https://doi.org/10.3126/adj.v18i1.82087

EFFECTS OF DIFFERENT TILLAGE AND NITROGEN MANAGEMENT PRACTICES ON MAIZE YIELD PARAMETERS, AND SOIL PROPERTIES IN MID HILLS OF NEPAL

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ABSTRACT

A field experiment was conducted in March 2022 at Lamjung Campus, Sundarbazar, Nepal, to study the effects of tillage and nitrogen management practices on soil properties, yield, and yield attributes of the Posilo Makai-1 variety of maize. Two tillage systems (ZT-zero tillage and CT-conventional tillage) and four nitrogen management approaches (N1-traditional farmer's practice, N2-recommended dose of NPK fertilizer (RDF), N3-50% RDN from urea+50% from FYM (farmyard manure) + recommended dose of phosphorous and potassium, and N4-leaf color chart (LCC)-based application of nitrogen + recommended dose of phosphorus and potassium) as main-plot and sub-plot factors were replicated thrice in a split-plot design. Research results revealed that nitrogen management practices significantly affected yield attributes and yield of the maize. LCC-based nitrogen application produced the highest cob length (15.2 cm), cob diameter (40.70 cm), grains per row (29.7), ear weight (89.0 g), grains per cob (420.03), 100-grain weight (20.70 g), and grain yield (4913.89 kg/ha), while the lowest values for yield attributes and yield were reported from farmer's practice with the lowest yield (3227.47 kg/ha). Although statistically similar, LCC-managed plots had higher residual soil nitrogen (0.15%), organic matter (2.83%), soil available phosphorus (11.97 kg/ha), and available potassium (142.44 kg/ha), with reduced soil acidity (pH 5.35). However, tillage systems showed no statistically significant effect on yield parameters, yield, and soil parameters. These findings suggest that LCC-based nitrogen management could be a better practice for sustainable soil management and resource conservation in the long run.

Keywords:

LCC, Nutrient management, Soil properties, Tillage, Yield

INTRODUCTION

Maize is one of the most important cereal crops in the world, ranking first in productivity (5872.8 kg/ha), followed by rice (4744.4 kg/ha) and wheat (3505.9 kg/ha) (FAOSTAT, 2021). In Nepal, maize is the second most cultivated cereal after rice, with an average national productivity of 3.06 tons/ha (MoALD, 2022). It is used extensively for food, feed, and industrial purposes (Goodla et al., 2012). Nearly two-thirds of Nepal's total maize production comes from the mid-

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hill regions, where farming is predominantly maize-based (Devkota et al., 2015). However, existing soil and nutrient management practices fall short of realizing the potential yield of maize, resulting in a substantial yield gap of 2.9 t/ha (Basukala & Rasche, 2022). Addressing this gap requires sustainable soil and nutrient management practices tailored to the region's complex topography, soil constraints, and limited resource access (Devkota et al., 2015).

The conventional tillage system governs the tillage practices in maize cropping in mid-hills, including the use of animal ploughs, mini-tractors, or tractors for primary tillage operations (Bajaracharya, 2001). These intensive practices disrupt soil structure, increase nitrogen losses, and deteriorate the soil quality, ultimately affecting maize yields (Atreya et al., 2006). Since tillage practices influence nutrient dynamics through runoff, erosion, and leaching and affect the crop yield, adoption of sustainable tillage methods that promise minimal soil disturbance is essential to optimize maize productivity (Sharma et al.,2021). In this regard, conservation tillage, which involves multiple tillage operations, including zero and minimum tillage, might be a potential measure to reduce soil structure deterioration, minimize nutrient losses, and increase maize yields (Atreya et al., 2006; Khan et al., 2021).

