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Effect of foliar sprays of nano-urea on growth, yield and quality of *rabi* maize (*Zea mays* L.)

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Abstract
The present investigation on "Effect of foliar spray of Nano urea on growth, yield and quality of *rabi* maize (*Zea mays* L.) was conducted during rabi 2022-2023 at Agronomy farm, College of Agriculture, Pune. In this regard, the present investigation was set out in randomized block design with thirteen treatments and three replications. The study revealed that adoption of 75% N through conventional urea + 25% N through two foliar spray of IFFCO Nano urea, twice at 30 and 45 DAS was superior in influencing morphology, yield attributes and yield of rabi maize. However, since adoption of 75% N through conventional urea + Two foliar spray of COAP Nano urea @ 12 ml/L twice at 30 and 45 DAS was significantly at par with 75% N through urea + Two foliar sprays of 2% urea this might be a most appropriate managerial alternative to achieve sustainability.

Keywords: Maize, conventional urea, nano-urea, foliar spray, nitrogen. COAP

Introduction

Maize (*Zea mays* L.) belongs to family Poaceae and it is world third important cereal crop after rice and wheat and is widely cultivated across the world (Sandhu *et al*., 2007) [18]. The word "maize" is derived from the Spanish word. Other common names for the plant include zea, silk maize, Makka, and barajovar (Kumar & Jhariya, 2013) [9]. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is only food cereal crop that can be grown in different seasons and ecologies. Globally it is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 m t) in the global grain production. The United States of America (USA) is the largest producer of maize contributes nearly 36% of the total production in the world and maize is the driver of the US economy. The USA has the highest productivity (>9.6 t ha^{1}) which is double than the global average (4.92 t ha^{-1}) (Parihar *et al*., 2011) [14].

The use of nitrogen fertilizers results in higher biomass and protein yield and increases the concentration of protein in the plant tissue. As the protein concentration of corn grain increases, zein makes up an increasing proportion of the protein (Tsai *et al*., 1992) [21].

Nitrogen fertilization also has problem of losses in soil application due to denitrification, volatilization, leaching, fixation and immobilization. To reduce the N losses and improve crop N uptake, it is suggested to increase the utilization efficiency of applied fertilizer (Hawkesford, 2014) [6]. NUE is referred to as the grain yields per unit of available N (Moll *et al*., 1982) [13], which can further be divided into N uptake and N utilization efficiency.

In today's world, agriculture is facing many problems. In one hand the population is increasing with a demand of huge supply of foods; on the other hand, input use efficiency is decreasing, food and land quality is degrading with a subsequent environmental misbalance. In this scenario adoption of more efficient tools which could mitigate the drawbacks and led the agriculture in a sustainable way is the need of the hour.

Nanotechnology is the study of science and technology at the Nano scale, which is measured in nanometers. Nanotechnology is a novel discovery being explored in almost all the fields and it may provide cleaner solutions for the current problems in the field of agriculture. Nanotechnology and bio fertilization are represented the most important tools in modern agriculture and anticipated to become a driving economic force in the near future (Hegab *et al*., 2018) [5].

Nano fertilizers are a novel concept in agricultural nutrient management, and while it is still in its early stages, there is a big push in agriculture for long-term crop development, with nano-nitrogen playing a significant role. Nano fertilizers are vital for promoting sustainable agricultural development because they are ecologically friendly (Shukla *et al*., 2019) [19]. This technology has enabled the use of small nanomaterials molecules that carry fertilizer to create the "smart fertilizer," which can improve nutrient efficiency while lowering environmental protection costs. Nano fertilizers have numerous advantages, including increase in nutrient use efficiency, increase in crop stress tolerance (Shukla *et al*., 2019) [19], reduction in chemical fertilizer requirements and increase in crop yield (Kumar *et al*., 2022) [9]. Nano urea is a source of nitrogen, which is an essential nutrient for crop growth and development. Recently IFFCO Company has launched their new product of Nano Urea. The size of one Nano Urea particle is about 30 nano metre (1 nm is one billionth of a meter), and when compare to the conventional urea it has about 10,000 times more surface area to volume size when compare to granular urea. Further, due to ultra-small size and surface properties of nano urea, it get absorbed by the plants when sprayed on their leaves. Upon penetration these nano particles reaches to plant parts where nitrogen is required and release nutrients in a controlled manner. When sprayed at important crop growth stages, Nano Urea liquid, successfully meets crop nitrogen requirements. It is substituted for conventional urea and other nitrogenous fertilizers in order to improve the environment, soil health, and farmer profitability. In its nano form, nano urea comprises 4% nitrogen by weight. It is claimed by company that, a half-litre bottle of nano urea can efficiently cut up to one bag of urea. With the decline in the application of conventional bulk urea, nano urea has a significant advantage in terms of a safe and clean environment.

