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Enhancing the Productivity and Quality of Fodder Maize (*Zea mays*) through Nano Urea

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ABSTRACT

The field experiment was conducted at Zonal Agricultural Research Station, Vishweshwaraiah Canal Farm, Mandya during *kharif* 2022 & 2023 with an objectives of identifying optimum concentrations of Nano urea for obtaining maximum growth, yield and quality in fodder maize under protective irrigated situation. The experiment consisted of ten treatments, which was laid out in randomized block design with three replications. The treatments included were T_1: Control (without N and P & K only) T_2: 100 % recommended dose of fertilizers (150:75:40 NPK kg/ha- 50% N as basal + 50% N at 30 days after sowing), T_3: 75 % recommended dose of N + Nano urea@0.2% @ 20 & 40 DAS, T_4: 50 % recommended dose of N + Nano urea @0.2% applied twice at 20 & 40 DAS, T_5: 75 % recommended dose of N + Nano urea@0.4% applied twice at 20 & 40 DAS, T_6: 50 % recommended dose of N + Nano urea@0.4%@ 20 & 40 DAS, T_7: 75 % recommended dose of N + Nano urea @0.6% @ 20 & 40 DAS, T_8: 50 % recommended dose of N + Nano urea @ 0.6% @ 20 & 40 DAS, T_9: 75 % recommended dose of N + urea (2 % spray) twice @ 20 & 40 DAS, T_{10}: 50 % recommended dose of N + urea (2 % spray) twice @ 20 & 40 DAS. The pooled data revealed that, application of 100 per cent recommended dose of nitrogen recorded significantly higher plant height (277.5 cm), leaf stem ratio (0.38), green forage (479.2 q ha^{-1}), dry matter (100.5 q ha^{-1}) and crude protein yield (5.88 q ha^{-1}). Similarly, higher gross, net returns and benefit cost ratio was also recorded with application of 100 per cent recommended dose of fertilizer (109318 Rs ha^{-1}, 77098 Rs ha^{-1} and 3.39, respectively).

Keywords : Fodder maize, Nano urea, Green fodder yield, Dry matter yield, Crude protein yield

MAIZE (*Zea mays* L.) is widely cultivated and known for its ability to withstand varied agro-climatic conditions (Arya *et al.,* 2015 and Kumar *et al.,* 2020a). It is the most suitable fodder crop due to its rapid growth, palatability, succulence and excellent quality of fodder for silage making without any anti-nutritional factors at all stages of crop growth Shekara *et al.* (2019). Maize being highly exhaustive, it demands more nutrients for growth and yield (Kumar *et al.,* 2017). Along with sweet and baby corn, maize is also farmed as a primary animal feed grain and for green fodder'. Maize is the state's main supply of green fodder and cattle feed due to the dairy industry's dominance. By providing energy and vital nutrients through bio-fortified maize hybrids, maize can be a vital component in bridging the quantitative and qualitative gap between the supply and demand of feed and fodder. Additionally, maize has become one of the state's most significant crops for industrial use (Mahadevu *et al.,* 2020). Selecting a source of nitrogen to achieve maximum production with minimum adverse environmental effects is essential for gaining higher yield and nitrogen use efficiency. Nitrogen fertilizers play an important role improving the quantity and quality of fodder maize. Nitrogen forms 1 per cent of the total dry matter of the plant and its deficiency reduces the production of chlorophyll, amino acids and energy, which has a direct impact on growth and yield (Patel *et al.,* 2007). Excessive and improper usage of nitrogen fertilizer causes problems for humans, the environment and crops. It is essential for a suitable alternative source of nitrogen which reduces harm to the environment and human beings.

Nano-fertilizers are either raw fertilizer components, manufactured or modified versions of conventional fertilizers or extracts from plants, microorganisms or animals (Husen and Iqbal, 2019). Nano fertilizers enable plants to absorb nutrients efficiently without suffering losses due to leaching, volatilization, fixation, and other processes by gradually releasing nutrients over the course of the crop's growth period (Guru *et al.*, 2015). Due to their high surface area to volume ratio, which makes them easier for plants to absorb (Al-Juthery and Saadoun, 2018). Nano fertilizers also have a lower nutrient loss than conventional fertilizers, which leads to a 20–30 per cent increase in use efficiency (Kumar *et al*., 2020a and Kumar *et al*., 2020b).

