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Foliar nutrition of nano-urea with conventional urea on the productivity and profitability of fodder maize

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Abstract
Nano-technology based nutrient management practices in fodder crops are still in their nascent stage of growth. Fodder crops required more nitrogen and meeting this demand through nano-urea raises questions about its suitability for long-term fodder production. Therefore, a field trail on foliar nutrition of nano-urea with conventional urea on productivity and profitability of fodder maize was conducted at MARS, UAS, Dharwad during *kharif* season of 2021 and 2022. The results indicated that application of 75% RDN (112.5 kg N ha^{-1}) led to significantly higher growth, fodder yield and net returns as compared to other N levels. Between nano-urea concentration foliar application of 4 ml l^{-1} water recorded significantly higher growth, yield and economic returns in fodder maize. However, frequency of spray did not have a significant influence on growth, yield and economics of fodder maize. Among the interactions, application of 75% RDN regardless of nano-urea concentration and frequency of sprays recorded higher growth, yield and economics. When interactions were compared with checks, RPP showed significant superiority over the rest of the treatment combination in terms of growth, yield and economics. Compared to RPP, reducing conventional nitrogen by 25-100% resulted in a decrease in green fodder yield ranging from 9.4 to 70.5% in fodder maize. Similarly, net returns decreased by 18.3 to 77.6% with the reduction of conventional nitrogen by 25-75% RDN, regardless of nano-urea concentration and spray frequencies. Overall, there is no advantage of using nano-urea in fodder maize as a substitute for conventional urea.

Keywords: Economics, fodder maize, green fodder yield and nano-urea

Introduction
Agriculture and animal husbandry are interwoven to each other. Livestock sector acts as cushion for the rural economy and contributes 6.2% to total GVA in 2020-21 (Anonymous, 2022a) [4]. India ranks first in the world with a huge livestock population of 536.76 million and also ranks first in milk production (Anonymous, 2022b) [5]. In order to sustain a large livestock population, a continuous supply of both green and dry fodder is essential. Among the various fodder crops, fodder maize is the most preferred due to its high productivity and being free from anti-nutritional factors. The fodder maize mines high nutrients from the soil for its increased productivity, specifically requiring higher amounts of nitrogenous fertilizer along with other nutrients. However, applied nitrogen fertilizers are subjected to various kind of losses and the efficacy of applied fertilizer ranges between 30.2-53.2% (Anas *et al*., 2020) [3]. On the other hand, nano-technology based nutrient management practices are gaining importance due to their higher efficiency, which reduced the doze of fertilizer from kilograms to milligrams.

Recently, the Indian government gave approval for its use in agriculture, making nano-urea as first nano-technology based fertilizer for commercial use. The product has been included in schedule VII of the fertilizer control order 1985. IFFCO nano urea (liquid) contains 4.0% of total N (w/v) evenly dispersed in water. The size of the particles varies between 20-50 nm (55,000 times smaller than 1 mm urea granule). Most research studies claim that nano-urea can reduce the nitrogen demand by 50% in various field crops (Kumar *et al*., 2020) [13]. Strikingly, IFFCO claims that one bottle of nano-urea containing 20 g N (nano formulation) can replace one bag of urea (21 kg N). Furthermore, there is still no scientific base of the claims made by IFFCO. Henceforth, the research has been conducted on high nitrogen-demanding fodder crops, specifically maize to obtain valid results. Fodder maize responds to both upper and lower levels of nitrogen. This research was focused on using nano-urea in fodder maize to increase the biomass yield, minimize fertilizer consumption and increase farmer revenue.

Materials and Methods

Site details

A field trial was conducted at the Main Agriculture Research Station (MARS), University of Agricultural Sciences, Dharwad (Karnataka) during 2021 and 2022. Geographically, the experimental site situated at 15° 29' 47" N latitude, 74° 59' 06" E longitude and at an altitude of 678 m above MSL (Mean sea level).

Soil status

The soil of experimental site was neutral in pH (7.76), clay loam in texture, medium in organic carbon (0.65%), low in available N (219.7 kg ha^{-1}) and medium in available P (25.2 kg ha^{-1}) and K (236.4 kg ha^{-1}).