The field experiment was conducted to compare nutrient use efficiency among IFFCO Nano urea, conventional urea, COAP Nano urea. IFFCO Nano urea designed to replace bulk nitrogenous fertilizers like urea. One 500 ml bottle IFFCO Nano urea supplies 4% of nitrogen. It’s recommended to apply IFFCO Nano urea as foliar spray during the critical growth stages of crop. Where COAP Nano urea synthesized by Department Soil Science and Agriculture Chemistry of College of Agriculture, Pune. Through COAP Nano urea supplies 13800 ppm nitrogen in one 500 ml bottle.

Materials and Methods

The present study was conducted during 2022-23 in rabi season at Division of Agronomy Farm, college of Agriculture Pune under irrigated condition. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (7.8 pH), low in nitrogen (140 kg ha^{-1}), medium in available phosphorus (21 kg ha^{-1}) and high in potassium (381 kg ha^{-1}) respectively. To meet the appropriate tilth requirement of the maize crop, the soil in the study area was ploughed once with a tractor drawn cultivator followed by two turnings with a rotavator. The maize hybrid Rajarshi seeds were sown on 27 December 2022 with a seed rate of 25 kg/ha in flat bed method at 60 cm × 20 cm spacing and an earthing up was practiced at 25 days after sowing (DAS). The crop was harvested on 28 April 2023. The fertilizers were applied considering 120:60:40 kg/ha of N:P_2O_5: K_2O as recommended dose. Half dose of N and full dose of P and K were applied as basal dose and the remaining half of nitrogen was applied at 30, 45 and 60 DAS According to treatment. Apart from the treatments, all other agronomic management practices were performed as per the package of practice recommended to this region. The experiment was set out in randomized block design with 13 treatments and three replications. The treatments probed under this investigation were namely

Table 1: The experiment was set out in randomized block design with 13 treatments and three replications

Tr. No.	Treatments
T_1	Absolute control
T_2	GRDF 100% N through urea (120:60:40 N, P2O5, K2O + 10 t FYM/ ha)
T_3	75% N through urea + 25% N through two foliar spray of IFFCO Nano urea
T_4	50% N through urea + 50% N through two foliar spray of IFFCO Nano urea
T_5	50% N through urea + 50% N through three foliar spray of IFFCO Nano urea
T_6	50% N through urea + Two foliar sprays of IFFCO Nano urea @ 2 ml/L each
T_7	50% N through urea + Two foliar spray of IFFCO Nano urea @ 4 ml/L each
T_8	50% N through urea + Two foliar spray of COAP Nano urea @ 6 ml/L each
T_9	50% N through urea+ Two foliar spray of COAP Nano urea @ 12 ml/L each
T_{10}	75%N through urea + Two foliar spray of COAP Nano urea @ 6 ml/L each
T_{11}	75% N through urea + Two foliar spray of COAP Nano urea @ 12 ml/L each
T_{12}	50% N through urea + Two foliar sprays of 2% urea
T_{13}	75% N through urea + Two foliar sprays of 2% urea

The data related to plant height (cm) at 30, 90 DAS and at harvest, total dry matter per plant (g) at 30, 90 DAS and at harvest, number of functional leaves per plant at 30, 90 DAS and at harvest, length of the cob (cm), number of cobs per plant, number of grain rows per plant, number of grains per row, 1000 grain weight (g) were recorded at harvest.

All these observations were statistically analyzed by F-test at 5 percent level of significance (Gomez and Gomez, 1984) [4].