The ability of nano particles or nano encapsulated nutrients to efficiently release nutrients on demand to control plant growth and increase activity of enzymes (Derosa *et al.,* 2010). When compared to conventional fertilizers, foliar application of nano fertilizers may increase nutrient output and improve plant nutrition. By using nano fertilizers, one can meet the nutritional needs of plants by prolonging the period and rate at which elements are released in the plant system (Kumar *et al.,* 2021). The crop output will rise as a result of the plant's ability to absorb the most nutrients. The efficiency of urea is 30-35 per cent and subjected to various losses, hence recent technology of nano particles containing nitrogen may be alternative source of nitrogen fertilizers which required small quantity, slow and controlled release of nitrogen and enhancing the nutrient use efficiency, its enhancing nutrient use efficiency, crop productivity and economic returns (Kumar *et al.,* 2020b). Therefore, the experiment is proposed to assess the effect of nano urea on the productivity and quality of fodder maize and its nitrogen use efficiency.

Material and Methods

The present investigation was carried out at Zonal Agricultural Research Station, Vishweshwaraiah Canal Farm, Mandya, University of Agricultural Sciences, Bangalore, Karnataka under all India Coordinated Research Project on Forage Crops during *kharif* 2022 & 2023 with objectives of identifying optimum concentrations of Nano urea on growth, yield and quality of fodder maize under irrigated situation. The experimental site is situated in the Southern Dry Zone (ACZ-VI) of Karnataka and 695 meters above mean sea level. It is positioned between 12° 45' and 13° 57' North latitude and 76° 45' and 78° 24' East longitude. The soil is sandy loam in texture at the experimental location has a neutral soil reaction of 7.11, low organic carbon (0.44%), medium levels of accessible phosphorus (45.8 Kg/ha), potassium (159.2 Kg/ha) and low levels in available nitrogen (242.0 Kg/ha).

Two sprays of nano urea and urea were given at 20 and 40 days after sowing, keeping the spray solution of 500 liters of water per hectare. The treatments were replicated thrice in a randomized complete block design. The well known fodder maize variety African Tall was sown during 3rd week of July at a row spacing of 30 cm. The cultural operations and other production practices were followed as per package of practices. The crop was harvested when the crop attained dough stage and the known quantity of random samples of green fodder was obtained from each plot at the time of harvest for the purpose of analyzing the quality of the fodder. These samples were dried undershade for a few hours and then oven dried at temperature of 70±2 °C until they reached a constant weight. The known quantity of powdered samples was collected in order to analyze the nitrogen content of the plant using the micro-Kjeldahl method (Jackson, 1973) and other quality parameters. The yield of green fodder was converted into a dry matter yield based on the dry matter content of the samples. The powdered

The ten treatments combinations of the experiments are as mentioned below,

Treatment Number	Treatment details
T_1	Control (without N and P & K only)
T_2	100 % recommended dose of fertilizers (150:75:40 NPK kg/ha- 50% N as basal +50% N at 30 DAS)
T_3	75 % recommended dose of N + Nano urea@0.2% @ 20 & 40 DAS
T_4	50 % recommended dose of N + Nano urea @0.2% applied twice at 20 & 40 DAS
T_5	75 % recommended dose of N + Nano urea@0.4% applied twice at 20 & 40 DAS
T_6	50 % recommended dose of N + Nano urea@0.4%@ 20 & 40 DAS
T_7	75 % recommended dose of N + Nano urea @0.6% @ 20 & 40 DAS
T_8	50 % recommended dose of N + Nano urea @ 0.6% @ 20 & 40 DAS
T_9	75 % recommended dose of N + urea (2 % spray) twice @ 20 & 40 DAS
T_{10}	50 % recommended dose of N + urea (2 % spray) twice @ 20 & 40 DAS

samples were also used to determine the yield and content of crude protein (A.O.A.C., 1965). The formula used by Iqbal *et al.* (2013) was used to get the total digestible crude protein yield. The economics was worked out with prevailing market price and data was statistically analyzed for interpretation of results and draw valued conclusions. The leaf stem ratio, dry matter content, dry matter yield, crude protein content crude protein yield, B:C ratio and per day productivity of green fodder and dry matter were computed by using following formulae.