Treatments description

The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial concept, consisting eighteen treatment combinations including two checks and replicated thrice. Factor A consist of four levels of RDN (N_0-0; N_1-25%; N_2-50% and N_3-75% RDN), factor B consist two concentration of nano-urea (C_1-2 ml and C_2-4 ml l^{-1} of water) and factor C consist of frequency of sprays (S_1-twice at 20 and 40 DAS and S_2-thrice at 20, 40 and 60 DAS) along with two checks (absolute control for N and recommended package of practices). The recommended dose of fertilizer for fodder maize i.e., 150:100:50 kg N, P_2O_5, K_2O ha^{-1} and nitrogen fertilizer varied as per the treatments (0, 25%, 50% and 75% RDN). The fodder maize (African tall) was sown with seed rate of 60 kg ha^{-1} during the 2nd fortnight of July (20210 and the Ist fortnight of June (2022) with a spacing of 30 × 10 cm.

Biometric data observations

To measure growth parameters, five plants were randomly selected from the net plot area and tagged for consistent observation throughout the experiment period.

Economic analysis

The economics of each treatment were calculated based on the prevailing market prices of inputs and outputs for production and expressed as cost of cultivation, gross return, net return, and the benefit-to-cost ratio in the table.

Statistical analysis

Experimental data obtained on various parameters were subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984) [9]. The level of significance used in 'F' and 't' test was set P= 0.05. Critical difference values were calculated wherever the 'F' test was significant. Besides, the mean values of various factors and interactions were separately subjected to Duncan Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values.

Results and Discussion

Growth attributers

The growth attributes *viz*., plant height, leaf area, leaf stem ratio, SPAD value (41.1) and dry matter production (Table 1) was significantly influenced for each incremental dose of N from N_0 to N_3. Significantly higher plant (244.1 cm), leaf area (60.69 dm^2 $plant^{-1}$), leaf stem ratio (0.40) and dry matter production (103.08 dm^2 $plant^{-1}$) was recorded with the application of 75% of recommended dose of nitrogen (N_4, 112.5 kg N ha^{-1}) as compared to the rest of N levels. This might be the result of an abundant supply of nitrogen simulate shoot development by increasing cell division and elongation, leading to better light interception for photosynthesis. This in turn reflects various growth attributes in fodder maize and sorghum. It could also be due to the production of tryptophan amino acids, which aids in cell elongation and thus increases leaf area. Our results were in agreement with the reports of Yadegari (2013) [26], Rajesh *et al*. (2021) [15], Bhaurao (2022) [7] and Srivani *et al*. (2022) [24] who noticed higher growth attributes with increased levels of N.

Between the nano-urea concentration, application of nao-urea @ 4 ml l^{-1} of water resulted in significantly higher significantly higher plant (197.4 cm), leaf area (38.08 dm^2 $plant^{-1}$), leaf stem ratio (0.32), SPAD value (36.7) and dry matter production (73.99 dm^2 $plant^{-1}$) over 2 ml concentration. This phenomenon could be attributed to the rapid absorption and efficient translocation of nano-fertilizers by the plant, leading to an elevated rate of photosynthesis especially at higher nano-urea concentrations. These results were in tune with the findings of. Abdel-Salam (2018) [1], Ajithkumar *et al*. (2021) [2] and Rajesh *et al*. (2021) [15] who reported higher levels of photosynthesis with higher nano-urea concentrations The frequency of nano-urea spray did not significantly influence various growth parameters such as plant height, leaf area, leaf stem ratio and chlorophyll content. The additional spray at 60 DAS in three applications did not have a positive effect, possibly due to the severe deficiency resulting from reduced fertilizer dosage through conventional urea. This reduction in growth rate of the fodder maize between each subsequent application of nano-urea might fail to meet the nitrogen demand of fodder crops for optimum growth. The results were in line with Goud *et al*. (2022) [10] in sunflower.