Besides tillage practices, nitrogen (N) management is another critical factor limiting maize productivity (Thapa, 2021). Most of the farmers in the mid-hills of Nepal often apply urea and FYM without regard to crop demand or optimal timing (Vista et al., 2022), leading to nutrient losses and degradation of soil quality through leaching losses, volatilization losses, and reduced nitrogen use efficiency (Khadka, 2017). Minimizing such nutrient loss problems is a challenge for effective soil and plant nitrogen management. The concept of demand-based nutrient management is arising at present, where plants or soil are assessed for the amount and application timing of fertilizers. Demand-based N management strategies, such as the use of a Leaf Color Chart (LCC), can help synchronize fertilizer application with crop needs, thereby minimizing nitrogen losses and improving crop yields (Ladha et al., 2007). This budget-friendly, low-cost decision-making tool might be an efficient technology for many small-scale farmers of Nepal for N-management in cereal crops, including maize. Despite its cost-effectiveness and ease of use, the effectiveness of LCC as a tool to manage nitrogen and increase crop yield remains under-researched in Nepalese maize-based farming systems.

This study, thus, addresses a critical knowledge gap by experimentally evaluating the combined effects of tillage and nitrogen management practices on maize yield performance and soil nutrient status under mid-hill conditions in Nepal. The primary objective was to assess whether resource-conserving approaches specifically, zero tillage and real-time nitrogen application using the Leaf Color Chart (LCC) could enhance yield attributes, improve crop productivity of maize, and maintain soil fertility. It was hypothesized that the integration of zero tillage with LCC-based nitrogen management would result in significantly higher maize yields and improved soil nutrient status compared to conventional tillage and traditional nitrogen application methods. Findings from this research may provide accessible, low-cost solutions for smallholder farmers in Nepal's mid-hills, supporting more sustainable and efficient maize production systems.