$$\text{Leaf stem ratio} = \frac{\text{Fresh weight of leaves}}{\text{Fresh weight of stem}}$$

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of sample (g)}}{\text{Fresh weight of sample (g)}} \times 100$$

$$\text{Dry matter yield (q/ha)} = \frac{\text{Dry matter \%} \times \text{Green forage yield (q ha}^{-1}\text{)}}{100}$$

$$\text{Crude protein (\%)} = \text{Nitrogen content (\%)} \times 6.25$$

$$\text{Crude protein yield (q/ha)} = \frac{\text{Crude protein \%} \times \text{Dry matter yield (q ha}^{-1}\text{)}}{100}$$

$$\text{Per day green fodder productivity (q/ha/day)} = \frac{\text{Green fodder yield (q ha}^{-1}\text{)}}{\text{No. of days taken for harvest}}$$

$$\text{Per day dry matter productivity (q/ha/day)} = \frac{\text{Dry matter yield (q ha}^{-1}\text{)}}{\text{No. of days taken for harvest}}$$

$$\text{Benefit: Cost ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

$$\text{Total digestible crude protein yield (q ha}^{-1}\text{)} = [0.97 \times \text{crude protein yield}] - 0.67$$

$$\text{Crude fiber yield (\%)} = \frac{\text{(Weight of the sample before ashing) - (Weight of the sample after ashing)}}{\text{Weight of the dried plant sample taken}} \times 100$$

CF (%) ={(W1-W2)/ W0}×100

Where,

W1 = Weight of residue after acid and alkali digestion (g)

W2 = Weight of ash after ignition (g)

W0 = Initial sample weight (g)

$$\text{Crude fiber yield (q ha}^{-1}\text{)} = \frac{\text{Crude fiber (\%)} \times \text{Dry matter yield (q ha}^{-1}\text{)}}{100}$$

Results and Discussion

Plant height : The plant height differed significantly with the varied levels of nitrogen with foliar combinations of urea and nano urea is presented in Table 1. The mean plant height recorded at harvest was significantly influenced by varied nitrogen levels. The significantly higher mean plant height was recorded with application of 100 per cent recommended dose of nitrogen (277.5 cm). The control *i.e.,* no nitrogen treatment recorded significantly lower plant height (164.0 cm). This may be attributed to application of more nutrients during early vegetative growth and crop development stages, which led to maximum plant height. Apart from this nitrogen plays a pivotal role in photosynthetic activity and protein synthesis which might promote cell division and cell elongation that in turn accelerate vegetative growth. This is in conformity with the findings of Rana *et al.* (2013); Somashekar *et al.* (2015); Lahari *et al.* (2021) and Navya *et al.* (2022).

Leaf stem ratio: The mean leaf stem ratio was significantly higher with application of 100 per cent recommended dose of nitrogen (0.38). Whereas, lower leaf stem ratio was recorded with no nitrogen treatment (0.28). It is mainly due to rapid expansion of dark green foliage which intercept more solar radiation for the production of photosynthesis, which resulted in higher meristematic activity and nitrogen also influences on cell division and cell elongation which produced more functional leaves for longer period of time. The similar results were reported by Kumawat *et al.* (2016), Vimal *et al.* (2017) and Lagad *et al.* (2020).