The growth attributes were significantly influenced by the interaction effect of nitrogen levels, nano-urea concentration and frequencies of spray. Significantly higher plant height (252.2 cm), leaf area (66.54 dm^2 $plant^{-1}$), leaf stem ratio (0.41), SPAD value (41.8) and dry matter production (108.53 g $plant^{-1}$) was observed with the application of 75% RDN with three sprays of nano-urea @ 4 ml l^{-1} water ($N_3C_2S_2$). However, it was on par with $N_3C_2S_1$, $N_3C_1S_2$ and $N_3C_1S_1$ combinations for plant height, leaf stem ratio and SPAD value and with $N_3C_2S_1$ combination for leaf area and dry matter production. When the interactions were compared with checks (control (N) and RPP), RPP (recommended package of practices) recorded significantly higher plant height (271.1 cm), leaf area (73.04 dm^2 $plant^{-1}$), leaf stem ratio (0.44), SPAD value (43.8) and dry matter production (121.96 g $plant^{-1}$) as compared with rest of the treatment combinations. The higher growth attributes in RPP may be attributed to the exhaustive nature of maize which demand higher nitrogen fertilizer for its optimum growth which may not met by substitution of conventional urea with nano-urea. The balance supply N through RPP might have improved chlorophyll content, cell division, photosynthetic rate and root activities in plants. These effects lead to increased nutrient uptake and ultimately resulted in taller plants. Similar observations have also been reported by Rathnayaka *et al*. (2018) [17], Salama and Badry (2020) [18] and Sharma *et al*. (2022) [23]. Further, these activities promoted internodal elongation, increased the number of leaves, expanded leaf area and dry matter production with higher nitrogen levels. The increased in leaf area with the recommended package of practices may be attributed to the production of tryptophan amino acid which in turn promotes cell division and elongation lead to increased leaf surface area. The results were in tune with the findings of Ajithkumar *et al*. (2021) [2], Bhaurao (2022) [7] and Samanta *et al*. (2022) [19], Tilak (2022) [25] also observed higher growth attributing characteristics in RPP as compared with combined application of urea with liquid nano-urea.

Green fodder yield

The green fodder yield of maize increased linearly and significantly for each level of nitrogen. A significantly higher green fodder yield of maize of 40.08 t ha^{-1} was recorded with the application of 75% of RDN (N_4, 112.5 kg N ha^{-1}) over other N levels. The increase in the green and dry fodder yield with higher dose of nitrogen (N_3) may be attributed to its increased nitrogen uptake, which directly contributes to photosynthesis as a constituent of chlorophyll pigment. This, in turn aids in achieving higher crop growth rate and greater accumulation of dry matter. The present findings were in agreement with the reports of Sankar *et al*. (2020) [21], Samui *et al*. (2022) [20], and Kashyap *et al*. (2023) [11] who observed that higher levels of N through conventional urea increased the yield in various crops.

Between nano-urea concentrations, application of nano-urea @ 4 ml l^{-1} of water recorded significantly higher green fodder yield (29.43 t ha^{-1}) as compared to 2 ml l^{-1} water. Fodder maize respond favorably to higher nano-urea concentration compared to lower concentration due to its high demand for N fertilizer, which leads to increased nitrogen uptake for the accumulation of higher dry matter over lower concentration. The visible growth resulting from different concentrations of nano-urea are evidenced in the fluctuations in plant height, leaf count, leaf area, leaf: stem ratio and dry matter accumulations (DMA) at various growth stages and ultimately contributing to increased green fodder yield. Similar response of increased yield with higher nano-urea concentration was reported by Rajesh *et al*. (2021) [15] in sweet corn, Goud *et al*. (2022) [10] in sunflower and Navya *et al*. (2022) [14] in mustard. The frequency of nano-urea spray had no significant influence on the green fodder yield of maize during both the years of experimentation. However, three sprays of nano-urea at 20, 40 and 60 DAS produced higher green fodder yield over two sprays. This might be due to the no positive response of frequency of spray on various growth attributes ultimately reflects on green fodder yield in maize.

