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Effect of nitrogen levels and foliar application of nano-urea on productivity of pearl millet [*Pennisetum glaucum* (L.) R.Br. emend Stuntz]

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Abstract
Background: Pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz], is the most important crop in terms of its higher production with wider adaptability to climate and soil, which is mainly grown in *kharif* season 2023. Nitrogen is considered as most important primary mineral nutrient for the production of cereal crops. It has the greatest impact on the vegetative growth of plants. Foliar application of fertilizers is an effective strategy for rapidly addressing crop under nutrition at later growth stages, when the availability of soil nutrients may decrease owing to root senescence and dry weather conditions. Foliar application of nitrogen is beneficial for reducing nitrogen loss and environmental risk caused primarily by denitrification and nitrogen leaching. Nano fertilizers on the other hand are crucial determining factors in agriculture for enhancing growth, yield and provide higher nutrient use efficiency and less fertilizer waste.
Methods: In the present work, experiment was laid out in randomized block design *i.e.* with twelve treatment combinations with of RDN through urea and nano- urea spray of one or two spray was laid out on pearl millet variety RHB 177 at Research farm, Suresh Gyan Vihar University, Jaipur.
Results: The independent application of 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS at 60 DAS and at harvest produced significantly higher plant height and dry matter accumulation at 60 DAS and at harvest, number of effective tillers plant-1 at 40 DAS, ear head length(cm), test weight (g), grain yield, stover yield, biological yield, net returns and B:C ratio as compared to rest of the treatments and remained at par with 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS.

Keywords: Pearl millet, nitrogen levels, nano-urea, growth, yield and economics

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz], is the most important crop in terms of its production and wider adaptability to climate and soil, which is mainly grown in *kharif* season. It is also consumed as feed and fodder for livestock. India accounts for half of global millet production in the country. It is the sixth most important cereal crop in the world next to wheat, rice, maize, barley and sorghum. It is good source of energy, carbohydrate, fat (5-7%), ash, dietary fibre (1.2 g/100 g), protein (9-13%) and antioxidant such as coumaric acids with better digestibility. Pearl millet has higher content of nutrients such as iron, zinc, calcium, magnesium, copper, manganese, phosphorus, folic acid and riboflavin.
Nitrogen is considered as most important primary mineral nutrient for the production of cereal crops. It has the greatest impact on the vegetative growth of plants. Nitrogen is required for the development of leaves, tillers and also enables the plant to operate at peak photosynthetic capacity. Nitrogen is the major nutrient required by pearl millet and variable growth and yield response to nitrogen application has been demonstrated by various researchers. The applied nitrogen through fertilizers undergoes transformation processes such as biological nitrogen fixation, humus mineralization, immobilization, and nitrification at acidic and alkaline pH, respectively, denitrification and volatilization.
To achieve highest productivity of crops, adequate supply of essential nutrients through a right source is an appropriate approach. Soil application of nitrogenous fertilizers is influenced by various environmental factors and thereby limits its efficiency in nutrient use.

Foliar application of fertilizers is an effective strategy for rapidly addressing crop under nutrition at later growth stages, when the availability of soil nutrients may decrease owing to root senescence and dry weather conditions. Foliar application of nitrogen is beneficial for reducing nitrogen loss and environmental risk caused primarily by denitrification and nitrogen leaching.

Use of chemical fertilizers through traditional methods leads to excessive application but inefficient uptake by the plants due to volatilization, leaching into the soil, difficult absorption into the plant *etc*., causes negative impact on the natural environment. Nano-fertilizers on the other hand are crucial determining factors in agriculture for enhancing growth, yield and provide higher nutrient use efficiency, and less fertilizer waste. Nanotechnology can reduce the rate of fertilizer nutrients loss through leaching and increase their availability to plants which ultimately leads to reduced water and soil pollution. Nowadays, nano fertilizers are emerging as an alternative to conventional fertilizers. In Order to solve higher fertilizer requirement during crop growth, environmental issues and economic aspects, the use of nitrogen through nano fertilizer is essential.

