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AGRONOMY

Growth and Productivity of Maize (*Zea mays* L.) as Influenced by Nitrogen Management Options

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ABSTRACT

Precision nutrient management is the most advanced agronomic strategy for improving crop yields and managing soil and environmental quality. Considering the above, a field experiment was conducted at the Agriculture Research Farm, Baghasala of Centurion University of Technology and Management during the *rabi* season of 2020-21 to find out the impact of nitrogen management options on growth and productivity of maize (*Zea mays* L.). The experiment was consisted of eight treatments, viz., T_1: control, T_2: 150% RDN, T_3: 125% RDN, T_4: 100% RDN, T_5: 75% RDN, T_6: 50% RDN, T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS) and T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 at 21 and 45 DAS). The treatments were laid out in Randomized Block Design with three replications. The maximum values of growth attributes, namely, plant height, dry matter accumulation, leaf area index and crop growth rate and yield attributes, such as cob length, cob girth, grains per cob, test weight inclusive of grain yield (6.65 t/ha), straw yield (8.42 t/ha) were obtained with the application of 150% RDN. For expression of crop growth characters, yield attributes and yields application of 150% RDN proved its superiority and it was followed by 125% RDN and 100% RDN at different growth stages. The treatments with precision N management tools like Leaf Colour Chart (LCC) and SPAD meter also resulted in crop performance with close proximity to 150% RDN, 125% RDN and 100% RDN treatments.

HIGHLIGHTS

- The highest result was obtained with 150% RDN and closely followed by 125% RDN, 100% RDN and Precision N management tools at different growth, yield attribute and yield.
- The N management practices improving nitrogen use efficiency (NUE) in *rabi* maize by precision nutrient management.

Keywords: Maize,precision nitrogen management, leaf colour chart (LCC), SPAD meter, growth and yield

Maize (*Zea mays* L.), a monocotyledonous plant and belongs to the family *Poaceae*, is one of the most important staple food crops of the world and ranks third in acreage and production next to wheat and rice (Maitra *et al.* 2019, 2020). The crop has the highest yield potential among cereals and is hence known as 'Queen of Cereals'. Being a C_4 plant, it has more ability to assimilate high amounts of carbon dioxide, and yield potential is high due to its efficiency of utilizing the greater quantity of radiant energy (Manasa *et al.* 2020; Meng *et al.* 2020). Nutritionally, it is rich in carbohydrates (70%) and contains about 10% of protein and 4% of oil (Jat *et al.* 2013) and thus considered to ensure food and nutritional security. Presently, 1148.5 million tonnes of maize are produced by over 169 countries from a harvested area of 197.2 million ha with an average yield of 5.82 t/ha (FAOSTAT, 2020). The cultivated area of maize in India was

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9.18 million ha with a production of 27.23 million tonnes vis-à-vis average productivity of 2965 kg/ha during 2018-19 (ICAR-IIMR 2019-20). In Odisha, it was cultivated over an area of 2.69 lakh ha with a production of 7.51 lakh MT and average productivity of 2791 kg/ha (Maitra *et al*. 2019). Out of the total maize production in the world, about one-third of production is used as cattle or poultry feed, and nowadays, about half of the production is being used as human food. The utilization and purpose of maize grain as an industrial crop as 76% of its production in India is used in feed, starch, and biofuel industries (Director's report 2020). Maize usually requires a considerable amount of nitrogen (N) for its better growth and development because of its exhaustive nature (Asibi *et al.* 2020; Nduwimana *et al.* 2020). Inappropriate soil and asymmetric nutrients management are the major causes for poor yield output (Maitra *et al.* 2018). Maize having the characteristics of high biomass production removes maximum amounts of plant nutrients from the soil surface (Hirpa and Bulto 2016). The application of urea, DAP, and MOP has been found to have lower fertilizer use efficiency, which ranges from 20 to 50 % for nitrogen owing to a different type of losses. N fertilizers are used to undergo various transformations, such as ammonia volatilization, denitrification, and leaching, leading to pollution of the surrounding agro-environment (Ghosh *et al.* 2020). Precision nitrogen management is agronomically, economically, and environmentally efficient for maize crops. Adoption of precision N management in maize crops increases the N use efficiency as well as reduces the N loss. Further, precision N management involves optimum use of N with the help of certain developed tools such as SPAD meter and green seeker (Mohanty *et al*. 2017) and leaf color chart (Adhikary 2021). Traditional farming following the blanket recommendation of fertilizer to maize crop can be replaced by the adoption of precision nutrient management which saves the plant and soil health (Kumar *et al*. 2017). According to Kumar *et al*. (2014), LCC helps in providing only the need-based N fertilizer application on the basis of soil N-supply and demand of maize. Considering the above, the present research has been conducted to optimize N requirement in rabi maize for proper growth and productivity of maize in south Odisha.

