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Effect of time, rate and sources of nitrogen on soil chemical properties in maize (*Zea mays* L.) hybrids

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Abstract
A field experiment was carried out at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka, during *rabi* season of 2021-22 and 2022-23. The experiment was laid out in the randomized complete block design with factorial concept consisted of three replications with 16 treatment combinations. The first factor consisted of two maize hybrids as first factor (H) *viz*., H_1: NK-6240 and H_2: DKC-9133 and the second factor consisted of eight nitrogen management treatments *viz*., N_1: Control (0 kg N ha^{-1}), N_2:RDN (150 kg ha^{-1}) through conventional fertilizers, N_3: 75 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6), N_4: 75 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively), N_5: 100 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6), N_6: 100 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively), N_7: 125 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6) and N_8: 125 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively). On the basis of two years pooled results significantly higher soil available nitrogen was recorded with nitrogen fertilization at 150 kg ha^{-1} through conventional fertilizers alone in five splits with both the hybrids NK-6240 (248.3 kg ha^{-1}) and DKC-9133 (252.6 kg ha^{-1}) over conjoint application of conventional fertilizers and liquid nano-urea irrespective of the time and rate of application. Whereas, the soil available phosphorous and potassium did not vary across hybrids. However, nitrogen management treatments and interaction effects showed slight variations for available soil phosphorous and potassium.

Keywords: Maize hybrids, nano-urea, nitrogen

Introduction

Cereals are the most important source of food and energy for the growing world population (Anon, 2018) [3]. Among cereals, maize (*Zea mays* L.) is an important cereal crop because of its C4 photosynthetic pathway which makes it possible to grow under varied temperature conditions hence it is called as "super plant" (Walters, 2022) [12]. Maize is an established and important food crop in many nations. Globally, maize production has up surged in the past few decades because of its escalating demand coupled with technological advances, high yielding hybrids and area extension. It is a versatile and multipurpose crop, predominantly used as feed for animals, but also an important food crop and is now used as a major feedstock for biofuels production particularly bioethanol (Erenstein *et al*., 2022) [4]. Hence it is called a "renewable resource" (Viel *et al*., 2019) [11]. Maize is generally consumed as cob or mature kernels are fed to nixtamalization industries that transform grain maize into breakfast cereals, snacks, sweetners, beer and other potable alcoholic liquid refreshments. The future of maize looks bright because of gaining importance in production of value-added industrial products including renewable biofuel production along with feed and food.

Globally, 206.3 million ha is under maize cultivation, yielding 780 million tons and 3150 kg ha^{-1} of productivity, making it the second most widely cultivated crop in the world after wheat (Anon, 2022) [2]. In India maize is the third-most significant cereal crop after rice and wheat which was grown all around the year. In India, maize is being grown over an area of 9.86 million ha, with a production of 31.51 million tons ad productivity of 3195 kg ha^{-1} (Anon, 2022) [2]. Being one of the largest producer, Karnataka accounts for almost 16 percent of total maize produced in India (5.18 million tons), grown over an area of 1.68 million ha with a productivity of 3092 kg ha^{-1} (Anon, 2022) [2]. Out of 1.68 million ha in Karnataka, around 0.85 m ha is sown during *rabi* season (Anon, 2021) [1].

The management of nitrogen (N) is the key element in the production of maize. Nitrogen is an essential element of all amino acids and it is the component of chlorophyll, which is the site of photosynthesis. Plants that receive enough nitrogen will grow quickly and have leaves that are deep green in color. More than half of the world's population currently relies on food production made possible by the application of nitrogen fertilizer, particularly in cereal crops, even though only 30-50 percent of the applied N is recovered (Ladha *et al.*, 2016) [7]. Rate, source and timing of nitrogen application are crucial and it is one of the best management practices for achieving high maize production. Nitrogen application at a time when it is needed the most and taken up at high rates by maize could enhance nitrogen use efficiency by reducing the immobilization, denitrification and leaching losses. Hence, there is a need to minimize the losses to conserve and sustain resource base. Many approaches have been practiced for improving N utilization efficiency in crops, for example, optimal time, rate and methods of application for matching N supply with crop demand and the use of specially formulated forms of fertilizer. The results showed that N application by stages can significantly increase maize grain yield compared to disposable application as sowing manure (Yu *et al.*, 2010) [13].

