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Impact of tillage and precision nutrient management practices on productivity of *rabi* maize

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Abstract

A field experiment was conducted during the *rabi* season 2025-26 at Research Farm, School of Agricultural Sciences, Malla Reddy University, Hyderabad, to study the influence of tillage and nutrient management practices on maize (*Zea mays* L.) productivity and soil health. The texture of soil at the experimental site was sandy loam, moderately alkaline in reaction, non-saline in electrical conductivity, low in organic carbon and available phosphorus, medium in available nitrogen and potassium. The field experiment was laid out in a split plot design with three replications, comprising of two tillage practices (conventional tillage and Zero tillage + Crop residue @ 2Mg ha⁻¹) as main plots and four nitrogen management practices (50% RDN+ SPAD reading based nitrogen application, 50% RDN + LCC based nitrogen application, 100% RDN and Zero N application) as sub-plots. The data generated was analyzed using standard statistical procedures. The results revealed that, conventional tillage with 100% RDN (T₁N₃) recorded superior growth and yield characters of maize. A recommended dose of 120: 60: 30 kg N:P₂O₅:K₂O ha was applied as basal and in 30 days interval and the maize variety P3302 was sown in October at a spacing for all treatments was done using the graduated bucket method. The data generated were analysed using standard statistical procedures. The results revealed that T₁N₃ recorded the highest grain yield (7726 kg ha⁻¹), and lowest was recorded with the T₁N₄ (4815 kg ha⁻¹). Hence, integration of conservation tillage with 100% and balanced fertilization can be recommended as an efficient and sustainable strategy for improving productivity under semi-arid tropical conditions.

Keywords: Soil fertility, maize, SPAD, LCC, grain yield, nutrient and different tillage practices

Introduction

Maize (*Zea mays* L.) has become an important multipurpose crop in India, contributing significantly to food security, livestock feed, and industrial uses. Its cultivation has expanded in recent years due to growing demand from sectors such as poultry, starch, ethanol, and processed foods. During 2024–25, maize occupied about 12 million hectares with a production of 42.3 million tonnes and an average productivity of 3.52 t ha⁻¹ (DA & FW, 2024–25). Despite this progress, yields remain below global averages due to constraints like poor nutrient management, soil degradation, climate variability, and limited adoption of improved technologies.

Conventional tillage practices degrade soil structure, reduce organic matter, and increase erosion and greenhouse gas emissions (Lal, 2013) ^[11]. In contrast, conservation approaches such as zero tillage improve soil organic carbon, aggregation, and water-use efficiency (Hobbs & Govaerts, 2010) ^[5]. The addition of crop residues plays a crucial role in conservation agriculture systems by protecting the soil surface from erosion, reducing evaporation losses, moderating soil temperature, and enhancing soil organic carbon and microbial activity (Singh *et al.*, 2022; Lal, 2005) ^[18, 11]. Crop residue retention also improves nutrient recycling by gradual decomposition and enhances nitrogen availability in soil (Govaerts *et al.*, 2007; Kassam *et al.*, 2015) ^[4, 7].

Nitrogen management is another critical challenge. Excessive nitrogen use lowers nitrogen use efficiency (NUE) and increases environmental risks (Raun & Johnson, 1999) ^[16]. Precision nitrogen management tools such as SPAD meters and Leaf Colour Charts (LCC) enable real-time assessment of crop nitrogen status, improving fertilizer use efficiency and reducing losses (Sharma *et al.*, 2023) ^[17]. The SPAD chlorophyll meter is a widely used portable device that provides a rapid, non-destructive estimate of leaf chlorophyll content, which is closely related to

plant nitrogen status and photosynthetic efficiency (Singh & Singh, 2022; Zhang *et al.*, 2022) ^[18, 22]. SPAD-based nitrogen management has been reported to significantly improve nitrogen use efficiency and crop productivity in maize-based systems. Similarly, the Leaf Colour Chart (LCC) is a low-cost, farmer-friendly tool that helps in visual assessment of leaf greenness for need-based nitrogen application at critical growth stages, thereby improving yield and reducing nitrogen losses.