Green forage yield : The mean green fodder yield was significantly influenced by nitrogen levels (Table 2). Application of 100 per cent recommended dose of fertilizers recorded higher green forage yield (479.2 q/ha), which was on par with application of 75 per cent recommended nitrogen with urea 2 per cent spray and nano urea @ 0.6% spray twice at 20

Table 1

Growth parameters of forage maize as influenced by nano urea recorded at harvest

Treatments	Plant height (cm)			Leaf Stem Ratio		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	132.9	195.0	164.0	0.30	0.26	0.28
T2 : RDF (N:P:K @150:60:40 kg/ha)	215.0	340.0	277.5	0.42	0.34	0.38
T3 : 75% recommended dose of N + Nano urea @0.2%	184.3	320.4	252.3	0.35	0.31	0.33
T4 : 50% recommended dose of N + Nano urea @0.2%	169.3	304.2	236.7	0.34	0.27	0.30
T5 : 75% recommended dose of N + Nano urea @0.4%	192.7	324.3	258.5	0.37	0.33	0.35
T6 : 50% recommended dose of N + Nano urea @0.4%	176.2	308.1	242.1	0.35	0.31	0.33
T7 : 75% recommended dose of N + Nano urea @0.6%	203.4	332.5	267.9	0.39	0.34	0.37
T8 : 50% recommended dose of N + Nano urea @0.6%	180.6	317.2	248.9	0.37	0.32	0.34
T9 : 75% recommended dose of N + Urea (2 % spray)	207.3	335.7	271.5	0.40	0.33	0.37
T10 : 50% recommended dose of N + Urea (2 % spray)	172.9	316.8	244.9	0.34	0.31	0.33
S. Em±	5.4	13.8	9.6	0.02	0.02	0.02
C.D at 5%	16.2	41.0	28.6	0.06	0.05	0.06

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS)

TABLE 2

Green forage and dry matter yield parameters of forage maize as influenced by nano urea recorded at harvest

Treatments	Green Forage Yield (q ha^{-1})			Dry Matter Yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	215.2	207.9	211.6	33.9	35.5	34.7
T2 : RDF (N:P:K @150:60:40 kg/ha)	419.6	538.9	479.2	82.3	118.7	100.5
T3 : 75% recommended dose of N + Nano urea @0.2%	356.8	424.4	390.6	65.3	79.3	72.3
T4 : 50% recommended dose of N + Nano urea @0.2%	315.1	354.9	335.0	54.0	65.3	59.6
T5 : 75% recommended dose of N + Nano urea @0.4%	371.4	441.3	406.3	68.4	80.9	74.6
T6 : 50% recommended dose of N + Nano urea @0.4%	333.5	376.3	354.9	59.2	67.9	63.5
T7 : 75% recommended dose of N + Nano urea @0.6%	383.9	476.3	430.1	74.6	100.0	87.3
T8 : 50% recommended dose of N + Nano urea @0.6%	334.0	410.4	372.2	59.8	77.7	68.7
T9 : 75% recommended dose of N + Urea (2% spray)	397.8	482.1	439.9	77.8	101.4	89.6
T10 : 50% recommended dose of N + Urea (2% spray)	333.6	419.1	376.4	56.5	86.8	71.6
S. Em±	18.3	22.3	20.3	3.7	5.6	4.7
C.D at 5%	54.7	66.1	60.4	9.9	16.7	13.3

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS)

and 40 days after sowing (439.9 q and 430.1 q ha^{-1}, respectively). The trend was similar during both the years of the study. The no nitrogen treatment recorded significantly lower mean green fodder yield (211.6 q ha^{-1}). This is mainly due to nitrogen playing a pivotal role in metabolic processes in plants, such as cell division and expansion, enzymatic activity, photosynthetic efficiency and meristematic activity, which led to better vegetative growth, which is evidenced by higher plant height and leaf stem ratio, which in turn resulted in higher green biomass production. The findings of Singh and Sumeria (2010), Bhoya *et al*. (2013) and Meena *et al*. (2021) also confirmed the same results. The highest forage yield with nano urea was confirmed with the findings of Abdel (2018), Naveena *et al*. (2021a) and Shekara *et al*. (2022).