MATERIALS AND METHODS

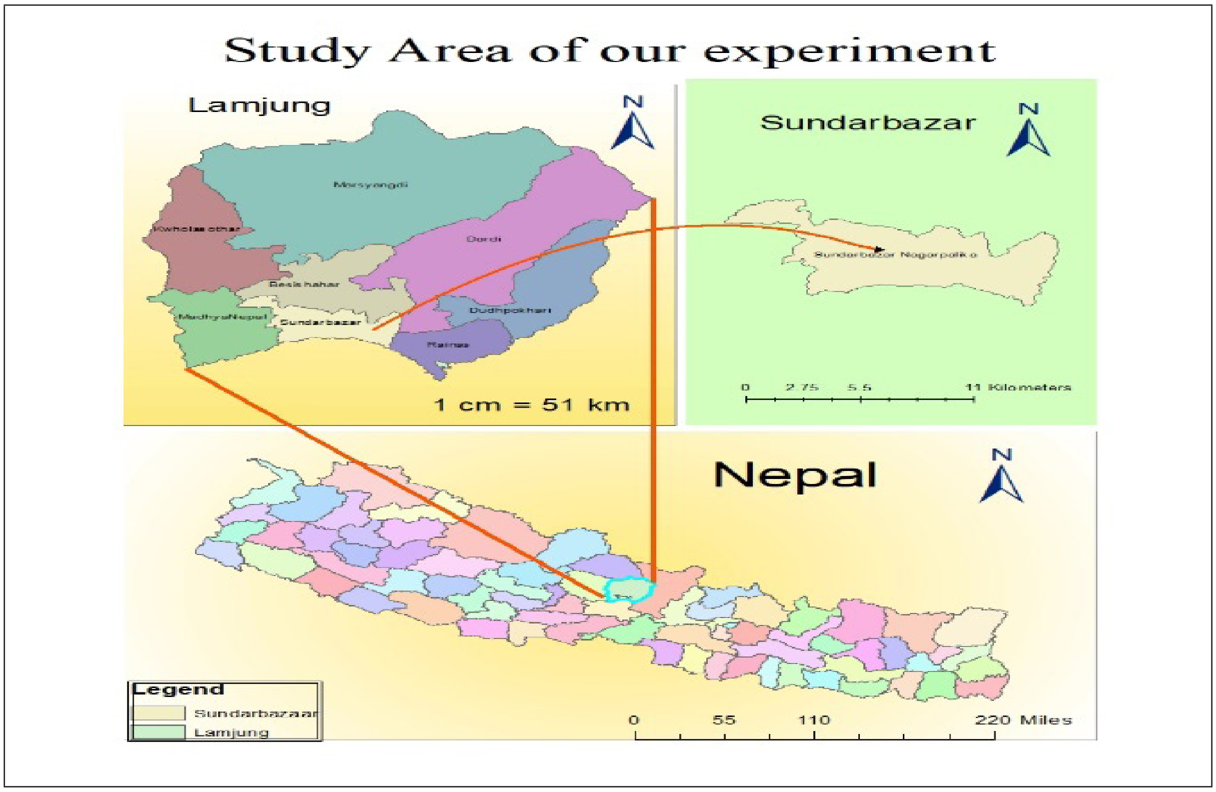

Figure 1: Map showing the experimental site.

Description of the experimental site

The experiment was carried out from March 2022 to July 2022 in the field of Lamjung Campus, Sundarbazar municipality, Lamjung district of Nepal. The site represents the mid-hill region and is situated at 28⁰ 7' N latitude and 84⁰ 25' E longitude and at an elevation of 857 masl (Figure 1). The mid-hill agro-ecological zone of Nepal ranges from approximately 600 to 1800 masl (NARC). Laboratory work was conducted in the Soil and Fertilizer testing laboratory, Kaski.

Details of climate and soil properties

The mean rainfall of the nearest meteorological station (Kaski) during the experimental months is shown in the figure 2:

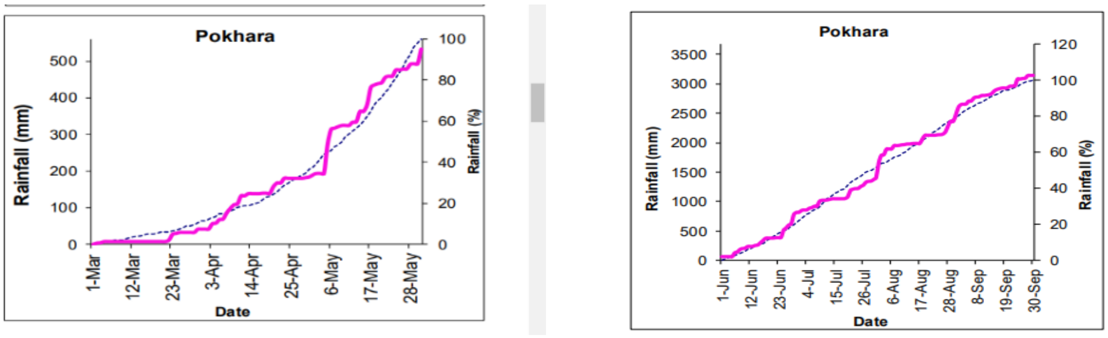

Figure 2: Mean rainfall(mm) in Pokhara during experimental months of 2022
Source: DHM reports,2022

(- - - -): Daily accumulated normal precipitation during the Pre-Monsoon (March to May) and Monsoon Season (June to September)

(------): Daily accumulated precipitation of the Pre-Monsoon and Monsoon Seasons of the experimental year 2022.

The soil characteristics of the field before conducting the study is given below in the table 1.

Table 1: Soil characteristics before sowing

pH	OM (%)	Total N (%)	P_2O_5(kg/ha)	K_2O(kg/ha)	Soil texture
6.7	4.49	0.22	17.06	204	Clay loam

Experimental design and treatments

A two-factor factorial experiment in a split-plot design with three replications was carried out, in which **tillage** was the main plot factor and **nitrogen management** was the subplot factor. The main plot factor consisted of two treatment levels: zero tillage (ZT) and conventional tillage (CT). Conventional tillage followed farmers' practice of tilling the soil to a depth of 15–20 cm using a hand tractor, while zero tillage involved surface seeding of maize without disturbing the soil.

The subplot factor included four nitrogen management treatments: **(N1)** Farmer's practice, **(N2)** Recommended dose of fertilizers (RDF)**, (N3)** 50% Recommended dose of Nitrogen (RDN) through urea + 50% RDN through farmyard manure (FYM)+ Recommended dose of Phosphorous and Potassium**,** and **(N4)** Leaf Color Chart (LCC)-based nitrogen management+Recommended dose of Phosphorous and Potassium.