Integrating zero tillage, residue management, and real-time nitrogen management offers a promising pathway for sustainable maize production. These practices can improve yield, enhance NUE, maintain soil health, and reduce environmental impacts (Govaerts *et al.*, 2009; Kassam *et al.*, 2015; Liu *et al.*, 2018) ^[4, 7, 12]. In the context of climate change, such integrated approaches are even more essential. This is particularly important under semi-arid conditions like Telangana, where efficient resource use is crucial.

Therefore, this study aims to evaluate the combined effects of zero tillage, crop residue retention, and real-time nitrogen management (using SPAD and LCC) on maize productivity, NUE, and soil health under semi-arid conditions. The objective is to develop sustainable, climate-smart, and economically viable recommendations for maize farmers.

Materials and Methods

The Field experiment was carried out during Rabi, 2025-26 in the Field No. D-2 of the Experimental Farm, Department of Agronomy, School of Agricultural Sciences (SoAS), Malla Reddy University, Maisammaguda, Hyderabad, Telangana. The experimental site is situated at 17°19'16.4" latitude and 78°24'43" E longitude at an altitude of 542.3 meters above mean sea level. The weather of Maisammaguda is moderately warm with cool and dry winter. The mean maximum temperature is 31.3 °C while the mean minimum temperature is 17.9 °C, and the mean relative humidity is 60%. The soil of the experimental field is alkaline in nature with a pH of 8.12.

The field experiment was laid out in split-plot design comprising 12 treatments with 3 replications. The gross plot size adopted was 4.8 m × 4.0 m, and observations were recorded from a net plot area of 3.6 m × 3.0 m. The treatments are (T₁N₁) Conventional Tillage + 50%RDN + SPAD based nitrogen application, (T₁N₂) Conventional Tillage + 50%RDN + LCC based nitrogen application, (T₁N₃) Conventional Tillage + 100% RDN, (T₁N₄) Conventional Tillage + Zero N application, (T₂N₁) Zero tillage + Crop residue (@ 2 Mg ha⁻¹) + 50%RDN + SPAD based nitrogen application, (T₂N₂) Zero tillage + Crop residue (@ 2 Mg ha⁻¹) + 50%RDN + LCC based nitrogen application, (T₂N₃) Zero tillage + Crop residue (@ 2 Mg ha⁻¹) + 100% RDN, (T₂N₄) Zero tillage + Crop residue (@ 2 Mg ha⁻¹) + Zero N application.

The Maize variety P3302 was employed as a test crop using a recommended seed rate of 80 kg ha⁻¹ and a row spacing of 60 cm × 20 cm. P2O₅ and K₂O were distributed evenly among all treatment plots in the form of diammonium phosphate and muriate of potash, respectively. Measurements related to growth, yield, and yield attributes were recorded from five randomly chosen plants, and the mean values for each treatment were computed and recorded. Following the harvest and threshing of the crop, the yield was measured for each net plot. The experimental data collected on plant growth parameters, yield components, and yield were subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1954). Wherever F-test was significant, for comparison between the treatment means, an appropriate value

of critical difference (C.D.) was worked out. All the data were analysed and the results are presented and discussed at a probability level of 5%.

The SPAD chlorophyll meter was used as a rapid, non-destructive diagnostic tool for assessing leaf chlorophyll content and nitrogen status, enabling real-time nitrogen management in maize, as reported by Shivashankar *et al.*, (2025) ^[21] and Kumar *et al.*, (2023) ^[8]. Similarly, the Leaf Colour Chart (LCC) was employed as a simple visual tool for monitoring leaf greenness to guide need-based nitrogen application at critical growth stages, thereby improving nitrogen use efficiency and reducing nitrogen losses, as supported by Singh *et al.*, (2022) ^[18].