Results and Discussion

Growth attributing character

The growth attributes, *viz*., plant height (cm), total dry matter palnt^{-1} (g) and number of functional leaves plant^{-1} of maize at 30.90 and at harvest were analyzed statistically and presented in Table 2. The results indicated that the growth attributes evaluated in this study were significantly influenced by all the treatments over control (No nitrogen application). The minimum plant height, low dry matter accumulation, number of functional leaves were recorded with 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea which was statistically at par with 75% N through urea as basal dose + Two foliar spray of COAP Nano urea @ 12ml/L each and 75% N through urea + Two foliar sprays of 2% urea applied at 30, 90 DAS and at harvest, respectively. However, 75% N through urea as basal dose + Two foliar spray of COAP Nano urea @ 12ml/L each was statistically at par with 75% N through urea + Two foliar sprays of 2% urea and no statistical difference were observed among these treatments. In comparison, foliar spray of nano-urea, COAP urea and 2% urea at 30 DAS and at harvest could not bring about statistical differences, in plant height, total dry matter plant-1 and number of functional leaves plant^{-1} recorded at 30, 90 DAS and at harvest when supplemented with 75% RDN. While significantly minimum plant height, low total dry matter per plant^{-1} and number of functional leaves plant^{-1} was recorded in control with no nitrogen application.

The application of 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea recorded maximum number of plant height, total dry matter plant^{-1} and number of functional leaves plant^{-1} might be due to sufficient amount of nitrogen through Nano urea at critical stages which would have maintain continuous supply of nitrogen, led to the meristematic activity and stimulation of cell elongation in plant resulted in maximum growth attributes. Similar result reported by Samui *et al*., (2022) [17], Ajithkumar (2021) [1], Manikandan and Subramanian (2016) [10] and Rani *et al*., (2019) [15], Movahhedi (2015) [12] and Mohapatro *et al*. (2021) [11].

Table 2: Growth attributing character

Tr. No.	Plant height (cm)				No. of functional leaves plant^{-1}				Dry matter plant^{-1}			
	30	60	90	At harvest	30	60	90	At harvest	30	60	90	At harvest
T_1	28.00	104.66	143.00	144.00	5.15	8.14	8.38	5.20	7.95	63.65	124	141.90
T_2	40.38	139.33	199.33	207.69	6.46	10.32	12.79	7.57	10.04	100.40	220	248.33
T_3	35.42	154.66	220.81	229.34	5.73	11.46	14.15	8.40	9.41	112.83	243	275.01
T_4	32.70	132.33	182.33	192.02	6.80	10.09	12.29	6.31	8.51	79.34	187	212.80
T_5	44.73	137.33	194.66	202.68	6.50	10.33	12.50	7.26	10.21	87.46	210	240.33
T_6	33.40	130.66	177.33	186.02	5.93	9.30	12.21	5.94	8.61	76.00	178	206.66
T_7	42.73	135.00	191.00	200.01	6.50	10.28	12.42	6.57	8.88	82.41	195	230.00
T_8	31.36	122.00	165.66	182.65	5.60	9.46	10.48	5.65	8.46	70.16	162	188.66
T_9	40.35	125.33	172.66	175.63	5.16	9.59	11.65	5.80	8.37	74.00	169	195.00
T_{10}	35.33	138.33	196.00	207.52	6.58	10.31	12.62	7.40	10.15	95.33	217	246.32
T_{11}	29.34	146.66	208.87	216.01	6.03	10.73	13.58	7.80	9.85	104.83	228	256.33
T_{12}	34.34	134.33	187.33	196.66	6.77	10.13	12.36	6.50	8.75	80.08	191	220.95
T_{13}	34.70	147.66	213.05	220.65	6.23	10.98	13.98	8.27	9.52	108.50	234	264.00
S.E. (m)+	3.61	4.82	6.66	7.29	0.45	0.38	0.42	0.23	0.64	3.24	6.9	8.23
C.D. at 5%	NS	14.09	19.46	21.29	NS	1.11	1.24	0.69	NS	9.46	20	24.02

Yield attributing characters

Apart from 1000 grain weight (g), the results related to all other yield attributes presented in Table 3 indicated that nano-urea, COAP-urea, 2% urea supplementation through foliar spray, in addition to 75% RDN was superior over other treatments respectively. Among the treatments, significantly maximum length of the cob (cm), number of cobs per plant, grain rows per cob, grains per cob and girth of cob were recorded with 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea which was statistically at par with 75% N through urea as basal dose + Two foliar spray of COAP Nano urea @ 12ml/L each and 75% N through urea + Two foliar sprays of 2% urea applied at 30 and 45 DAS of the maize. However, significantly inferior response with respect to yield attributes was conferred by control (No nitrogen). The 1000 grain weight was one of the most stable varietal attributes in turn did not vary significantly with management of nutrients.