MATERIALS AND METHODS

A field experiment was carried out during the *rabi* season of 2020-21 at the Agricultural Research farm (located at 23°39′N latitude and 87°42′E longitude and at an altitude of 145 meters above mean sea level) of M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Gajapati, Odisha under the agro-climatic conditions of eastern plateau and hills region (northeastern ghats of Odisha). The experiment was carried out by Complete Randomized Block Design (CRBD). The field was ploughed once by tractor driven cultivator followed by cross harrowing. The rotavator was used to break the clods and level the field, and get good soil tilth for germination. The sowing was done in the first week of October 2020. The experiment was consisted of three replications and eight treatments, i.e., T_1: control,T_2:150% RDN, T_3:125% RDN, T_4:100% RDN, T_5:75% RDN, T_6:50% RDN, T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS), T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 @ 21 and 45 DAS). The maize hybrid considered was 'Kavery 50'. The sources of fertilizers were urea for N, single super phosphate for P_2O_5, and muriate of potash for K_2O. The basal dose (one-fourth) of N fertilizer was applied in the plots and the remaining par applied in two equal splits at knee-high stage and before tasseling stage. Full doses of fertilizer phosphorous and potassium were applied as basal doses according to the experimental plan. The net plot size was 7 m × 6 m. The recommended dose of nitrogen (RDN) applied was 120 kg $ha^{-1,}$ and the quantity of N was applied through Leaf color chart (LCC) and Soil Plant Analysis Development (SPAD) meter-based N management treatments was 115 kg ha^{-1}. Seeds were sown at a spacing of 60cm (row to row) and 25 cm (plant to plant). The weights of grain and straw were recorded plot-wise, and the data was converted into tonnes ha^{-1}. The maximum temperature ranged from 33.5°C in October to 32°C in February whereas the minimum temperature ranged from 30.28°C in October to 29.85°C in February during the cropping season (Figure 1). During the crop growing period, the relative humidity varied from 79.5% to 82.5%, and the average sunshine hours ranged from 8.45 hrs day^{-1} in October to 9.12 hrs day^{-1} in February (Fig. 1). As the experiment was carried out in the *rabi* season, the crop received a minimum rainfall (mm) during the crop period. The crop was irrigated as per the requirement for maintaining the desired soil moisture for seed germination, growth, and development of the crop. The soil samples of the experimental plots were collected randomly from a depth of 0–15 cm prior to sowing. The samples were dried under shade and sieved through 2 mm sieve for analysis. The plot-wise soil samples were also collected after the harvesting of the crop. Before sowing of the crop, the data recorded in respect to physio-chemical properties of the experimental site revealed that the soil was clayey loam in texture with slightly acidic pH (5.6) with low in available nitrogen (177.3 kg ha^{-1}), medium in available phosphorous (13.2 kg ha^{-1}) and low in available potassium (126.3 kg ha^{-1}). The plant height was measured from five randomly labeled plants at different growth stages using a wooden meter scale. The height was measured from the base of the plant to its top leaf until the tassels emerged. The samples were placed in the hot air oven at 65˚C for 48 hours to determine the dry weight of each sample, and finally, the dry matter accumulation of each treatment was calculated. The LAI was calculated by dividing the leaf area by the land area (formula mentioned below). The dry weight of each plant was taken at regular intervals for the calculation of the crop growth rate. The harvest index was calculated by dividing the economic yield with the biological yield (Donald 1962), and the formula is mentioned in the equations given below. Different parameters and Nuse efficiencies such as agronomic N efficiency (AE), Physiological N efficiency (PE), and Nutrient harvest index (NHI) were calculated by following formulae.

