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Effect of liquid nano-urea fertilizer under different nitrogen levels on physiological parameter of pearl millet (*Penisetum glaucum* L.)

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Abstract
Pearl millet is a crucial cereal crop in India, particularly for arid and semi-arid regions. However, its productivity is often limited by insufficient nutrient availability and poor fertilizer efficiency. This research investigated the potential of nano urea a new fertilizer technology to enhance plant growth in pearl millet. Field experiments were conducted over two consecutive summer seasons (2022 and 2023) using a randomized complete block design with twelve treatments and three replications. The study site had loamy sand soil with slightly alkaline pH. Pearl millet was grown and various nano urea treatments were applied in combination with urea at different rates and timings. These included foliar sprays of liquid nano urea fertilizer at specific days after sowing (DAS). The findings revealed significant effects of nano urea treatments on chlorophyll content and leaf area compared to the control. Treatment T_{10} (100% recommended dose of nitrogen through urea with foliar sprays of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS) consistently exhibited the highest chlorophyll content at all measurement stages (25, 50 DAS, and harvest) and leaf area at harvest across both years. Research suggested that applying both conventional urea and foliar nano urea to pearl millet crops has a synergistic effect. This combination improves physiological parameters like chlorophyll content and leaf area, resulting in increased crop productivity.

Keywords: Nano urea, chlorophyll, pearl millet

Introduction

Pearl millet, the sixth most significant cereal globally, is the fourth most extensively cultivated food crop in India after rice, wheat, and maize. As the leading producer, India cultivates pearl millet across 76.52 lakh hectares, yielding 108.63 lakh tonnes with a productivity of 1420 kg/ha (Anon., 2021-22) [1]. Major states contributing 90% to national production include Rajasthan, Maharashtra, Uttar Pradesh, Gujarat, and Haryana. In Gujarat, cultivation spans 4.60 lakh hectares, producing 10.08 lakh tonnes with a productivity of 2192 kg/ha (Anon., 2021-22) [1]. Key growing districts are Banaskantha, Junagadh, Jamnagar, Rajkot, Mahesana, Kheda, Amreli and Kutch.

Pearl millet (*Pennisetum glaucum* L.), a vital crop in arid and semi-arid regions of India, plays a crucial role in food security and nutrition. Functioning as a dual-purpose crop, pearl millet serves as an affordable source of nutrition, rich in various essential nutrients such as protein, fats, carbohydrates and minerals, making it valuable for impoverished populations (Sharma *et al.*, 2022) [12]. Pearl millet is particularly noteworthy for its high productivity potential, especially in regions facing severe environmental stress conditions, notably drought. This crop plays a crucial role in addressing food needs for the underprivileged in dry areas, offering staple food in a short time. However, its productivity is often hampered by insufficient nutrient availability and poor fertilizer efficiency.

Overview of Nitrogen (N) in Plant Metabolic System Being a major part of amino acids, nitrogen is a prominent food for plants and therefore found in protein positions as well as the chlorophyll of most plant parts. Nitrogen is an essential element necessary for most of the physiological processes (Leghari *et al.*, 2016) [6]. Fertilizers have a great significance in increasing food production of hitherto undeveloped or developing countries - particularly after the utilization of high yielding and fertilize responsive crop varieties. A considerable part of nitrogen, mainly that applied through fertilizers, goes through transformation processes such as biological nitrogen fixation, humus mineralization, immobilization and nitrification at acidic or alkaline pH respectively (denitrification - volatilization) (Patra *et al.*, 2006) [10]. This complexity and diversity result in an extremely variable nitrogen management, which is hard to be turned into enhanced nitrogen use efficiency. Over the last few decades, to enhance the nitrogen-use efficiency by plants, alternative strategies have been proposed. Of all these nanotechnology boasts significant positive implications in the agricultural ecosystem. Fertilizer technologies such as nano fertilizers are meant to release nutrients in a regulated manner according to the crop requirement hence indirectly improving the nutrient use efficiency without having the associated ill-effects (Naderi *et al.*, 2013) [7]. Nano-fertilizers are the key components in agriculture to increase crop growth, yield and quality parameters, decrease fertilizer wastage and cost of cultivation. Nanotechnology reduces the rate of fertilizer nutrients loss through leaching process of fertilizers and makes the available to plant and thus it decreased both water pollution and soil pollution. The nano fertilizers belong to the category of anode in the present day displaying them as a rational substitute for the traditional fertilizers (Guru *et al.*, 2015) [3]. Now a day because of higher fertilizer requirements during crop growth, environmental issues and also considering economic aspects the use of nitrogen nano fertilizer is very much necessary. Hence, with the above facts in view an experiment titled "Effect of Liquid Nano-Urea fertilizer under Different Nitrogen Levels on physiological parameter of Pearl millet (*Penisetum glaucum* L.)" was undertaken during summer season of 2022 and 2023.