In N1, the farmer's practice involved applying FYM at 7 kg per plot (equivalent to approximately 13.67 tons/ha), along with DAP (67 g per plot/ 130.43kg/ha) before sowing and applying the full dose of urea (80 g per plot/15.63kg/ha) at the time of first weeding or 25 DAS.

For N2 (RDF), the recommended dose of fertilizer 120:60:40 kg/ha $N:P_2O_5:K_2O$ with 10 tons/ha FYM was used. Based on the 5.12 m^2 plot size, each plot received approximately 134 g of urea (~260.87 kg/ha), 67 g of DAP (~130.43 kg/ha), and 34 g of MOP (~66.67 kg/ha). The full amount of DAP and MOP, along with half of the total urea (~67 g), was applied as a basal dose during sowing. The remaining half of urea (~67 g) was top-dressed at around 25–30 DAS, to meet the plant's peak nitrogen demand. Notably, the fertilizer treatments did not include micronutrients like zinc and boron. Their omission may limit potential yield and soil enrichment, especially in micronutrient-deficient soils. Future studies should incorporate these elements to ensure more comprehensive nutrient management. In N3, 60 kg/ha of nitrogen was supplied through urea (~67 g per plot), while the remaining 60 kg N/ha was supplemented using well-decomposed FYM at 20 tons/ha (equivalent to ~14 kg/plot). Phosphorus and potassium sources (DAP and MOP) were supplied in amounts similar to the RDF treatment.

In N4, nitrogen was managed using a six-panel Leaf Color Chart (LCC) following ICAR guidelines, allowing real-time, demand-based urea application. Phosphorus and potassium sources (DAP and MOP) were supplied in amounts similar to the RDF treatment.

There were 24 experimental units, each with a plot size of 5.12 m² (3.2 m × 1.6 m). A spacing of 1 m was maintained between blocks and 0.5 m between plots. Row-to-row and plant-to-plant spacing were maintained at 75 cm and 25 cm, respectively.

Variety of maize

Posilo makai-1 variety of maize was selected since it is a recommended variety for mid-hill regions of Nepal.

Agronomic practices.

In all experiment plots, two seeds per hill were planted and thinned to a single plant per hill after the first weeding. The recommended dose of fertilizer is 120:60:40 kg/ha N: P_2O_5:K_2O respectively. All the adjustments regarding the treatment combinations were done accordingly. Cultivation practices were carried out as recommended by the National Maize Research Program, Rampur, Chitwan. Two hand-weeding was carried out at 25 DAS and 45 DAS respectively.

Data collection

Various agronomic data were recorded from five random sample plants per plot to analyze yield and yield attributing characters. Pre-crop soil samples were collected from soil depth 0-20cm and analyzed for soil physical, and chemical properties one month prior to land preparation. Post-crop soil samples from soil depths 0-20 cm were taken from 24 experimental units and analyzed for soil physical and chemical properties.

Data Analysis

Data collected was tabulated in MS Excel and analyzed using R-studio software at a 5% level of significance.

The following parameters were observed and recorded during the study period (Table 2):

Table 2: Observed yield and soil parameters

	Observed Parameters	**Method**
YIELD PARAMETERS	Grains/row	Manual Counting
	No. of grains/cob	Manual Counting
	Cob length	Measuring scale
	Cob diameter	Vernier calipers
	Ear weight	Weighing balance
SOIL PARAMETRS	Residual Soil OM	Walkley-Black method
	Residual Total Soil N	Kjeldahl Distillation method
	pH	pH Meter
	Residual soil P_2O_5	Modified Olsen's bicarbonate method
	Residual Soil K_2O	Using Flame Photometer

Grain yield is calculated using the formula=

[Grain Weight×10×(100 – Moisture content)]/ [(100 − Adjusted moisture content) × Plot Area)]