The increase in yield attributes might have been owing to better utilization of resources under improved N supply, as it is an integral part of proteins the building blocks of plant. The improvement in all these yield attributes might have been due to favourable effect of nitrogen on physiological parameters resulting in the increase of photosynthetic efficiency and subsequent translocation of photosynthates into reproductive organs (Kumar *et al*. 2004) [7].

These results are in agreement with the research findings of Manikandan and Subramanian (2016) [10], Al-Juthery *et al.* (2018) [2], Rathnayak *et al.,* (2018) [16] and Samui *et al*., (2022) [17].

Table 3: Yield attributing characters

Tr. No.	Cobs plant^{-1}	Length of cob (cm)	Girth of cob (cm)	No. of grains cob-1	No. of rows cob-1	Test weight
T_1	1.00	10.26	11.00	271.00	8.00	206
T_2	1.56	15.53	14.50	450.00	11.10	206
T_3	1.69	18.53	16.07	528.46	12.45	213
T_4	1.39	15.14	14.08	415.33	10.09	207
T_5	1.39	15.36	14.38	429.33	10.64	208
T_6	1.69	15.09	14.00	410.66	10.05	211
T_7	1.39	15.23	14.21	421.00	10.24	214
T_8	1.38	13.91	13.06	330.00	9.00	209
T_9	1.36	15.06	13.98	376.33	10.00	214
T_{10}	1.39	15.48	14.41	444.66	10.54	216
T_{11}	1.68	18.42	15.94	520.13	11.75	218
T_{12}	1.43	15.20	14.19	418.00	10.15	208
T_{13}	1.68	18.49	16.03	524.06	12.31	211
S.E.(m)+	0.05	0.54	0.50	17.28	0.41	17.50
C.D. at 5%	0.14	1.59	1.47	50.44	1.20	211.40

Yield

In the present investigation, grain yield, stover yield and harvest index were significantly influenced by the foliar spray of urea both at macro and nano scale (Table 4). The results indicated that application of 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea at 30 and 45 DAS was significantly superior over 100% GRDF without foliar supplementation, all the treatments with 75%, 50% RDN and control (no nitrogen), respectively. In this study, statistically significant yield increment was reported with the increase in recommended dosage of nitrogen. Comparatively, significantly inferior response with respect to grain yield, stover yield and harvest index was registered by control (No nitrogen). The increase in grain yield might be due to the favorable influence of nitrogen in increasing the source size and establishing an appropriated source to sink relationship, respectively. However, increased stover yield was attributed due to enhanced morphological characters. Similarly, improvement in harvest index was mainly attributed to allocation of photosynthates to grain filling rather accumulating in the straw. Similar findings were observed by Bhuiya *et al*. (2020) [3] and Samui *et al*., (2022) [17].

Table 4: In the present investigation, grain yield, stover yield and harvest index were significantly influenced by the foliar spray of urea both at macro and nano scale

Tr. No.	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	24.26	63.03
T_2	59.33	94.33
T_3	68.88	108.40
T_4	40.93	83.86
T_5	46.40	90.00
T_6	39.30	83.63
T_7	44.73	89.66
T_8	33.45	77.66
T_9	37.95	82.46
T_{10}	58.66	92.00
T_{11}	63.66	99.33
T_{12}	42.83	88.93
T_{13}	65.55	102.00
S.E.(m)	1.81	3.34
C.D. at 5%	5.30	9.77

Conclusion

Based on the present investigation, it can be concluded from that adoption of 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea at 30 and 45 DAS could be an ideal technological alternative to achieve sustainability in irrigated maize cultivated under pune conditions as this treatment was found to be at par with 75% N through urea as basal dose + Two foliar spray of COAP Nano urea @ 12ml/L each and 75% N through urea+ Two foliar sprays of 2% urea in terms of growth, yield attributes and yield of maize. However, for a large farmer basically targeting higher returns rather than nitrogen optimization, adoption of 75% N through urea + 25% N through two foliar spray of IFFCO Nano urea at 30 and 45 DAS might be an appropriate alternative, respectively.

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