAS, 80 DAS and at harvest as shown in Table 1. This could be attributed to the fact that, application of urea enhances protein synthesis, cell enlargement which in turn increases vegetative growth of the crop. The findings were in line to those recorded by Haruna *et al.* (2011); Ogundare *et al.* (2015); Zenawi and Mizan, (2019); Kumar *et al.* (2022).

Effect of foliar application of nano urea

Among the foliar application of nano-urea to sesame, treatment F_4- 25% N recorded significantly higher plant height (cm), no. of functional leaves $plant^{-1}$, stem girth (cm) and dry matter accumulation ($plant^{-1}$ g) over lower levels of nano urea and found statistically at par with treatment F_3- 20% N (Table 1). Nano urea foliar application can influence hormonal balance in plants. Urea metabolism within the plant leads to the production of various metabolites, including ammonium and carbon dioxide. These metabolites can affect the synthesis and distribution of plant hormones such as auxins and cytokinins, which play a crucial role in regulating plant growth and development. The hormonal changes induced by nano urea application can stimulate cell division and elongation, resulting in thicker stems. Similar results were quoted by Alwakel *et al.* (2021); Goud *et al.* (2022) and Navya *et al.* (2022).

Interactions

The effect of different interactions among the parameters tested were found to be non significant in case of different growth attributes.

Yield attributes and yield of sesame

The number of green capsules $plant^{-1}$ at 60, 80 DAS and number of dry capsules $plant^{-1}$ at harvest, number of seeds $capsules^{-1}$ at harvest presented in Table 2 indicates that it varied significantly with the various treatments. Test weight of seed was non significantly influenced by various treatments. Seed yield, straw yield (q ha^{-1}) and oil content (%) were significantly influenced by various treatments.

Effect of mineral nitrogen

Table number to indicate that F_3 -100% RDN through soil application of mineral nitrogen to sesame recorded significantly higher number of green capsules $plant^{-1}$ over rest of treatments at 60 DAS and 80 DAS. This could be due to effective pollination and fertilization Nitrogen availability can influence the reproductive process in plants. It affects pollen production and viability, as well as the growth and development of the female reproductive structures (pistil) within flowers. When nitrogen is abundant, it can improve pollination success and enhance the fertilization process. This can lead to a higher rate of capsule formation in sesame, this, in turn, leads to an increased number of seeds per capsule (Reddy *et al.,* 2021).

However at harvest higher number of dry capsules $plant^{-1}$, number of seeds $capsules^{-1}$, seed yield (q ha^{-1}), straw yield (q ha^{-1}) and oil content (%) were registered by F_3-100% RDN through soil application of mineral nitrogen to sesame over all other treatments. This might be because of increased plant biomass. Nitrogen is a key component of proteins and enzymes, which are essential for plant growth and development. Adequate nitrogen availability stimulates the synthesis of proteins, resulting in increased plant biomass. This increased biomass can lead to higher grain and straw yields. Also due to the presence of higher yield attributing characters (Ali and Jan, 2014; Zenawi and Mizan, 2019).

Effect of foliar application of nano urea

Among the foliar application of nano-urea to sesame, treatment F_4 - 25% N recorded significantly higher number of green capsules $plant^{-1}$ over rest of treatments at 60 DAS and 80 DAS over lower levels of treatments and found at with treatment F_3- 20% N. Foliar application of F_4 - 25% N and F_3- 20% N both being at par with each other and registered significantly higher number of dry capsules $plant^{-1}$, number of seeds $capsules^{-1}$, seed yield (q ha^{-1}), straw yield (q ha^{-1}) and oil content (%) over remaining levels of foliar

Table 1: Effect of different levels of nitrogen and nano urea on growth attributes, yield attributes and quality and yield of sesame.