RESULT AND DISCUSSION

Effect of nitrogen management and tillage methods on soil properties

Post-harvest laboratory analysis of soil samples revealed that plots managed with LCC-based nitrogen management (N4) had no significant influence on soil parameters i.e. residual soil total, organic matter, available phosphorus, available potassium, and soil pH, although consistently reported the highest values for residual soil total N (0.146%), organic matter (OM; 2.83%), available phosphorus (P_2O_5; 11.97 kg/ha), and available potassium (K_2O; 142.44 kg/ha), along with the highest soil pH (5.35). Conversely, plots under farmers' practice (N1) reported the lowest values across all these parameters, with soil pH value at 4.92. Krishnakumar and Haefele (2013) reported similar results of soil parameters with use of LCC in irrigated transplanted rice. The higher residual N in LCC-managed plots could be attributed to demand-based fertilizer application, reducing nitrogen losses through leaching and volatilization. This increase in residual nitrogen content likely contributed to improved OM levels, as the C:N ratio in soil remains relatively stable (~10:1), and greater N availability enhances microbial decomposition of organic residues (Brady and Weil, 2008).

Although not statistically significant, conventional tillage (CT) showed slightly higher soil nutrient values than zero tillage (ZT), likely due to better initial mixing of fertilizers and improved nutrient availability in the short term. However, this advantage may diminish or reverse over multiple seasons, as zero tillage has been associated with gradual improvements in soil structure, organic matter buildup, and moisture retention, which collectively enhance soil health and long-term productivity (Bhattacharyya et al.,2012). Additionally, the short duration of the experiment (one season) may not have been sufficient to capture the long-term benefits of zero tillage, which often manifest over time through improved soil structure and moisture conservation, as noted by Bhattacharyya et al. (2012). Similar findings were reported by Bhattarai et al. (2016) in the western mid-hills of Nepal and Sharma et al. (2021) in the eastern hill region, both observing enhanced organic matter and nutrient conservation over multiple cropping seasons under conservation tillage systems.

Table 3: Effect of tillage and nitrogen management treatments on soil properties at Lamjung campus, Sundarbazar in 2022

Treatment	pH	Residual Soil N (%)	Residual SOM (%)	Residual Soil P_2O_5 (kg/ha)	Residual Soil K_2O(kg/ha)
Tillage treatments					
ZT	5.01	0.129	2.49	9.71	127.54
CT	5.22	0.135	2.60	10.09	128.63
LSD	NS	NS	NS	NS	NS
N treatments					
Farmers practice (N1)	4.92	0.126	2.43	7.81	119.05
RDF (N2)	5.08	0.127	2.45	11.18	129.13
½ RDN + ½ FYM (N3)	5.11	0.129	2.48	8.64	121.71
LCC (N4)	5.35	0.146	2.83	11.97	142.44
LSD	NS	NS	NS	NS	NS

Effect of nitrogen management and tillage methods on grain yield and yield attributes of maize

1.Cob length, cob diameter, and ear weight

Significant effects ($p < 0.05$) of nitrogen management were observed on cob length, cob diameter, and ear weight, with the highest values recorded in LCC-based N management (N4) and the lowest in farmer's practice (N1). Tillage did not show a significant impact on these parameters (Table 4). Enhanced nitrogen availability under LCC likely improved nutrient uptake and increased nutrient assimilation ,with increased supply of photosynthates for cob development and biomass (Morales et al.,2000). These results agree with those of Sapkota et al. (2020), who also observed increased cob traits in maize using LCC under similar hill environments.

2.Grains row^{-1}, Grains cob^{-1}, and 100-grain weight

LCC based nitrogen management (N4) also led to significantly higher grains row^{-1} and grains cob^{-1} compared to other nitrogen management treatments, whereas 100-grain weight did not differ significantly among treatments (Table 4). Likewise, tillage had no significant effect on 100-grain weight, grains row^{-1} and, grains cob^{-1} The lack of tillage effect on these traits suggests that short-term tillage variations may not be sufficient to influence reproductive growth in maize.