The present study was carried out to evaluate the effect of time, rate and sources of nitrogen on soil chemical properties in Maize (*Zea mays* L.) hybrids. The objectives are to evaluate the effects of different N fertilizer application on soil chemical characters and to identify the approach for optimal N fertilizer application in maize management program.

Materials and Methods

A field experiment was carried out on "Effect of time, rate and sources of nitrogen on soil chemical properties in Maize (*Zea mays* L.) hybrids" at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka, during *rabi* season of 2021-22 and 2022-23. The soil of the experimental site was black clayey in texture, alkaline in pH (7.7) with normal in electrical conductivity (0.28 dS m^{-1}), low in organic carbon content (0.45%), medium in available nitrogen (257 kg ha^{-1}), high in available phosphorous (32.0 kg ha^{-1}) and potassium (360 kg ha^{-1}). The experiment was laid out in RCBD (Factorial concept) with three replications and 16 treatment combinations. The first factor consisted of two hybrids (H) *viz.*, H_1: NK-6240 and H_2: DKC-9133 and the second factor consisted of eight nitrogen management treatments *viz.*, N_1: Control (0 kg N ha^{-1}), N_2:RDN (150 kg ha^{-1}) through conventional fertilizers, N_3: 75 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6), N_4: 75 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively), N_5: 100 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6), N_6: 100 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively), N_7: 125 percent recommended N in 2 splits (1/3 through conventional fertilizers at sowing and 2/3 through liquid Nano-urea at V6) and N_8: 125 percent recommended N in 3 splits (1/3 through conventional fertilizers at sowing and 1/3 each through liquid Nano-urea at V6 and VT, respectively). The recommended dose of fertilizers for maize under irrigated condition is 150:65:65 kg N-P_2O_5-K_2O ha^{-1} and FYM 10 t ha^{-1}. Nitrogen was applied as per the treatments (Table 1), recommended dose of phosphorus, potassium and farm yard manure were applied at the time of sowing. Conventional fertilizers (CF) and liquid nano-urea (NU) were used as a source of nitrogen. Urea was used as a source of conventional fertilizer. FYM at 10 t ha^{-1} was applied uniformly to all the treatments except N_1 treatment.

Table 1: Treatment-wise nitrogen application schedule

Treatments	N level	Nitrogen applied (ha^{-1})					
		Basal dose (CF)	4th leaf stage (CF)	6th leaf stage (V6) (NU)	8th leaf stage (CF)	Tasseling stage (VT) (CF/NU)	Dough stage (CF)
N_1	0 kg ha^{-1}	-	-	-	-	-	-
N_2	100% RDN	30 kg	30 kg	-	30 kg	45 kg	15 kg
N_3	75% RDN	37.5 kg	-	1786 ml	-	-	-
N_4	75% RDN	37.5 kg	-	893 ml	-	893 ml	-
N_5	100% RDN	50 kg	-	2381 ml	-	-	-
N_6	100% RDN	50 kg	-	1190 ml	-	1190 ml	-
N_7	125% RDN	62.5 kg	-	2976 ml	-	-	-
N_8	125% RDN	62.5 kg	-	1488 ml	-	348 ml	-

*CF: Conventional fertilizers
NU: IFFCO Nano-urea
RDN: Recommended dose of nitrogen (150 kg ha^{-1})

Post-harvest soil analysis

Soil samples were collected from a depth of 0 - 30 cm after the harvest of the crop from each treatment. The total N content of soil was calculated by using the Alkaline permanganate method (Subbiah and Asija, 1956) [10], total P content using Olsen's method (Jackson, 1973) [6], and total K content using Flame photometer method (Jackson, 1973) [6].