Leaf area index

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area per plant (sq.cm)}}{\text{Land area (sq.cm)}}$$

Crop growth rate

$$CGR = \frac{W2 - W1}{T2 - T1}\ \text{(g/sq. m/day)}$$

Where, W_2= Final dry weight, W_1= Initial dry weight, T = time

Harvest Index

$$\text{Harvest Index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

Agronomic N efficiency (AE) (kg kg^{-1})

$$AE = \frac{\left(\begin{array}{l}\text{Grain yield in N applied plot} -\\ \text{Grain yield in control plot}\end{array}\right)}{\text{Amount of N applied in fertilizer plot}}$$

Physiologica lN efficiency (PE) (kg kg^{-1})

$$PE = \frac{\left(\begin{array}{l}\text{Biological yield in N applied plot} -\\ \text{Biological yield in control plot}\end{array}\right)}{\left(\begin{array}{l}\text{Nutrient uptake in fertilized plot} -\\ \text{Nutrient uptake in control plot}\end{array}\right)}$$

Nutrient harvest index (NHI) (%)

$$NHI = \frac{\text{Nutrient uptake by grain}}{\text{Total nutrient uptake for production of biological yield}}$$

The data were analyzed as per the standard procedure for analysis of variance as described by Gomez and Gomez (1984). The significance of treatments was tested by F test. The standard error of the mean was computed in all cases. The difference in the treatment means was tested by using critical difference (CD) at 5% level of probability. The Excel software (Microsoft Office Home and Student version 2019-en-us, Microsoft Inc., Redmond, Washington, (USA) was used for statistical analysis and drawing figure (Shankar *et al*. 2021).

RESULTS AND DISCUSSION

Growth Parameters

The various growth attributes were recorded, statistically analyzed, and presented in Table 1. The growth parameters of maize were significantly influenced by nitrogen management levels. During the time of harvesting, the plant height in the treatment with 150% RDN remained highest (203.5 cm) and was found to be statistically at par with treatments receiving 125% RDN (197 cm), 100% RDN (189.9 cm), LCC based(189.9 cm) and SPAD

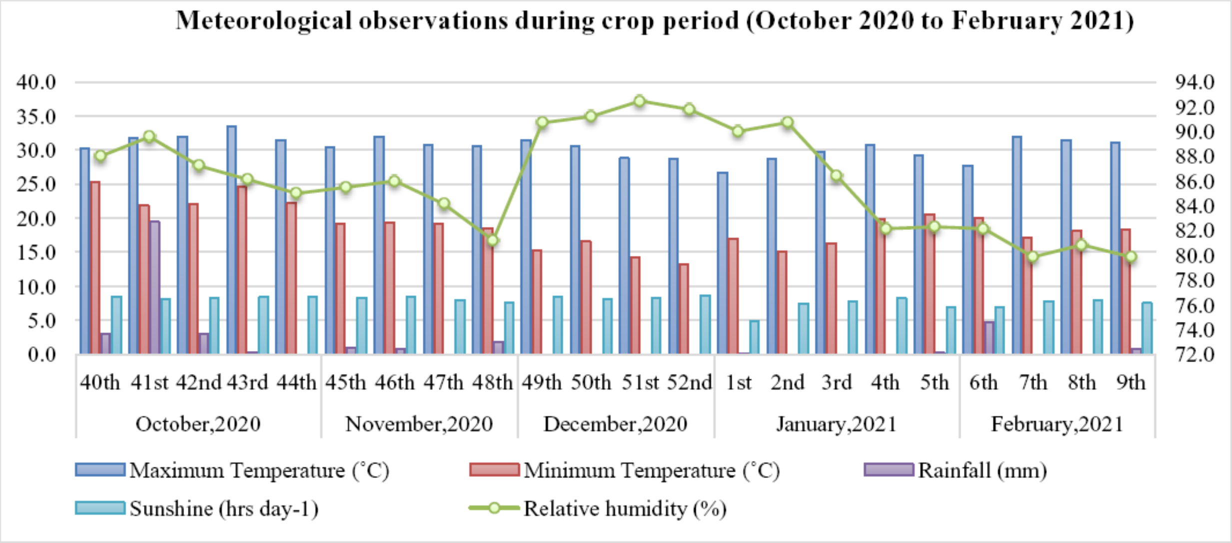

Fig. 1: Meteorological observations during crop period

Table 1: Effect of nitrogen management options on growth attributes of *Rabi* maize

Treatments	Plant height (cm) at harvest	Dry matter accumulation (g/m²) at harvest	Leaf area index at 60 DAS	Crop growth rate (g/m²/day) at 60-90 DAS
T1: Control	98.9	824.5	3.0	13.5
T2: 150% RDN	203.5	1693.5	5.5	34.4
T3: 125% RDN	197.0	1685.8	5.0	34.0
T4: 100% RDN	189.9	1653.8	5.0	34.2
T5: 75% RDN	173.1	1045.3	4.1	16.5
T6: 50% RDN	140.3	917.7	3.7	12.8
T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS)	189.0	1550.5	4.8	29.9
T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 at 21 and 45 DAS)	196.3	1557.5	5.4	30.4
SEm(±)	9.5	65.63	0.24	2.46
CD at 5%	29.0	199.1	0.7	7.5