Treatments	Plant height (cm)					No. of leaves plant^{-1}					Stem girth (cm)					Dry matter production (g plant^{-1})				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
A. Mineral nitrogen																				
F_1- 0% N	15.10	31.69	47.42	51.10	51.10	8.28	12.88	13.88	5.78	5.03	1.28	1.98	2.23	2.39	2.39	0.89	2.56	16.99	28.10	20.42
F_2- 50% N	15.75	60.57	81.48	97.65	97.65	8.64	21.92	25.25	13.95	8.53	1.45	2.49	2.85	3.11	3.11	0.93	3.69	29.35	50.00	33.02
F_3- 100% N	16.22	68.07	92.83	119.0	119.0	9.06	29.95	33.90	17.87	10.53	1.54	3.08	3.45	3.54	3.54	1.02	4.86	36.48	63.15	43.55
S.E(m) ±	0.22	1.23	1.65	1.85	1.85	0.15	0.48	0.52	0.36	0.17	0.07	0.05	0.07	0.06	0.06	0.02	0.07	0.60	1.18	1.07
CD at 5%	NS	4.84	6.49	7.26	7.26	NS	1.88	2.03	1.40	0.65	NS	0.20	0.26	0.25	0.25	NS	0.28	2.34	4.62	4.20
B. Nano urea																				
N_1- 0% N	15.48	49.82	70.03	93.89	93.89	8.49	18.94	20.80	11.57	8.00	1.40	2.33	2.67	2.80	2.80	0.92	3.20	24.29	41.33	28.13
N_2- 10% N	15.68	51.99	73.20	87.02	87.02	8.45	21.14	24.32	12.09	8.22	1.41	2.45	2.76	2.89	2.89	0.94	3.66	26.57	44.68	30.68
N_3- 20% N	15.70	54.33	75.20	90.98	90.98	8.84	23.01	25.68	12.98	9.00	1.40	2.62	2.92	3.12	3.12	0.96	3.93	29.13	49.54	34.27
N_4- 25% N	15.91	57.63	78.06	95.14	95.14	8.85	23.22	26.44	13.48	9.33	1.47	2.68	3.02	3.24	3.24	0.96	4.02	30.44	52.78	36.23
S.E(m) ±	0.16	1.25	1.67	1.79	1.79	0.17	0.64	0.68	0.44	0.25	0.10	0.07	0.07	0.07	0.07	0.02	0.16	0.64	1.17	0.91
CD at 5%	NS	3.72	4.97	5.31	5.31	NS	1.89	2.01	1.30	0.73	NS	0.20	0.20	0.22	0.22	NS	0.47	1.91	3.47	2.71
Interactions of A×B																				
S.E(m) ±	0.27	2.17	2.99	3.10	3.10	0.29	1.10	1.17	0.76	0.43	0.17	0.12	0.12	0.13	0.13	0.04	0.27	1.12	2.03	1.58
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of different levels of nitrogen and nano urea on yield attributes and quality and yield of sesame.

Treatments	Yield contributing characteristics of sesame					Yield of sesame		Quality of sesame
	Number of green capsules plant^{-1}		At harvest					
	60 DAS	80 DAS	Number of dry capsules plant^{-1}	Number of seeds capsule^{-1}	Test weight (g)	Seed (q ha^{-1})	Straw (q ha^{-1})	Oil (%)
A. Mineral nitrogen								
F_1- 0% N	19.35	24.71	23.20	26.54	1.79	2.22	4.18	30.80
F_2- 50% N	30.37	36.45	34.64	37.91	2.28	4.49	8.90	39.89
F_3- 100% N	40.56	44.16	42.95	48.57	2.71	6.39	14.47	45.81
S.E(m) ±	0.80	0.92	0.99	0.65	0.18	0.10	0.16	1.10
CD at 5%	3.16	3.60	3.90	2.54	NS	0.39	0.61	4.32
B. Nano urea								
N_1- 0% N	26.23	31.51	30.31	33.93	2.10	4.17	8.69	37.11
N_2- 10% N	28.49	33.76	32.22	36.41	2.18	4.26	8.86	38.09
N_3- 20% N	31.80	36.43	34.82	39.62	2.31	4.43	9.43	39.18
N_4- 25% N	33.96	38.72	37.04	40.72	2.45	4.60	9.76	40.95
S.E(m) ±	0.83	0.86	0.78	0.65	0.11	0.07	0.15	0.89
CD at 5%	2.45	2.56	2.32	1.92	NS	0.21	0.45	2.64
Interactions of A×B								
S.E(m) ±	1.43	1.49	1.35	1.12	0.19	0.12	0.26	1.54
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

applications of nano urea as swon in Table 2. This could be due to, increased nutrient partitioning. Nano urea has been shown to enhance nutrient partitioning within plants. This means that the nutrients provided by the fertilizer are efficiently distributed to different plant parts, including reproductive structures like flowers, capsules and seeds. As a result, the application of nano urea can lead to an increased number of capsules per plant and a higher seed set per plot (Ahmed *et al.,* 2020). Similar results were reported by Balyan *et al.* (2023); Devi *et al.* (2024).

Interactions

The effect of different interactions among the parameters tested were found to be non significant in case of different yield attributes, yield and quality of sesame.

CONCLUSION

Soil application of 100% RDN through mineral nitrogen and foliar application of 25% N through nano urea to sesame recorded significantly higher growth attributes, yield attributes, seed and straw yield of sesame over lower level of treatments and followed by soil application of 100% RDN through mineral nitrogen and foliar application of 20% N through nano urea.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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