Materials and Methods

The experiment was conducted during *kharif*, 2023 at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan). Geographically, this region falls under agro-climatic zone III A of Rajasthan (Semi-arid Eastern Plain Zone) and this area is located at 75° 51'44" E longitude and 26°48'35'' N latitude and at an altitude of 432 m above mean sea level. The experiment was laid out in randomized block design with three replications. The experiment consisting of 12 treatment combinations with RDN through urea and nano- urea spray of one or two spray was laid out. The seeds of pearl millet variety RHB 177 were sown on 11th July, 2023. The sowing was done at row spacing of 45 cm x 15 cm using a seed rate of 4 kg ha-1 by "Kera" method with the help of *desi* plough. The seeds were dropped manually in furrow opened by plough at a depth of 2-3 cm. The soil samples were collected from 0-15 cm depth of soil profile with the help of screw auger before sowing. It was air dried in shade, ground and analyzed for determination of physical and chemical properties of soil. Soils are loamy sand with 0.22% organic carbon, 136.74 kg ha^{-1} N, 20.09 kg ha^{-1} P2O5 and 237.34 kg ha^{-1} K2O. The total rainfall received during the crop season was 494.7 mm. On the basis of gross plot size the quantity of fertilizer required as per treatment was calculated and weighed for different plots. Fertilizer application was made as per the treatments. Full dose of phosphorus and potassium and half dose of nitrogen were applied at the time of sowing at 5 cm below the seeding depth. Nitrogen as per treatment and phosphorus and potassium according to recommended dose were applied through urea, DAP and MOP. Nano-urea was sprayed once or twice on the foliage at 25 and 45 DAS as per treatments.

One hoeing and weeding was done manually at 25 DAS to facilitate aeration and removing the weeds. All the plant protection measures were adopted to take healthy crop at maturity stage, after leaving two rows on each side as well as 50 cm along the width of each side, a net plot area was harvested separately for recording the yield. Data on growth, yield and yield attributes of pearl millet were statistically analyzed.

Results and Discussion

Growth Attributes

Results showed in that application of nitrogen levels along with foliar application of nano-urea increased the growth attributes of pearl millet *viz.* plant height, dry matter accumulation and chlorophyll content at various stages (Table 1). The maximum values of these parametres were recorded due to application of 100% RDN + two spray of nano- urea (4 ml/litre) at 25 & 45 DAS followed by 75% RDN + two spray of nano-urea (4 ml/litre) and100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS over control.

A large leaf area enhances the capacity of the plants to intercept adequate sunlight; leading to the production of more assimilates, thereby enhancing growth and development. Thus, with an adequate supply of nitrogen, plants grow taller, produce more leaf area index (LAI), and ultimately achieve greater total dry matter accumulation. These results are in close conformity with the findings of Bhanuchandar *et al.* (2020) [2], Choudhary *et al.* (2020) [3] and Rana and Prasad (2020) [9].

Nano-fertilizers play an important role in the physiological and biochemical processes of plant by increasing the availability of nutrients, which helps enhance metabolic processes and promote meristematic activities, leading to higher apical growth and photosynthetic area. The foliar application of nano nitrogen caused an increase in nitrogen uptake through the leaves and roots, which might have led to the increased mobilization of synthesized carbohydrates into amino acids and proteins, stimulating rapid cell division and cell elongation. The results were partially similar to the findings of Sharma *et al.* (2022) [10] and Rajsekar *et al.* (2017).

Yield attributes and yield

Data presented in Table 2 revealed that yield attributes *viz.* number of effective tillers per plant, earhead length and test weight of pearl millet were significantly increased by application of nitrogen along with foliar application of nano-urea. Application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS produced the highest number of effective tillers which indicated an increase over control, control + one spray, two spray and 50% RDN + control. However it remained statistically at par with rest of the treatments. In case of ear length maximum ear length (31.01 cm) was recorded with application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS. This treatment was at par with 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS, 100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS, 100% RDF + control, 50% RDN + two spray, 75% RDN + one spray, 50% RDN + one spray, 75% RDN + control, 50% RDN + control but significantly superior over control, control + one spray, two spray and 50% RDN + control. Application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS and 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS increased the above parameter by 31.34 and 27.11 per cent as compared to control.

The increased nutrient uptake resulted in enhanced cell division, meristematic activity, and cell elongation, thereby producing more productive tillers per plant. Similar results were also obtained by Meena *et al.* (2017) [7], Jassim *et al.* (2019) [4] in rice.

Application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS recorded highest grain yield (2350 kg/ha), stover yield (6311kg/ha) and biological yield (8661 kg/ha). This treatment was at par with 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS, 100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS, 100% RDF + control, 50% RDN + two spray and 75% RDN + one spray. The higher values of yield attributes of pearl millet, such as effective tillers per metre row length, number of grains per ear, ear length, and test weight,

coupled with the higher crop dry matter observed with these treatments, might be the most probable reason for the higher grain and stover yield. The increase in grain yield of hybrid pearl millet with these treatments was also largely due to the high harvest index, which showed a high partitioning of the plant assimilates towards the sink. These findings were in agreement with these of Arya *et al.* (2022) [1] and Kumar *et al.* (2020) [5] in pearl millet.