Materials and Methods

Field experiments were carried out at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (coordinates: N 22˚-35'and E 72˚-55'). The experimental site featured loamy sand soil that was slightly alkaline (pH 8.22) and non-saline (EC 0.23 dS/m). The soil's plough layer (0-15 cm) had 0.36% organic carbon, 198 kg/ha of available nitrogen, 39.36 kg/ha of available phosphorus and 258 kg/ha of available potassium. Additionally, the soil contained 5.81 mg/kg of DTPA-extractable iron, 6.97 mg/kg of manganese, 1.78 mg/kg of zinc and 2.74 mg/kg of copper.

Field experiments were conducted in two consecutives summer season of 2022 and 2023 with pearl millet crop, utilizing a randomized complete block design (RCBD) with twelve different treatments and three replications. Phosphorus fertilizers were applied uniformly at recommended rates across all plots to ensure consistency. Specific treatment details can be found in Table 1.

Table 1: Treatments details of experiments undertaken in pearl millet crop

Treatment No.	Treatment
T_1	Absolute control
T_2	100% RDN through urea
T_3	75% RDN through urea
T_4	50% RDN through urea
T_5	T_3 + Foliar spray of 2% urea at 25 and 50 DAS
T_6	T_4 + Foliar spray of 2% urea at 25 and 50 DAS
T_7	T_2 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS
T_8	T_3 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS
T_9	T_4 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS
T_{10}	T_2 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS
T_{11}	T_3 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS
T_{12}	T_4 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS

Chlorophyll content was measured on randomly three leaves were taken from lower, middle and upper portions of five tagged plants and their average was recorded as amount of total chlorophyll content present at 25, 50 DAS (before spray) and at harvest for each treatment. Whereas leaf area was measured on five plants from each plot were taken out from the border row at harvest to calculate leaf area (cm^2).

The statistical analysis of data of the characters was studied by the investigation through procedure appropriate to the design of the experiment. The significance of difference was tested by the 'F' test (Panse and Sukhatme, 1985) [9]. Summary tables for treatment effects were prepared and presented with standard error of means (S.Em. ±) and co-efficient of variations (C.V.%).

Results and Discussion

Effect on Chlorophyll content

Effect of various nano urea treatments on chlorophyll content (by SPAD meter) at 25, 50 DAS and at harvest of pearl millet is reported in Table 2. A perusal of data given in Table 2 revealed that treatment T_{10} (T_2 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS) recorded significantly higher chlorophyll content at 25 DAS (21.26, 23.54 and 22.40) and 50 DAS (93.66, 98.12 and 95.89) during the year 2022, 2023 and on pooled basis, respectively. It was statistically at par with treatments T_{11}, T_7, T_2, T_5 and T_8 during both years 2022 and 2023 as well as on pooled basis at 25 DAS and T_{11} and T_7 was at par during 2022, 2023 and on pooled analysis at 50 DAS. Whereas, lower chlorophyll content (14.97, 16.21 and 15.59) at 25 DAS and (60.88, 62.75 and 61.82) at 50 DAS was recorded under treatment T_1 (Absolute control) during the year 2022, 2023 and on pooled basis, respectively. Data shown in Table 2 demonstrate that different treatments had significant effects on chlorophyll content present at harvest, both within individual years and on a pooled basis. Significantly maximum chlorophyll content at harvest (60.77, 63.09 and 61.93 during the year 2022, 2023 and on pooled basis, respectively) was obtained with application of 100% RDN through urea + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS (T_{10}), however, treatments T_{11}, T_7, T_2, T_5 and T_8 found statistically at par during 2022. While, treatments T_{11}, T_7 and T_2 were at par with treatment T_{10} during 2023. However, treatment T_{10} was at par on pooled basis with treatment T_{11} and T_7. Significantly lower chlorophyll content at harvest (42.14, 44.63 and 43.39) was observed in treatment T_1 (Absolute control) during the year

2022, 2023 and on pooled basis, respectively.

The rise in chlorophyll content observed in pearl millet could be attributed to the enhanced absorption of nano urea particles by the plant. This increased absorption provides more nitrogen to various plant parts, facilitating chlorophyll synthesis and consequently leading to a higher number of chloroplasts in the leaves. Chloroplasts are organelles in plants responsible for containing chlorophyll. Comparable findings were reported by Navya *et al*. (2022) [8] in mustard and Sharma *et al.* (2022) [12] in pearl millet.