Statistical analysis

Data recorded from the experiments were analysed using Analysis of Variance (ANOVA) and mean comparisons were performed based on Duncan's multiple range test (DMRT) at 5% probability level to separate treatment means.

Results

Available soil nitrogen (kg ha^{-1})

The average pooled data pertaining to available soil nitrogen content is indicated in Table 2. Among two maize hybrids, DKC-9133 (221.5 kg ha^{-1}) showed higher soil available nitrogen but was on par with NK-6240 (218.1 kg ha^{-1}). Nitrogen management treatments showed significant difference for available soil nitrogen. Nitrogen applied at 100 percent RDN through conventional fertilizers registered significantly higher available soil N (250.4 kg ha^{-1}) over rest of the treatments. However, significantly the lower available soil N (202.8 kg ha^{-1}) was recorded with sequential application of 125 percent recommended nitrogen through conventional and liquid nano-urea in two splits (N_7) and was on par with rest of the treatments except N_2. Among the interactions, significantly higher available soil N nitrogen was recorded with DKC-9133 fertilized with 150 kg N ha^{-1} through conventional fertilizers (252.6 kg ha^{-1}), which had no significant difference with NK-6240 (248.3 kg ha^{-1}). The soil available nitrogen reduced significantly when 125 percent RDN was applied in two splits through both conventional fertilizers and nano-urea across both the maize hybrids. This had no remarkable difference with rest of the interactions except H_1N_2 and H_2N_2.

Table 2: Available soil nitrogen, phosphorous and potassium as influenced by time, rate and sources of nitrogen in maize hybrids

N/H	Available soil nitrogen (kg ha^{-1})			Available soil phosphorous (kg ha^{-1})			Available soil potassium (kg ha^{-1})		
	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean
N_1	220.5^{bc}	222.6^{bc}	221.6^{bc}	25.3^{d}	27.0^{cd}	26.2^{b}	318.1^{a}	323.4^{a}	320.7^{b}
N_2	248.3^{ab}	252.6^{a}	250.4^{a}	28.7^{a-d}	29.1^{a-d}	28.9^{ab}	326.3^{a}	332.0^{a}	329.2^{ab}
N_3	220.1^{bc}	225.6^{bc}	222.8^{bc}	30.8^{a-c}	33.3^{a}	32.0^{a}	362.9^{a}	353.3^{a}	358.1^{a}
N_4	214.5^{c}	217.4^{bc}	216.0^{bc}	30.5^{a-c}	31.7^{a-c}	31.1^{a}	355.3^{a}	347.9^{a}	351.6^{ab}
N_5	225.6^{a-c}	223.4^{bc}	224.5^{b}	31.9^{ab}	28.5^{b-d}	30.2^{a}	347.8^{a}	338.9^{a}	343.3^{ab}
N_6	210.4^{c}	210.5^{c}	210.5^{bc}	33.3^{a}	29.0^{a-d}	31.1^{a}	333.6^{a}	344.4^{a}	339.0^{ab}
N_7	201.3^{c}	204.3^{c}	202.8^{c}	28.6^{b-d}	30.4^{a-c}	29.5^{a}	321.0^{a}	341.2^{a}	331.1^{ab}
N_8	204.3^{c}	215.7^{bc}	210.0^{bc}	30.3^{a-c}	29.6^{a-d}	29.9^{a}	337.5^{a}	335.6^{a}	336.5^{ab}
Mean	218.1^{a}	221.5^{a}		29.9^{a}	29.8^{a}		337.8^{a}	339.6^{a}	
SV	S.Em. ±			S.Em. ±			S.Em. ±		
H	3.58			0.48			5.46		
N	7.15			0.97			10.92		
H×N	10.11			1.37			15.44		

Available soil phosphorous (P_2O_5 kg ha^{-1})