Dry Matter Yield : The dry matter yield was significantly influenced by the levels of nitrogen (Table 2). Application of recommended dose of fertilizer recorded significantly higher dry matter yield on pooled basis (100.5 q ha^{-1}), which was on par with application of 75 per cent recommended nitrogen along with urea 2 per cent spray and nano urea 0.6 per cent spray twice at 20 & 40 days after sowing (89.6 q and 87.3 q ha^{-1}, respectively). The no-nitrogen treatment recorded significantly lower dry matter yield (34.7 q ha^{-1}); a similar trend was observed during both the years of study. The increased dry matter yield might be due to enhanced crop growth and photosynthetic activity which led to better supply of carbohydrates, better partitioning of photosynthates and higher accumulation of nutrients ultimately resulting in higher dry matter content and green biomass yield. Which led to higher dry matter yield. The similar findings were reported by Singh *et al.* (2012); Meena *et al.* (2021); Naveena *et al.* (2021b), Theerthana *et al.* (2022) and Shekara *et al.* (2024).

Per day productivity of green fodder : The application of different levels of nitrogen along with foliar spray of urea and nano urea significantly influences the per day productivity of green fodder (Table 3). The pooled mean data revealed that application of 100 per cent recommended dose of fertilizers recorded significantly higher per day green fodder yield (5.99 q ha^{-1} day^{-1}), which was on par with application of 75 per cent recommended nitrogen with urea 2 per cent foliar spray twice at 20 and 40 days after sowing (5.46 q ha^{-1} day^{-1}). Whereas, no nitrogen treatment recorded lower per day green fodder yield (2.63 q ha^{-1} day^{-1}), The trend was similar during both the years of study. The narrow difference in time taken for harvest due to attaining the dough stage of cob, which is the right time of harvest in fodder maize and difference in green fodder yield potential might be the reason for variation in per day green fodder yield in the present study. Similar results were also reported by Prajapati (2017), Jha and Tiwari (2018) and Manoj (2020).

Per day productivity of dry matter : The per day yield of dry matter was significantly influenced by varied levels of nutrients especially nitrogen applied in the form of urea and nano urea (Table 3). The pooled mean data indicated that application of 100 per cent recommended nutrients recorded significantly higher per day dry matter yield (1.11 q ha^{-1} day^{-1}). Whereas, no nitrogen treatment recorded lower per day productivity of dry matter (0.43 q ha^{-1} day^{-1}). The trend was similar during both the years of study. The higher per day productivity of dry matter with higher levels of nutrients is due to higher dry matter content and green fodder yield. These results are in accordance with the findings of Prajapati (2017), Jha & Tiwari (2018) and Manoj (2020).

Crude Protein Yield : The crude protein yield is one of the important quality parameters and it was significantly influenced by nitrogen levels. Application of 75 per cent recommended nitrogen with

TABLE 3

Per day productivity of green fodder and dry matter yield of forage maize as influenced by nano urea recorded at harvest

Treatments	Per day productivity (q ha^{-1} day^{-1})					
	Green Forage Yield			Dry Matter Yield		
	2022	2023	Mean	2022	2023	Mean
T1: Control (without N)	2.67	2.59	2.63	0.42	0.44	0.43
T2: RDF (N:P:K @150:60:40 kg/ha)	5.25	6.74	5.99	1.03	1.48	1.26
T3: 75 % recommended dose of N + Nano urea @0.2%	4.40	5.24	4.82	0.81	0.98	0.89
T4: 50 % recommended dose of N + Nano urea @0.2%	3.94	4.36	4.15	0.68	0.80	0.74
T5: 75 % recommended dose of N + Nano urea @0.4%	4.60	5.45	5.02	0.85	1.00	0.92
T6: 50 % recommended dose of N + Nano urea @0.4%	4.12	4.66	4.39	0.73	0.84	0.79
T7: 75 % recommended dose of N + Nano urea @0.6%	4.78	5.90	5.34	0.93	1.24	1.08
T8: 50 % recommended dose of N + Nano urea @0.6%	4.19	5.13	4.66	0.75	0.97	0.86
T9: 75 % recommended dose of N + Urea (2 % spray)	4.91	6.00	5.46	0.96	1.26	1.11
T10: 50 % recommended dose of N + Urea (2 % spray)	4.14	5.22	4.68	0.70	1.08	0.89
S. Em±	0.23	0.28	0.14	0.05	0.07	0.04
C.D at 5%	0.92	1.15	0.58	0.19	0.29	0.16