Effect on Leaf area

Data regarding on leaf area (cm^2) at harvest as affected by various nano urea treatments in 2022 and 2023 as well as in the pooled results are illustrated in Table 3. Different treatments had significant effects on pearl millet leaf area at harvest in both the years and in the pooled analysis. Treatment T_{10} (T_2 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS) recorded significantly higher leaf area at harvest (210.77, 213.67 and 212.22 cm^2 during the years 2022, 2023 and on pooled basis, respectively) which was at par with treatments T_{11}, T_7, T_2 and T_5 during the year 2022 and 2023 and it was at par only with treatment T_{11} and T_7 in pooled analysis. Minimum leaf area at harvest (133.23, 138.23 and 135.73 cm^2) was recorded under the treatment T_1 (Absolute control) during the year 2022, 2023 and on pooled basis, respectively.

This might be attributed to the fact that foliar application of nano nutrient sources significantly enhanced nutrient content within leaves, leading to heightened meristematic activities and cell elongation associated with protein synthesis. This process facilitated the production of more functional leaves and extends the duration of photosynthetic activity, ultimately contributing to an increase in leaf area over time. The results of this study align with the investigations carried out by Salama and Badry (2020) [11] in maize, Kumar *et al.* (2021) [5] in different crops, Anushka *et al.* (2023) [2] in rice and Kaviyazhagan *et al.* (2022) [4] in sweet corn.

Table 2: Effect of liquid nano urea fertilizer on chlorophyll content (by SPAD meter) at 25, 50 DAS and at harvest of pearl millet (before spray)

Treatments	Chlorophyll content at 25 DAS (Before spray)			Chlorophyll content at 50 DAS (Before spray)			Chlorophyll content at harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	14.97	16.21	15.59	60.88	62.75	61.82	42.14	44.63	43.39
T_2	20.09	21.25	20.67	76.99	84.62	80.80	54.92	56.48	55.70
T_3	18.33	19.26	18.80	73.23	77.57	75.40	49.64	51.63	50.64
T_4	15.46	16.72	16.09	65.12	68.02	66.57	45.11	47.79	46.45
T_5	19.30	20.32	19.81	76.06	79.82	77.94	52.98	53.56	53.27
T_6	16.44	17.55	16.99	71.02	73.08	72.05	48.22	50.17	49.20
T_7	20.83	21.94	21.39	80.03	85.71	82.87	56.42	58.19	57.30
T_8	18.88	20.13	19.50	75.20	78.89	77.05	51.95	52.24	52.10
T_9	15.96	16.80	16.38	68.10	71.12	69.61	47.14	50.06	48.60
T_{10}	21.26	23.54	22.40	93.66	98.12	95.89	60.77	63.09	61.93
T_{11}	20.95	22.34	21.65	85.81	88.44	87.12	57.54	58.52	58.03
T_{12}	16.64	17.60	17.12	71.46	73.09	72.28	49.14	51.02	50.08
S.Em. ±	0.99	1.19	0.78	4.78	4.66	3.34	3.21	2.92	2.17
C. D. at 5%	2.92	3.49	2.21	14.03	13.68	9.52	9.42	8.58	6.19
Year and Year × Treatment	-	-	NS	-	-	NS	-	-	NS
CV%	9.46	10.61	10.09	11.07	10.30	10.68	10.84	9.54	10.19

Table 3: Effect of liquid nano urea fertilizer on leaf area at harvest of pearl millet

Treatments		Leaf area (cm^2)		
		2022	2023	Pooled
T_1	Absolute control	133.23	138.23	135.73
T_2	100% RDN through urea	185.37	190.47	187.92
T_3	75% RDN through urea	162.73	167.83	165.28
T_4	50% RDN through urea	143.60	145.80	144.70
T_5	T_3 + Foliar spray of 2% urea at 25 and 50 DAS	182.80	189.87	186.33
T_6	T_4 + Foliar spray of 2% urea at 25 and 50 DAS	156.20	159.30	157.75
T_7	T_2 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS	190.57	194.37	192.47
T_8	T_3 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS	167.43	171.46	169.45
T_9	T_4 + Foliar spray of 2 mL/L liquid nano urea fertilizer at 25 and 50 DAS	152.77	157.67	155.22
T_{10}	T_2 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS	210.77	213.67	212.22
T_{11}	T_3 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS	199.00	207.60	203.30
T_{12}	T_4 + Foliar spray of 4 mL/L liquid nano urea fertilizer at 25 and 50 DAS	159.83	164.23	162.03
S.Em. ±		10.88	10.37	7.51
C. D. at 5%		31.91	30.40	21.41
Year and Year × Treatment		-	-	NS
CV%		11.06	10.26	10.66

Conclusion

Field experiments demonstrated that nano urea treatments significantly increased chlorophyll content and leaf area in pearl millet compared to the control group (no treatment). Treatment T_{10}, which involved applying a combination of urea and foliar nano urea fertilizer at specific points during growth, showed the most consistent improvement in both chlorophyll content and leaf area across multiple years.

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