Available soil phosphorous did not vary significantly with hybrids. However, numerically it was high with NK-6240 (29.9 kg ha^{-1}). Time, rate and sources of nitrogen management practices were comparable with respect to soil available phosphorous except with absolute control (26.2 kg ha^{-1}). However, it ranged between 28.9-32.0 kg ha^{-1} among N management treatments. Interaction effect between hybrids and nitrogen management showed significant variation for available soil phosphorous (Table 2). All the interactions were on par with each other for soil available phosphorous with except no N application with NK-6240 (25.3 kg ha^{-1}) and DKC-9133 (27.0 kg ha^{-1}), 100 percent RDN through both conventional fertilizers and liquid nano-urea in two splits with DKC-9133 (28.5 kg ha^{-1}) and 125 percent RDN through both conventional fertilizers and liquid nano-urea in two splits with NK-6240 (28.6 kg ha^{-1}).

Available soil potassium (K_2O kg ha^{-1})

Available soil potassium did not vary significantly with hybrids. However, numerically it was higher under DKC-9133 (339.6 kg ha^{-1}) as compared to NK-6240 (337.8 kg ha^{-1}). Whereas it varied significantly as influenced by N fertilization through conventional fertilizers and liquid nano-urea. N fertilizer through either conventional fertilizers or both conventional and liquid nano-urea irrespective of the rate and time of application found on par with each other for soil available potassium (Table 2) with superiority over no N application (320.7 kg ha^{-1}). Interaction effect between hybrids and nitrogen management showed similar response for available soil potassium. NK-6240 with 75 percent RDN through conventional fertilizers and liquid nano-urea in two splits recorded numerically higher (362.9 kg ha^{-1}) soil available potassium. However, low soil available potassium was recorded under absolute control with NK-6240 (318.1 kg ha^{-1}).

Discussion

Available soil N varied significantly across time, rate and sources of nitrogen in maize hybrids. Significantly higher soil available N was recorded when 150 kg of nitrogen was applied through conventional urea as compared to other treatments. The higher amount of application of nitrogen through conventional urea raised the total nitrogen content in soil which ultimately aided in increasing the N balance of the soil. This could be due to the efficient utilization of the applied nitrogen without greater loss which helped in sustainable maintenance of native N. The lower soil soil N balance was recorded with 125 percent RDN applied through both conventional and nano-urea sources and was on par with all other treatments included nano-urea source. The lower soil available N under these treatments is mainly due to the depletion of the soil mineral N, irrespective of the time and rate of nano-urea applications for the crop growth. Sarkar *et al*. (2023) [9] reported that superior performance of 100 percent RDN was mainly owing to higher availability of nitrogen compared to nano-urea- based nitrogen-management options as nano-urea contained only 4 percent N (weight/ volume basis) and providing hardly 50 to 100 g nitrogen ha^{-1} which might not be able to substitute to 25 or 50 percent of RDN (30 or 60 kg N/ha) of wheat in spite of having higher efficiency of nano-fertilizers. An increase in the nitrogen fertilizer application through conventional fertilizers led to the higher soil available nitrogen in the soil, which increased the plant growth and development by increasing nitrogen uptake which also resulted in the extraction of higher amount of P and K from the soil resulting in lower phosphorous and potassium in the soil. The findings made by Hanjanatti (2016) [5] in maize and Mohanty *et al*, (2016) [8] in wheat are similar with the results obtained.

Conclusion

Based on the findings of the two years pooled data, it can be concluded that both the hybrids were highly potential with respect to available soil nutrients and nitrogen fertilization through conventional fertilizers in five splits can be efficiently practiced over conjoint application of conventional fertilizers and liquid nano-urea irrespective of the time, rate and source of nitrogen. Nitrogen application at 150 kg ha^{-1} through conventional urea alone influenced the available soil nitrogen with minimum loss as compared to initial soil N content which helps in sustainable maintenance of native nitrogen.

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