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS) urea 2 per cent spray twice at 20 and 40 days after sowing significantly recorded higher crude protein yield (5.88 q ha^{-1}) on pooled mean basis and it was on par with 100 per cent recommended dose of nutrients (5.44 q ha^{-1}) and 75 per cent recommended nitrogen along with nano urea 0.6 per cent spray twice at 20 & 40 days after sowing (5.10 q ha^{-1}) and trend was similar during both the year of study. The no-nitrogen treatment recorded lower crude protein yield (2.13 q ha^{-1}). This might be due to nitrogen being constituents of amino acids and regulates cellular metabolism of amino acids and proteins that forms biological catalysts of phosphorylated compounds involved in energy transformation. It's a structural constituent of cell and cell wall, thus, increasing the quality of fodder by improving the protein content. Similar results were reported by Shekara *et al.* (2015) and Meena *et al* (2021).

Total digestible crude protein yield : Application of different levels of nutrients had a significant influence on total digestible crude protein (Table 5). The pooled mean data revealed that application of 75 per cent recommended nitrogen + urea 2 per cent spray twice at 20 & 40 days after sowing recorded significantly higher total digestible crude protein yield (5.04 q ha^{-1}). Which was on par with 100 per cent recommended nutrients (4.61 q ha^{-1}) and 75 per cent recommended nitrogen + nano urea 0.6 per cent spray twice at 20 & 40 days after sowing (4.28 q ha^{-1}), Whereas no nitrogen treatment recorded lower total digestible crude protein (1.39 q ha^{-1}). The increased total digestible crude protein yield with higher level of nutrients is due to higher crude protein yield and content, it is further evidenced by strong positive correlation between crude protein yield and total digestible crude protein yield. These results are in line with the findings of Bilal *et al.* (2016). The similar trend was noticed during both the years of study.

Crude fiber Yield : The crude fiber yield was significantly influenced by varied nitrogen levels and concentrations of urea and also nano urea as a source of nitrogen (Table 6). The pooled data revealed that

TABLE 4

Quality parameters of forage maize as influenced by nano urea recorded at harvest

Treatments	Dry Matter (%)			Crude Protein (%)		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	15.8	17.0	16.4	6.3	6.02	6.1
T2 : RDF (N:P:K @150:60:40 kg/ha)	19.6	22.0	20.8	5.6	5.29	5.4
T3 : 75% recommended dose of N + Nano urea @0.2%	18.3	18.7	18.5	7.0	6.76	6.9
T4 : 50% recommended dose of N + Nano urea @0.2%	17.2	18.3	17.8	7.1	6.76	6.9
T5 : 75% recommended dose of N + Nano urea @0.4%	18.5	18.3	18.4	5.0	5.00	5.0
T6 : 50% recommended dose of N + Nano urea @0.4%	17.8	18.0	17.9	4.8	4.85	4.8
T7 : 75% recommended dose of N + Nano urea @0.6%	19.5	21.0	20.2	6.0	5.73	5.8
T8 : 50% recommended dose of N + Nano urea @0.6%	17.9	19.0	18.5	6.3	5.88	6.1
T9 : 75% recommended dose of N + Urea (2 % spray)	19.5	21.0	20.3	6.9	6.32	6.6
T10 : 50% recommended dose of N + Urea (2 % spray)	16.9	20.7	18.8	5.8	5.73	5.8
S. Em±	0.5	0.6	0.4	0.2	0.25	0.2
C.D at 5%	2.1	1.8	1.3	0.7	0.76	0.7

Note :RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS)

TABLE 5

Crude protein and total digestible crude protein yield of forage maize as influenced by nano urea recorded at harvest

