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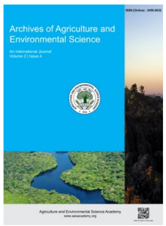

ORIGINAL RESEARCH ARTICLE

Tillage and leaf colour chart-guided nitrogen management: Key to growth and yield improvement of winter maize in Chitwan, Nepal

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ABSTRACT

Maize requires efficient nitrogen management to maximize productivity and sustainability. This research aimed to establish a critical Leaf Colour Chart (LCC) values for maize under zero tillage and conventional tillage. This research also focuses on evaluating LCC-based nitrogen management versus recommended practices. The experiment was conducted during the winter season of 2016-17 at the National Maize Research Program, Rampur, Chitwan, Nepal. The experiment was performed using a strip plot design with three replications. The main plot factor included two tillage methods (conventional and zero tillage) while the sub-plot factor comprised six nutrient management practices, namely nitrogen omission, recommended dose of nitrogen, nitrogen application at leaf color chart (LCC) values 3 (45 kg N/ha), LCC value 4 (88.33 kg N/ha), LCC value 5 (119.7 kg N/ha), and LCC value 6 (140 kg N/ha). Standard split nitrogen application and LCC-based nitrogen management at LCC 4, 5, and 6 critical values resulted in statistically similar LAI during all dates of observations; however, it was high at 90 days after sowing (DAS). Total dry matter accumulation was significantly higher under LCC-5 at 90 DAS. Grain yield was strongly influenced by nitrogen management, with LCC-5 achieving the highest yield (4814.26 kg ha^{-1}), followed by LCC-6 (4511 kg ha^{-1}). Conventional tillage slightly outperformed zero tillage in grain yield. According to the study, LCC threshold 5 is useful for real-time nitrogen application in maize. Therefore, maize farmers are encouraged to embrace LCC-based split nitrogen application rather than following standard nitrogen fixed schedules for sustainable and profitable production.

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INTRODUCTION

Agricultural contribution to the national GDP of Nepal is 24.12% and more than 60% of active population are involved in it for their livelihood. Maize (*Zea mays* L.) is a significant cereal crop globally, serving as a staple food for humans and primary feed for animals. Maize has high yield potential compared to other cereals, which has earned it's title "queen of cereals"(Magar *et al.*, 2018). Due to the expansion of the poultry and feed industry maize demand is increasing rapidly in Nepal (Dhakal *et al.*, 2022). Maize ranks second in terms of area (940,256 ha) and production (2,969,222 t) with a productivity of 3.16 t ha^{-1} (MoALD, 2024). Maize crops contribute approximately 7.61% to the Agricultural Gross Domestic Product (MoALD, 2023). Despite its importance, maize productivity remains low in Nepal due to a lack of high-yielding varieties, low plant population management, and unscientific fertilization practices. Farmers are carelessly applying fertilizer, without proper timing, dosages, or methods. In addition, the rising cost of labor and inputs also increases production costs in Nepal (Karki *et al.*, 2015). The yield of the crop is also significantly affected by various tillage techniques. Conventional tillage practices damage the soil, alter its natural structure, and increase surface runoff and soil erosion (Moussadek *et al.*, 2014). Compared to traditional tillage systems, zero tillage helps to conserve a significant amount of soil and nutrients, which has a favorable long-term influence on crop production (BK & Shrestha, 2014). Karki *et al.* also observed that growing maize using the zero-tillage method in rainfed areas of the mid-hill and terai regions minimizes soil disturbance, preserves organic carbon, and reduces production cost, which might be a financially feasible choice. According to Jat *et al.* (2013) nitrogen is a critical nutrient for maize growth and development.

Since maize is a heavy feeder crop, its productivity must be increased with a balanced dose of both organic and inorganic fertilizer. Excessive use of nitrogenous fertilizers without considering nutrient recommendations, crop nitrogen demand, and crop stage results in nutrient imbalance and economic losses. Applying nitrogen efficiently with the Leaf Color Chart (LCC) can boost maize yield, and improve food grain and soil health. Leaf color is a reliable and visible indicator for assessing crop nitrogen and can guide farmers in applying nitrogen more effectively. Critical LCC values differ significantly within maize genotypes due to genetic background, crop type, and leaf color so critical LCC value should be determined to guide the nitrogen application (Sen *et al.*, 2011 as cited Singh *et al.*, 2002). Although the use of LCC has been successfully utilized in rice, its application on maize remains unexplored in Nepal. When deciding nitrogen requirements, the LCC can be a useful tool for maize growers as it applies nitrogen based on crop demand and reduces excessive fertilizer use. Improper nitrogen management and soil deterioration under conventional tillage affect the yield potential of Nepalese farmers. The absence of localized research on LCC application in maize and the low adoption of conservation tillage practices emphasized the knowledge gap. This study introduces an innovative approach to nitrogen management through the pioneer use of LCC in maize cultivation. By combining LCC with tillage practices, this research tries to promote sustainable agriculture practices. This study aims to derive the critical threshold LCC value for maize under zero and conventional tillage and evaluate the effects of conventional and zero tillage practices on maize growth and yield. The findings are expected to provide actionable insights for farmers to adopt real guiding LCC nitrogen management tools for optimizing maize yield.