Results and Discussion

The results of the present investigation clearly indicated that the growth and yield of maize were significantly influenced by tillage and nutrient management practices. Among the treatments, T₁N₃ (Conventional tillage + 100% RDN) recorded the highest growth parameters like plant height (230.3 cm), dry matter accumulation (267.62 g plant⁻¹) at harvest, leaf area index (3.10 g) at 90 DAS. Similarly, highest grain yield (7726 kg ha⁻¹), stover yield (10187 kg ha⁻¹), stone yield (2776 kg ha⁻¹) and harvest index (37.37%) was also recorded with the same treatment. This superior performance can be attributed to the adequate and timely availability of nitrogen, which enhanced chlorophyll formation, photosynthetic efficiency, protein synthesis, and overall vegetative growth. Nitrogen plays a key role in cell division and elongation, resulting in increased plant height, leaf area, and dry matter accumulation. Conventional tillage further contributed by improving soil tilth, aeration, and root penetration, thereby facilitating efficient nutrient and water uptake. These findings are supported by Lal (2013) ^[11], who reported better crop performance under proper tillage, Raun and Johnson (1999) ^[16], who highlighted the importance of nitrogen in increasing nitrogen use efficiency and yield, Marschner (2012) ^[13], emphasizing the physiological role of nitrogen, Fageria *et al.*, (2011) ^[2], who observed enhanced crop productivity with balanced fertilization, and recent studies by Zhang *et al.*, (2022) ^[23], who reported that adequate nitrogen supply significantly improves chlorophyll content, photosynthetic rate and biomass accumulation in maize. Further, the use of SPAD chlorophyll meter and Leaf Colour Chart (LCC) for nitrogen management has been widely recommended for real-time nitrogen diagnosis and need-based fertilizer application, which helps in maintaining optimum leaf greenness, improving nitrogen use efficiency and reducing nitrogen losses. SPAD values directly correlate with leaf chlorophyll and nitrogen status, while LCC provides a simple visual assessment of crop nitrogen requirement at critical growth stages.

The treatment T₁N₂ (50% RDN + LCC based nitrogen application) also performed well, with plant height (191.3 cm), leaf area index (2.80g), dry matter accumulation (247.16 g plant⁻¹), grain yield (6605 kg ha⁻¹), stover yield (9028 kg ha⁻¹), stone yield (2525 kg ha⁻¹) and harvest index (37.27%), and it was the second best treatment in the study, showing on par results with the first best treatment. This better performance can be attributed to the fact that LCC-based nitrogen application helps in maintaining optimum crop nitrogen status throughout the growth period, ensuring steady chlorophyll formation, better canopy development, and efficient dry matter production, which ultimately supports higher yield formation even at reduced fertilizer levels. Parihar *et al.*, (2018) ^[15] reported that LCC-guided nitrogen application improves crop performance mainly by enhancing nitrogen uptake efficiency and maintaining

uniform crop greenness during critical growth stages. Jat *et al.*, (2020) ^[7] observed that real-time nitrogen management using LCC reduces excess fertilizer use and improves nitrogen recovery efficiency, leading to better crop growth under different tillage systems. Singh *et al.*, (2021) ^[20] found that LCC-based nitrogen scheduling supports synchronized nitrogen supply with crop demand, resulting in improved biomass accumulation and yield stability. Kumar *et al.*, (2022) highlighted that split nitrogen application based on LCC readings minimizes nitrogen losses and enhances physiological efficiency of the crop. Meena *et al.*, (2023) ^[14] also reported that LCC-based nutrient management improves yield attributes by ensuring continuous nitrogen availability during peak crop demand periods, thereby sustaining productivity even under reduced nitrogen input conditions.

In contrast, the lowest growth and yield were recorded under T₁N₄ (Conventional tillage + zero nitrogen application), with plant height (170.87 cm), leaf area index (1.68g), dry matter

accumulation (170.87 g plant⁻¹), grain yield (4815 kg ha⁻¹), stover yield (6195 kg ha⁻¹), stone yield (2267 kg ha⁻¹) and harvest index (36.19%), likely due to severe nitrogen deficiency reducing chlorophyll content, photosynthetic activity, and biomass accumulation. Nitrogen deficiency also limits enzyme activity, protein synthesis, and grain formation, resulting in poor growth and yield. Additionally, continuous conventional tillage without organic inputs depletes soil organic matter, reduces microbial activity, and deteriorates soil structure. These observations are supported by Giller *et al.*, (2009) ^[3] and Singh *et al.*, (2022) ^[19], along with recent studies by Kumar *et al.*, (2021) ^[9], who emphasized that nitrogen omission severely reduces maize growth, yield attributes and physiological efficiency. Therefore, while T₁N₃ ensures higher immediate productivity due to sufficient nitrogen availability, integrating conservation practices with balanced fertilization, as in T₂N₃, is essential for sustaining soil health and long-term maize productivity under semi-arid conditions.