Economics

Data in Table 3 further revealed significant increase in the highest net returns and B: C ratio with application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS highest net returns and benefit cost ratio (65438/ha & 3.93). This treatment was at par with 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS, 100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS and 100% RDF + control. This may be attributed to the lower cost of cultivation and higher net returns in the above treatments as reported by Kumar *et al.* (2024) [6]. Minimum net returns and B: C ratio were recorded in control (38232/ha and 2.30) in pearl millet.

Table 1: Effect of nitrogen and foliar application of nano-urea on growth attributes of pearl millet

	Treatments	Plant height (cm)		Dry matter accumulation per metre row length (g)		Chlorophyll content (mg/g)
		60 DAS	At Harvest	60 DAS	At Harvest	At 40 DAS
T1	Control	101.09	155.69	131.42	208.94	2.58
T2	Control + one spray of nano-urea (4 ml/litre) at 25 DAS	118.31	176.18	148.64	239.43	2.77
T3	Control + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	119.39	178.49	149.72	241.74	2.79
T4	50% RDN + control	120.88	179.84	151.21	243.09	2.82
T5	50% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	127.52	183.76	157.85	247.01	2.80
T6	50% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	129.46	185.40	159.79	248.65	2.81
T7	75% RDN + control	125.76	183.05	156.09	246.30	2.81
T8	75% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	129.81	184.45	160.14	247.70	2.79
T9	75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	144.25	200.88	175.79	266.13	2.88
T10	100% RDN + control	139.34	189.36	170.88	254.61	2.84
T11	100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	141.50	195.52	173.04	260.77	2.87
T12	100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	147.10	205.73	179.85	276.98	2.89
	SEm±	5.70	6.95	5.81	9.10	0.05
	C.D. (P=0.05%)	16.73	20.37	17.04	26.70	0.13

Table 2: Effect of nitrogen and foliar application of nano-urea on yield attributes, yield and harvest index of pearl millet

	Treatments	Yield Attributes			Yield (kg ha-1)			
		No of effective tillers plant-1	Ear head length (cm)	Test weight (g)	Grain	Stover	Biological	Harvest index (%)
T1	Control	17.40	21.61	6.23	1555	4289	5844	26.57
T2	Control + one spray of nano-urea (4 ml/litre) at 25 DAS	21.10	25.31	7.07	1867	5089	6956	26.86
T3	Control + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	21.20	25.41	7.09	1892	5126	7018	26.96
T4	50% RDN + control	21.20	25.41	7.18	1925	5221	7146	26.94
T5	50% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	22.70	26.91	7.36	1993	5365	7358	27.09
T6	50% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	23.17	27.38	7.55	2062	5561	7623	27.02
T7	75% RDN + control	22.40	26.61	7.27	1975	5311	7286	27.09
T8	75% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	23.00	27.21	7.46	2036	5487	7523	27.06
T9	75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	24.30	28.51	7.78	2285	6163	8448	27.08
T10	100% RDN + control	23.30	27.51	7.67	2180	5882	8062	27.02
T11	100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	23.80	28.01	7.72	2225	5995	8220	27.07
T12	100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	24.80	29.01	7.88	2350	6311	8661	27.09
	SEm±	1.15	1.20	0.27	99.97	243.85	340.38	0.28
	C.D. (P=0.05%)	3.36	3.52	0.78	293.20	715.18	998.30	NS

Table 3: Effect of nitrogen and foliar application of nano-urea on economics of pearl millet

	Treatments	Economics	
		Net returns (/ha)	B:C ratio
T1	Control	38232	2.30
T2	Control + one spray of nano-urea (4 ml/litre) at 25 DAS	48940	2.94
T3	Control + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	49665	2.98
T4	50% RDN + control	50846	3.05
T5	50% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	53031	3.19
T6	50% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	55495	3.33
T7	75% RDN + control	52372	3.15
T8	75% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	54565	3.28
T9	75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	63300	3.80
T10	100% RDN + control	59634	3.58
T11	100% RDN + one spray of nano-urea (4 ml/litre) at 25 DAS	61170	3.68
T12	100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS	65438	3.93
	SEm±	3331	0.20
	C.D. (P=0.05%)	9769	0.59

Conclusion

Based on results of one year experiment, it may be concluded that application of 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS produced significantly higher plant height, dry matter accumulation, chlorophyll content, grain, stover, biological yield, net return and B: C ratio over control and other treatments and also remained at par with 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS.

Therefore, application of 100% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS and 75% RDN + two spray of nano-urea (4 ml/litre) at 25 & 45 DAS may be recommended for higher production and profitability of pearl millet under semi-arid condition of Rajasthan.

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