Irrespective of nano-urea spray concentration and frequency of sprays, there was a linear and significant increase in green fodder yield of maize with interactions of increasing levels of RDN during both the years. Among the treatment combinations, application of 75% RDN with three sprays of nano-urea @ 4 ml l^{-1} water recorded significantly higher green fodder yield (42.15 t ha^{-1}). However, it was on par with $N_3C_2S_1$ (40.88 t ha^{-1}), $N_3C_1S_2$ (39.06 t ha^{-1}) and $N_3C_1S_1$ (38.21 t ha^{-1}) combinations. By contrast, sole nano-urea sprayed treatments without conventional N application ($N_0C_2S_2$, $N_0C_2S_1$, $N_0C_1S_2$ and $N_0C_1S_1$) recorded significantly lower green fodder yield across each year and in pooled. When the interactions were compared with checks (control (N) and RPP), RPP (with 150 kg N ha^{-1}) was significantly superior in green fodder yield (46.52 t ha^{-1}) as compared to all other treatment combinations. In RPP application of nitrogen only through conventional urea supported the prolonged accumulation of carbohydrates which enhanced the green leaf retention (leaf area duration) for a considerable period of time. The well-balanced supply of nutrients in response to crop demand significantly increased various growth-related attributes including plant height, leaf count, leaf area, leaf-to-stem ratio and accumulation of dry matter which were highly contributing for increased fodder yield of maize. The drying of lower leaves and yellowing of upper leaves has reduced the leaf area for photosynthesis which had negative impact on dry matter accumulation in fodder maize with decreased dose of N (By 25 -100%) through nano-urea. The above findings were in agreement with Khalil *et al*. (2019) [12] in maize, Bhaurao (2022) [7] in maize, Sharma *et al*. (2022) [23] in pearl millet and Sarkar *et al*. (2023) [22] who reported that replacing 25 or 50% of RDN with nano-urea reduced the wheat yield by 14.81 and 28.26% when compared to RDN.

Economics

The ultimate aim of a farmer is to obtain a high return on every rupee invested. The economic feasibility of the conjunctive use of urea with liquid nano-urea in fodder maize is depicted in Figure1. The significantly highest gross returns (Rs. 1,00,194 ha^{-1}), net returns (Rs. 57,659 ha^{-1}) and B:C ratio (2.35) were recorded with application of 75% RDN as compared to other N levels. This is attributed mainly to higher green fodder yield in fodder maize. Higher economic returns realized by the use of higher levels of N was also reported by Devi *et al*. (2014) [8] and Bedse *et al*. (2015) [6].

Between nano-urea concentrations, significantly higher gross returns (Rs. 73,564 ha^{-1}), net returns (Rs. 32,328 ha^{-1}) and benefit cost ratio (1.77) were recorded with the application of nano-urea @ 4 ml l^{-1} of water as compared to the 2 ml spray of nano-urea. The frequency of nano-urea spray had no significant effect on the gross returns, net returns and B: C ratio in fodder maize during both years of experiment. This be attributed to the absence of any additional advantage in green fodder yield in maize through an additional spray of nano-urea.

Among the interactions, application of 75% RDN with three spray of nano-urea recorded significantly higher gross returns (Rs. 1,05,383 ha^{-1}), net returns (Rs. 61,726 ha^{-1}) and benefit cost ratio (2.41). However, it was on par with $N_3C_2S_1$ for gross returns and with $N_3C_2S_1$, $N_3C_1S_2$ and $N_3C_1S_1$ combinations for net returns and B: C ratio. When the interactions were compared with checks (control (N) and RPP), RPP recorded significantly higher gross returns (Rs. 1,16,301 ha^{-1}), net returns (Rs. 75,537 ha^{-1}) and B:C ratio (2.85) as compared with rest of interactions. This was due to the increased labour costs for spraying nano-urea at different intervals and the cost of nano-urea itself. Conventional urea on the other hand, was found to be both cost-effective and convenient for application resulting in increased fodder yields of maize. These findings were consistent with the research of Sankar *et al*. (2020) [21], Bhaurao (2022) [7], Goud *et al*. (2022) [10] and Rajesh *et al*. (2022) [16]. They observed higher net returns with the application of full dose conventional nitrogen compared to its substitution with nano-urea.