RDN: *Recommended Dose of Nitrogen;* **LCC**: *Leaf Colour Chart;* **SPAD**: *Soil Plant Analysis Development;* **SEm** (±): *Standard Error mean;* **CD** : *Critical Difference.*

meter-based (196.3 cm) N management treatments. The Dry matter accumulation (DMA) showed an increasing trend from 30 DAS to the harvesting stage. At the harvesting stage, the maximum DMA (1693.5 g/m²) was obtained with the treatment receiving 150% RDN, and it was statistically at par with 125% RDN (1685.8 g/m²), 100% RDN (1653.8 g/m²), LCC based (1550.5 g/m²) and SPAD meter-based (1557.5 g/m²) N management. The leaf area index (LAI) of maize was also influenced in the same pattern as noted in plant height and DMA. At 60 DAS, the highest LAI was found in 150% RDN (5.5), and it was found to be statistically at par with treatments receiving 125% RDN (5.0), 100% RDN (5.0), LCC (4.8), and SPAD meter-based (5.4) N management treatments. The Crop growth rate (CGR) was found to be highest at 60-90 DAS in the treatment with 150% RDN (34.4g/m²/ day) which remained statistically at par with treatments 125% RDN (34.0 g/m²/ day), 100% RDN (34.2g/m²/ day), LCC based (29.9g/m²/ day) and SPAD meter-based (30.4g/m²/ day) N management treatments. The results are in conformity with the findings of Hammad *et al.* (2011), Matusso *et al.* (2014), and Naik

Table 2: Effect of nitrogen management options on yield attributes of *Rabi* maize

Treatments	Cob Length (cm)	Cob girth (mm)	Number of grains/ cob	Test Weight (1000 grain weight) (g)
T1 : CONTROL	22.7	30.7	281.3	214.7
T2 : 150% RDN	28.3	55.4	560.1	218.3
T3: 125% RDN	26.5	53.5	523.4	213.3
T4: 100% RDN	24.6	49.7	469.9	208.3
T5: 75% RDN	21.2	42.8	410.7	213.3
T6: 50% RDN	20.6	38.5	313.8	212.2
T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS)	25.0	51.2	465.6	220.2
T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 at 21 and 45 DAS)	25.3	53.0	510.0	215.4
SEm(±)	1.08	1.90	30.71	4.09
CD at 5%	3.3	5.8	93.2	NS

et al. (2019), who noted the earlier similar type of effects of N management.

Yield attributes

The results recorded on yield attributes, namely, cob length, cob girth, number of grains/cob, and test weight, revealed that the highest cob length was observed in the treatment 150% RDN (28.3 cm), which was statistically at par with the treatments receiving 125% RDN (26.5 cm), 100% RDN (24.6 cm), LCC based (25.0 cm) and SPAD meter-based treatments (25.3 cm). A similar trend was also noted in the expression of the cob girth in *rabi* maize. The maximum cob girth was noted with the application of 150% RDN (55.4 mm), which remained statistically at par with the treatments receiving 125% RDN (53.5 mm), 100% RDN (48.6 mm), LCC based (51.2 mm), and SPAD meter-based treatments (53.0 mm).In the case of a number of grains and test weight also the same trend was noted. Nitrogen supply in sufficient quantity is the pre-requisite for the enhancement of hybrid maize yield attributes as the nutrient regulates physiological and metabolic activities (Yue *et al*. 2021; Zhou *et al*. 2019). Moreover, the obtained results are similar to the early findings of Biradar *et al*. (2012) and Jat *et al*. (2013).