Table 1: Effect of tillage and nutrient management practices on plant height (cm) in *rabi* maize

Treatments	30 DAS	60 DAS	90 DAS	At Harvest
Main Plot				
CT	44.2	147.7	177.3	181.9
ZT + Crop residue @ 2Mg ha ⁻¹	41.6	142.0	172.1	179.4
SEd±	4.5	13.7	10.7	19.8
LSD (p=0.05)	NS	NS	NS	NS
Sub Plot				
50% RDN + SPAD based nitrogen application	41.8	137.8	172.4	176.4
50% RDN + LCC based nitrogen application	44.2	150.9	181.2	191.3
100% RDN	46.2	186.2	226.0	230.3
Zero N application	39.4	86.2	119.2	124.5
SEd±	2.7	10.1	20.1	21.4
LSD (p=0.05)	NS	22.0	43.7	46.6
Interaction				
SEd±	3.8	14.3	28.4	30.3
LSD (p=0.05)	NS	NS	NS	NS

Table 2: Effect of tillage and nutrient management practices on yield attributes of *rabi* maize

Treatments	Cob length (cm)	Cob girth (cm)	No. of cobs per plant	No. of Kernel rows per cob	No. of kernels per cob	Seed index (g)
Main Plot						
CT	18.9	15.9	1.64	14.6	492	28.8
ZT + Crop residue @ 2Mg ha ⁻¹	15.7	14.9	1.58	14.0	490	27.3
SEd±	1.2	0.7	0.02	0.6	48	0.7
LSD (p=0.05)	NS	NS	NS	NS	NS	NS
Sub Plot						
50% RDN + SPAD based nitrogen application	17.5	15.7	1.62	14.2	491	27.1
50% RDN + LCC based nitrogen application	18.4	15.9	1.66	14.7	496	29.0
100% RDN	19.9	16.6	1.72	15	533	29.4
Zero N application	16.4	13.4	1.46	13.3	442	26.6
SEd±	1.6	0.9	0.03	1.2	89	1.4
LSD (p=0.05)	NS	NS	0.06	NS	NS	NS
Interaction						
SEd±	2.3	1.2	0.1	1.7	126	2.1
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

Table 3: Effect of tillage and nutrient management practices on grain yield (kg/ha) *rabi* maize

Treatments	Grain yield	Stover yield	Stone yield	Harvest Index
Main Plot				
CT	6750	9179	2605	37.06
ZT + Crop residue @ 2Mg ha ⁻¹	6078	7921	2427	36.97
SEd±	368	331	361	0.57
LSD (p=0.05)	1582	NS	NS	NS
Sub Plot				
50% RDN + SPAD based nitrogen application	6510	8791	2497	37.22
50% RDN + LCC based nitrogen application	6605	9028	2525	37.27
100% RDN	7726	10187	2776	37.37
Zero N application	4815	6195	2267	36.19
SEd±	463	814	211	0.44
LSD (p=0.05)	1010	1774	459	0.97
Interaction				
SEd±	655	1151	298	0.6
LSD (p=0.05)	NS	NS	NS	NS

Conclusion

The results of the present study clearly show that tillage and nutrient management had a strong influence on crop growth and yield. Among all the treatments, conventional tillage with 100% RDN gave the best performance, recording higher growth, yield attributes, grain yield, and stover/haulm yield, mainly because the crop received sufficient and timely nutrients throughout its growth period. At the same time, conventional tillage with 50% RDN + LCC-based nitrogen application performed almost the same as the best treatment, which indicates that real-time nitrogen management using LCC can efficiently supply nitrogen according to crop need and help maintain yield even with reduced fertilizer use. On the other hand, conventional tillage with zero nitrogen recorded the lowest growth and yield values, showing very clearly how important nitrogen is for proper crop development. Overall, the study suggests that while applying the full recommended nitrogen dose gives maximum yield, using LCC-based nitrogen management can achieve similar results in a more efficient and sustainable way by improving nitrogen use and reducing unnecessary fertilizer application.

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