Treatments	Crude Protein Yield (q ha^{-1})			Total digestible crude protein yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	2.12	2.13	2.13	1.39	1.40	1.39
T2 : RDF (N:P:K @150:60:40 kg/ha)	4.58	6.30	5.44	3.77	5.44	4.61
T3 : 75% recommended dose of N + Nano urea @0.2%	4.59	5.34	4.96	3.78	4.51	4.15
T4 : 50% recommended dose of N + Nano urea @0.2%	3.85	4.41	4.13	3.06	3.60	3.33
T5 : 75% recommended dose of N + Nano urea @0.4%	3.40	4.05	3.73	2.63	3.26	2.95
T6 : 50% recommended dose of N + Nano urea @0.4%	2.87	3.31	3.09	2.11	2.54	2.32
T7 : 75% recommended dose of N + Nano urea @0.6%	4.45	5.75	5.10	3.65	4.91	4.28
T8 : 50% recommended dose of N + Nano urea @0.6%	3.74	4.56	4.15	2.96	3.75	3.36
T9 : 75% recommended dose of N + Urea (2 % spray)	5.36	6.41	5.88	4.53	5.55	5.04
T10 : 50% recommended dose of N + Urea (2 % spray)	3.29	4.98	4.13	2.52	4.16	3.34
S. Em±	0.29	0.45	0.37	0.28	0.44	0.25
C.D at 5%	1.19	1.34	1.27	1.16	1.78	1.01

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS)

TABLE 6

Crude fiber content and yield of forage maize as influenced by nano urea recorded at harvest

Treatments	Crude fiber (%)			Crude fiber yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	32.9	34.1	33.5	11.1	12.1	11.6
T2 : RDF (N:P:K @150:60:40 kg/ha)	25.4	22.8	24.1	20.9	26.9	23.9
T3 : 75% recommended dose of N + Nano urea @0.2%	26.4	26.9	26.7	17.3	21.4	19.3
T4 : 50% recommended dose of N + Nano urea @0.2%	26.7	27.9	27.3	14.5	18.2	16.3
T5 : 75% recommended dose of N + Nano urea @0.4%	25.7	24.5	25.1	17.5	19.9	18.7
T6 : 50% recommended dose of N + Nano urea @0.4%	28.7	26.4	27.6	17.0	18.0	17.5
T7 : 75% recommended dose of N + Nano urea @0.6%	23.5	23.6	23.5	17.6	23.6	20.6
T8 : 50% recommended dose of N + Nano urea @0.6%	25.8	25.5	25.7	15.4	19.9	17.6
T9 : 75% recommended dose of N + Urea (2 % spray)	21.9	22.5	22.2	17.0	22.8	19.9
T10 :50 % recommended dose of N + Urea (2 % spray)	24.3	25.1	24.7	13.7	21.8	17.8
S. Em±	0.79	0.69	0.64	1.05	1.4	0.65
C.D at 5%	3.21	2.05	1.89	4.28	4.2	1.94

Note : RDF = Recommended dose of fertilizers; Nano-urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS) application of 100 per cent recommended dose of fertilizer recorded significantly higher crude fiber yield (23.9 q ha^{-1}). Whereas, the lower crude fiber yield was observed with no nitrogen treatment (11.6 q ha^{-1}). The similar trend was also observed during both the years of study. This is due to crude fiber yield being a function of dry matter yield and crude fiber content, even though the crude fiber content was lower, the increase in crude fiber yield was mainly due to higher dry matter yield (the total amount of dry plant material) accumulation in plants. These results are in accordance with the findings of Yashas (2016). It is also further evidenced by strong negative correlation between nitrogen and crude fibre content. Similar results were also noticed by Vasileva (2013) and Mubeena *et al.* (2020).

Ash Yield : The Ash yield was significantly influenced by nitrogen levels and concentrations supplied through urea and nano urea (Table 7). The 100 per cent recommended dose of fertilizers recorded significantly higher ash yield (5.27 q ha^{-1}) followed by application of 75 per cent recommended nitrogen + urea 2 per cent spray twice at 20 and 40 days after sowing (4.80 q ha^{-1}). Whereas, no nitrogen treatment recorded significantly lower ash yield (1.36 q ha^{-1}). The trend was similar during both the years of study. The increase in ash yield was mainly due to higher dry matter yield and slight increase in ash content due to larger quantity of biomass, not by a significant change in the proportion of ash within it.-These results corroborate with the findings of Yashas (2016) and Mubeena *et al.* (2020).