Table 4: Effect of tillage and nitrogen management treatments on yield attributes of maize at Lamjung campus, Sundarbazar in 2022

Treatment	Grains / row	Grains / cob	Cob length(cm)	Cob diameter(mm)	100- grain weight	Ear weight (gm)
Tillage treatments						
ZT	25.26	357.77	13.28	37.91	18.96	69.91
CT	26.61	371.64	14.23	37.59	19.25	67.99
LSD	NS	NS	NS	NS	NS	NS
N treatments						
Farmers practice (N1)	22.25[c]	320.65	12.61[b]	36.31[b]	17.91	56.07[b]
RDF (N2)	26.82[ab]	361.02	14.13[ab]	37.70[b]	20.71	72.21[ab]
½ RDN + ½ FYM (N3)	24.98[bc]	357.12	13.05[b]	36.29[b]	17.08	58.50[b]
LCC (N4)	29.70[a]	420.03	15.22[a]	40.70[a]	20.70	89.02[a]
LSD	4.47	NS	2.97	2.81	NS	27.72
p-value	0.022	NS	0.028	0.016	NS	0.012

NS= non-significant

3. Grain yield

Grain yield was significantly influenced by nitrogen management but not by tillage. The highest grain yield (4913.89 kg/ha) was obtained from LCC-based nitrogen managed plots, which was significantly higher than other nitrogen treatments (Table 5). This can be attributed to improved synchronization of nitrogen supply with plant demand, leading to enhanced grain formation and filling. The yield superiority of LCC over RDF, FYM, and farmer's practice aligns with earlier studies in similar agro-ecological settings (Bashyal et al., 2020; Gautam et al., 2022). In line with our findings, Kharel et al. (2019) reported a 25–30% yield advantage under LCC-based management in mid-hill maize compared to traditional urea broadcasting.

Although LCC (N4) showed the highest performance in grain yield and yield attributing parameters, RDF (N2) also performed well, with yield and yield attributes statistically similar to N4 for several traits such as cob length and ear weight. This suggests RDF could be a practical option where LCC use is limited due to labor or knowledge constraints. Additionally, the N3 treatment (½ RDN + ½ FYM) showed promising result in maintaining soil organic matter, likely due to the gradual nutrient release from FYM. Its benefits might become more evident in long-term trials, as organic inputs typically take time to fully integrate into soil nutrient cycles.

Table 5: Effect of tillage and nitrogen management treatments on grain yield of maize at Lamjung Campus, Sundarbazar in 2022

Treatment	**Grain yield(kg/ha)**
Tillage treatments	
ZT	3905.91
CT	4053.6
LSD	NS
N treatments	
Farmers practice (N1)	3227.47^{b}
RDF (N2)	4363.86^{ab}
½ RDN + ½ FYM (N3)	3413.8^{b}
LCC (N4)	4913.8^{a}
LSD	1164.9
p-value	0.025

CONCLUSION

In conclusion, LCC-based nitrogen management significantly improved yield-attributing characters and grain yield of maize over other nitrogen management treatments. Significant effects on soil parameters were not reported. Also, yield attributes, grain yield, and soil parameters did not vary significantly among different tillage practices. Thus, the research results revealed the potentiality of incorporating LCC-based nitrogen management in maize over farmers' practice to increase its productivity, which assists in synchronizing nitrogen supply with the crop demand. RDF also demonstrated comparable results in yield traits and grain yield and could serve as a feasible option, particularly in less technology-intensive environments where frequent monitoring and decision-making required by LCC are challenging under resource-limited conditions. Moreover, the ½ RDN + ½ FYM treatment contributed positively to soil OM and could offer long-term benefits through sustained nutrient release. Although tillage effects were not statistically significant in this study, their long-term impact warrants further investigation through multi-season trials. These findings highlight practical, low-cost options for smallholder farmers and support future policy directions aiming to enhance input use efficiency and soil health in mid-hill agriculture by synchronizing N supply with crop demand. Moreover, long-term studies along with integration of zero-tillage practice and LCC-based nitrogen management in different agro-ecological belts are suggested to assess the impact of tillage and nutrient management practices on yield attributes, soil quality parameters, and grain yield of maize.

DECLARATION

The authors declare no conflict of interests.

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