Table 1: Growth attributes of fodder maize as influenced by conjunctive use of urea with liquid nano-urea at harvest (Mean of 2 years)

Treatment	Plant height (cm)	Leaf area (dm^2 plant^{-1})	Leaf stem ratio	SPAD value	Dry matter production (g plant^{-1})	Green fodder yield (t ha^{-1})
Nitrogen levels (N)						
N_0	129.5^{d}	11.79^{d}	0.23^{d}	29.8^{d}	36.97^{d}	15.30^{d}
N_1	171.7^{c}	25.74^{c}	0.28^{c}	35.2^{c}	58.23^{c}	24.77^{c}
N_2	215.6^{b}	42.90^{b}	0.35^{b}	38.2^{b}	81.78^{b}	31.96^{b}
N_3	244.1^{a}	60.69^{a}	0.40^{a}	41.1^{a}	103.08^{a}	40.08^{a}
S.Em.±	4.48	1.50	0.005	0.63	1.26	0.50
Nano-urea concentrations (C)						
C_1	183.0^{b}	32.47^{b}	0.30^{b}	35.4^{b}	66.04^{b}	26.63^{b}
C_2	197.4^{a}	38.08^{a}	0.32^{a}	36.7^{a}	73.99^{a}	29.43^{a}
S.Em.±	3.17	1.06	0.004	0.45	0.89	0.36
Frequency of spray (S)						
S_1	187.6^{a}	33.96^{a}	0.31^{a}	35.9^{a}	68.46^{a}	27.60^{a}
S_2	192.9^{a}	36.60^{a}	0.31^{a}	36.2^{a}	71.56^{a}	28.45^{a}
S.Em.±	3.17	1.06	0.004	0.45	0.89	0.36
Interaction (N×C×S)						
$N_0C_1S_1$	115.7^{i}	9.81^{h}	0.22^{h}	29.0^{g}	32.54^{i}	13.72^{h}
$N_0C_1S_2$	123.7^{i}	10.82^{h}	0.22^{h}	29.3^{g}	35.12^{hi}	14.70^{h}
$N_0C_2S_1$	136.8^{hi}	12.74^{gh}	0.23^{gh}	30.4^{fg}	38.96^{hi}	16.16^{h}
$N_0C_2S_2$	141.8^{g-i}	13.79^{gh}	0.24^{f-h}	30.7^{e-g}	41.25^{h}	16.62^{h}
$N_1C_1S_1$	161.4^{f-h}	21.53^{fg}	0.26^{e-g}	33.9^{d-f}	51.93^{g}	22.51^{g}
$N_1C_1S_2$	168.2^{fg}	24.47^{f}	0.27^{d-f}	34.5^{c-e}	55.56^{fg}	23.47^{fg}
$N_1C_2S_1$	175.5^{f}	27.75^{f}	0.29^{de}	36.2^{b-d}	61.74^{ef}	26.22^{ef}
$N_1C_2S_2$	181.6^{ef}	29.20^{f}	0.30^{d}	36.1^{b-d}	63.67^{e}	26.87^{e}
$N_2C_1S_1$	207.3^{de}	38.10^{e}	0.34^{c}	37.7^{b-d}	76.42^{d}	30.14^{d}
$N_2C_1S_2$	211.3^{cd}	41.12^{de}	0.34^{c}	37.7^{b-d}	78.40^{d}	31.20^{cd}
$N_2C_2S_1$	219.6^{b-d}	44.57^{de}	0.35^{c}	38.5^{a-c}	82.61^{cd}	32.50^{cd}
$N_2C_2S_2$	224.4^{a-d}	47.80^{cd}	0.36^{bc}	38.9^{ab}	89.69^{c}	34.01^{c}
$N_3C_1S_1$	237.0^{a-c}	54.91^{bc}	0.39^{ab}	40.4^{a}	98.04^{b}	38.21^{ab}
$N_3C_1S_2$	239.7^{a-c}	59.03^{ab}	0.39^{ab}	40.7^{a}	100.30^{b}	39.06^{ab}
$N_3C_2S_1$	247.4^{ab}	62.29^{ab}	0.40^{a}	41.4^{a}	105.44^{ab}	40.88^{ab}
$N_3C_2S_2$	252.2^{a}	66.54^{a}	0.41^{a}	41.8^{a}	108.53^{a}	42.15^{a}
S.Em.±	8.96	3.00	0.011	1.06	2.52	1.25
Checks						
Control (N)	111.0	9.10	0.21	27.8	31.85	13.46
RPP	271.1	73.04	0.44	43.8	121.96	46.52
S.Em.±	8.56	2.86	0.011	1.06	2.83	1.08
C.D. (P=0.05)	24.61	8.23	0.030	3.01	8.12	2.83