Economic analysis : The higher mean gross, net returns and benefit cost ratio was recorded with application of 100 per cent recommended dose of fertilizer (109318 Rs ha^{-1}, 77098 Rs ha^{-1} and 3.39 respectively) (Table 8) followed by application of 75 per cent nitrogen along with urea 2 per cent spray twice at 20 & 40 days after sowing (100038 Rs ha^{-1}, 66388 Rs ha^{-1} and 2.96, respectively). The no nitrogen treatment recorded lower net returns (17187 Rs ha^{-1}) and BC ratio (1.57). The increased net returns and B:C ratio may be due to higher green forage yield with lower cost of cultivation which resulted in higher

TABLE 7

Ash content and yield of forage maize as influenced by nano urea recorded at harvest

Treatments	Ash (%)			Ash yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	4.09	3.75	3.92	1.39	1.33	1.36
T2 : RDF (N:P:K @150:60:40 kg/ha)	5.25	5.23	5.24	4.32	6.21	5.27
T3 : 75% recommended dose of N + Nano urea @0.2%	4.82	4.58	4.70	3.14	3.63	3.39
T4 : 50% recommended dose of N + Nano urea @0.2%	4.55	4.27	4.41	2.46	2.78	2.62
T5 : 75% recommended dose of N + Nano urea @0.4%	5.21	5.04	5.13	3.56	4.08	3.82
T6 : 50% recommended dose of N + Nano urea @0.4%	5.05	4.96	5.00	2.98	3.37	3.18
T7 : 75% recommended dose of N + Nano urea @0.6%	5.15	5.13	5.14	3.84	5.12	4.48
T8 : 50% recommended dose of N + Nano urea @0.6%	4.98	5.02	5.00	2.98	3.90	3.44
T9 : 75% recommended dose of N + Urea (2 % spray)	5.23	5.45	5.34	4.08	5.52	4.80
T10 : 50% recommended dose of N + Urea (2 % spray)	4.92	5.14	5.03	2.78	4.45	3.61
S. Em±	0.09	0.03	0.05	0.19	0.27	0.14
C.D at 5%	0.36	0.10	0.14	0.77	0.80	0.42

Note : RDF = Recommended dose of fertilizers; Nano-urea and urea was sprayed at 20 and 40 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two equal splits (50% N as basal and 50% N at 30 DAS)

TABLE 8

Economics of forage maize as influenced by nano urea recorded at harvest

Treatments	Gross returns (Rs./ha)			Net returns (Rs./ha)			B:C ratio		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	43040	51985	47513	12844	21530	17187	1.43	1.71	1.57
T2 : RDF (N:P:K @150:60:40 kg/ha)	83920	134717	109318	51767	102430	77098	2.61	4.17	3.39
T3 : 75 % recommended dose of N + Nano urea @0.2%	71360	106089	88725	38140	72020	55080	2.15	3.11	2.63
T4 : 50 % recommended dose of N + Nano urea @0.2%	63020	88726	75873	30289	55115	42702	1.93	2.64	2.28
T5 : 75 % recommended dose of N + Nano urea @0.4%	74280	110324	92302	40496	75295	57895	2.20	3.15	2.67
T6 : 50 % recommended dose of N + Nano urea @0.4%	66620	94073	80347	33325	59502	46414	2.00	2.72	2.36
T7 : 75 % recommended dose of N + Nano urea @0.6%	76780	119063	97922	42416	83074	62745	2.23	3.31	2.77
T8 : 50 % recommended dose of N + Nano urea @0.6%	66980	102592	84786	33105	67061	50083	1.98	2.89	2.43
T9 : 75 % recommended dose of N + Urea (2 % spray)	79560	120517	100038	46876	85901	66388	2.43	3.48	2.96
T10 : 50 % recommended dose of N + Urea (2 % spray)	66720	104779	85750	34525	72015	53270	2.07	3.20	2.64

gross and net returns. Similar results were reported by Yogendra *et al.* (2020); Mohammad (2021) and Ajithkumar *et al.* (2021).

Based on the results it can be inferred that 100 per cent recommended nitrogen or 75 per cent recommended nitrogen with full dose of recommended phosphorous and potasium along with urea 2 per cent spray twice at 20 and 40 days after sowing found suitable, economical and viable technology for getting higher green fodder yield and quality in fodder maize under southern dry zone of Karnataka.

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