Yields

The results obtained from grain and stover yields have been represented in Table 3. **N**itrogen management treatments showed much influence on the grain yield of *rabi* maize. The data of grain yield revealed that the treatment received 150% RDN produced the highest yield of 6.48 t ha^{-1}. The treatments with 125% RDN and 100% RDN also produced statistically at par yields of 6.41 t ha^{-1} and 6.34 t $ha^{-1,}$ respectively. Further, precision N management treatments, namely, LCC-based N application (6.09 t ha^{-1}) and SPAD meter meter-based N application (6.06 t ha^{-1}), also resulted did not significantly differ in expression of grain yield. The treatments 75% RDN and 50% RDN receiving less nitrogen than the recommended dose produced decreased yields. However, the control treatment produced the least yield because of insufficient nutrition, probably due to lack of nutrients. The straw yield was found to be maximum in 150% RDN (8.42 t ha^{-1}), and it was closely followed by 125% RDN (8.41 t ha^{-1}), 100% RDN (8.33 t ha^{-1}), LCC based N management treatment (8.38 t ha^{-1}), and SPAD meter-based treatment (8.47 t ha^{-1}) and all the treatments were statically at par except treatments 75% RDN (6.00 t ha^{-1}) and 50% RDN (6.11 t ha^{-1}) which received less N application than the recommended dose. The control treatment was significantly inferior to all as it did not receive any exogenous nutrients. A similar observation of the effect of different nitrogen management levels on maize yields by Biradar *et al*. (2012), Suri *et al*. (2012) and Selassie (2015). In an expression of harvest index, the control treatment being statistically at par with 50% N and 75% N registered the least value, but the remaining treatments remained statistically at par.

Table 3: Effect of nitrogen management options on grain and stover yields and harvest index of *Rabi* maize

Treatments	Grain yield (t/ha)	Stoveryield (t/ha)	Harvest index (%)
T1: Control	3.09	5.08	37.9
T2: 150% RDN	6.65	8.42	44.1
T3: 125% RDN	6.41	8.41	43.2
T4: 100% RDN	6.34	8.33	43.2
T5: 75% RDN	4.17	6.00	41.0
T6: 50% RDN	3.98	6.11	39.3
T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS)	6.09	8.38	42.1
T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 at 21 and 45 DAS)	6.06	8.47	41.7
SEm(±)	0.20	0.20	1.14
CD at 5%	0.61	0.62	3.45

Table 4: Effect of nitrogen management options on nutrient use efficiency of *rabi* maize

Treatment	Nutrient Use Efficiency of Nitrogen		
	Agronomic efficiency (AE) (kg kg^{1})	Physiological efficiency (PE) (kg kg^{1})	Nutrient harvest index (NHI) (%)
T_1 :Control	0.0	0.0	0.0
T_2 :150% RDN	19.8	15.0	41.1
T_3 :125% RDN	22.2	14.7	42.4
T_4 :100% RDN	27.1	14.6	43.1
T_5 :75% RDN	12.0	10.0	47.8
T_6 :50% RDN	14.8	9.9	50.7
T_7: LCC (25 Kg/ha N @basal, 45 Kg/ha N at 21 DAS, 45 Kg/ha N @ LCC<5 at 45 DAS)	26.1	14.4	41.6
T_8: SPAD (75 Kg N/ha @basal, 20 Kg N/ha @SPAD<45 at 21 and 45 DAS)	25.8	14.4	41.0

Nutrient use efficiency

The nitrogen management levels expressed a significant impact on nutrient use efficiency, agronomic efficiency (AE), physiological efficiency (PE), and nutrient harvest index (NHI) of *rabi* maize. The higher value of agronomic efficiency was found in the treatment 100% RDN, and it was closely followed by treatments receiving 125 % RDN, LCC-based, and SPAD-based N management. The physiological nutrient use efficiency (PE) was highest in the treatment that received 150% RDN and was closely followed by 125% RDN, 100% RDN, LCC-based, and SPAD-based N management treatments. The crop receiving 50% RDN (T_6) recorded maximum nutrient harvest index (NHI) than all other treatments. The treatment 150% RDN (T_2) receiving the highest dose of fertilizer produced the lowest NHI, which was closely followed by 125% RDN (T_3), 100% RDN (T_4), 75% RDN (T_5), LCC based (T_7) and SPAD meter-based (T_8) N management treatments. The results are in conformity with the findings of Balasubramanian *et al.* (2004), Oktem *et al*. (2010), and Sharma and Bali (2018).

CONCLUSION

Nitrogen is an essential nutrient known to enhance the growth and productivity of different cereals, including maize. From the study, it can be concluded that the application of N fertilizer through precision management strategies by using precision tools like LCC and SPAD meter resulted in a considerably similar type of plant growth, yield attributes, and yields of *Rabi* maize crop as noted in RDF and more than RDF. Further, the N losses were also reduced with the utilization of LCC and SPAD meter-based Management treatments. Therefore, LCC and SPAD meter-based N management can be considered as efficient tools for N management in *Rabi* maize in south Odisha, and being handy tools, these can be recommended to the farmers in this region.

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