Factor A (Levels of RDN)	Factor B (Nano-urea concentration)	Factor C (Frequency of spray)
N_0: 0	C_1: 2 ml l^{-1} water	S_1: Two sprays at 20 and 40 DAS
N_1: 25%	C_2: 4 ml l^{-1} water	S_2: Three sprays at 20, 40 and 60 DAS
N_2: 50%		
N_3: 75%		

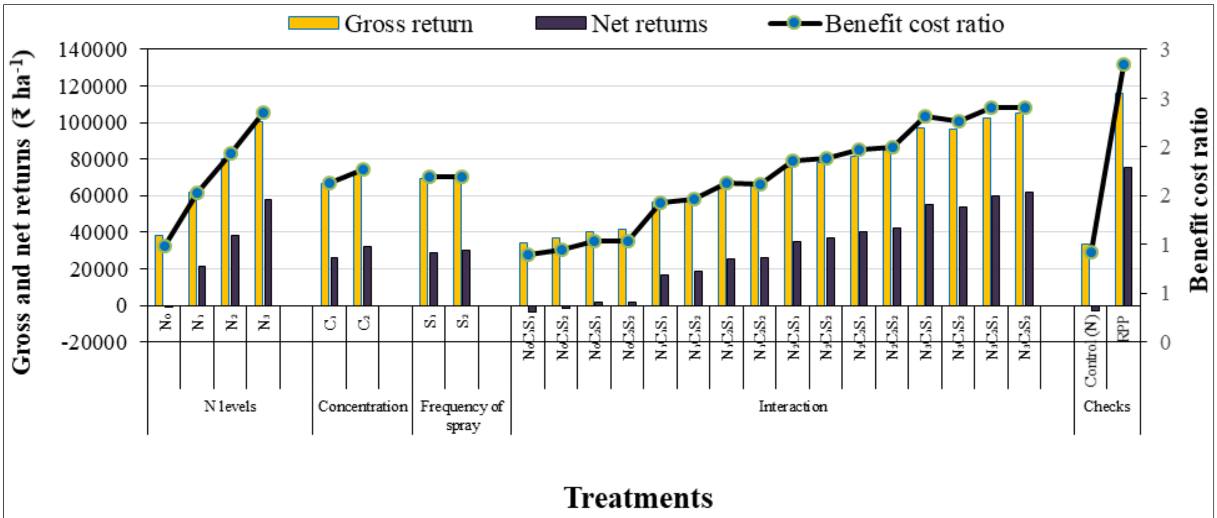

Fig 1: Economics of fodder maize as influenced by conjunctive use of urea with liquid nano-urea

Conclusion

The fodder maize responded positively for higher levels of N through conventional N (75% RDN) and higher concentration of nano-urea (4 ml l^{-1} water) with respective growth and green fodder yield. Among the interactions decreased dose of conventional N, coupled with the inclusion of nano-urea, led to a significant decrease in both growth and green fodder yield in maize. In comparison to RPP, reducing conventional nitrogen by 25-100% resulted in a decrease in green fodder yield ranging from 9.4 to 70.5% in fodder maize. Similarly, net returns decreased by 18.3 to 77.6% with the reduction of conventional nitrogen by 25-75% RDN, regardless of nano-urea concentration and spray frequencies. These findings suggest that there is no advantage to reducing conventional nitrogen through the substitution of nano-urea in fodder maize. Nano-urea appears to fall short in meeting the substantial nitrogen demand with smaller doses of fertilizer

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