MATERIALS AND METHODS

Study area

A winter field experiment was conducted at the National Maize Research Program (NMRP) located at Rampur, Chitwan, from October 2016 to March 2017. The experiment site had sandy loam soil with an acidic reaction. The soil had low nitrogen, medium potassium and high phosphorus content. Throughout the experiment, 124.4 mm of rain was recorded. The maximum temperature varied from 20.07°C to 33.17°C, while the average minimum temperature varied from 8.8°C to 24.25°C. The range of the relative humidity was 78.89% to 95%.

Experimental design and treatments details

A strip plot design with three replications was used in the experiment. Each plot measured 27m^2.

Main plot factor: Tillage methods
Zero tillage (ZT)
Conventional tillage (CT)

Subplot factor: Nitrogen management practice
0 kg nitrogen per hector
Recommended dose of nitrogen (120: 60: 40)
Nitrogen dose at LCC value 3
Nitrogen dose at LCC value 4
Nitrogen dose at LCC value 5
Nitrogen dose at LCC value 6

LCC reading

The LCC values were recorded at the middle lamina of the third leaf from the top of the plant at 10-day intervals, starting from 22 days after sowing (DAS) up to 70 DAS. The colour of each selected leaf was measured by holding the LCC and placing the middle part of the leaf on top of a colour strip for comparison (the leaf was neither detached nor destroyed). The average of 10 plants' LCC readings was calculated. Whenever the average of leaf colour readings fall below the preset critical value, nitrogen fertilizer was top dressed immediately to correct nitrogen deficiency.

Cultural operations

The field was plowed 7 days before sowing the seeds using a tractor. Zero tillage field was treated with the recommended dose of glyphosate 47SL (5 ml per liter of water) to eliminate weeds. At the time of sowing, the land was fine-tilthed and the experiment plan was followed in the layout of the plots. The soil was treated with urea, single superphosphate, and murate of potash to provide the appropriate doses of nitrogen (N), phosphorus (P), and potassium (K) (120:60:40 kg N, P_2O_5, K_2O per hectare) respectively. A full dose of P_2O_5 and K_2O, along with 20 kg N ha^{-1} was applied at sowing for all treatments except the control and recommended nitrogen dose. Nitrogen was applied based on the values indicated in the Leaf Color Chart (LCC). Healthy seeds of Rampur composite genotype were selected for sowing. Maize was sown on October 7, 2016. At each spot two seeds were dibbled up to 4 to 5 cm deep in the seed line by Jap planter maintaining the row spacing of 60 cm and plant-to-plant spacing of 25 cm. To maintain the ideal plant population, gap filling was carried out at 4th and 8th days after seeding. The thinning operation was carried out at fifteen days after sowing (DAS). The cutworm was identified as a problematic insect in the research field, and its control was accomplished by applying cypermethrin at a rate of 2 ml per liter water at 35 DAS. Using surface irrigation, irrigation was conducted on 40 DAS, 75 DAS, and 95 DAS during the experiment. The experimental plot was kept weed-free throughout the crop-growing season. Two manual weeding and inter-cultivation were carried out on 21 and 45 days after sowing. The date of harvesting was March 27, 2017.

Observations recorded and analysis

Plant attributes and yield data were documented. A variety of statistical tools, including MSTAT, GENSTAT, and Excel, were effectively employed to conduct analysis of variance and enhance data evaluation processes. Simple correlation and regression analysis were carried out on selected parameters, following the methodology of Gomez & Gomez (1984). The Analysis of Variance (ANOVA) was performed to assess the significant differences among each parameter at a 5% significance level.

RESULTS AND DISCUSSION

Plant height

The comparison of tillage methods revealed a non-significant difference in plant height; however, it was observed that conventional tillage resulted in greater plant height than zero tillage in this experiment. This increased height may be due to reduced weed competition in conventional tillage. Furthermore, better soil aeration, moisture retention, nutrient availability, and root growth contributed to significantly higher values for all crop growth parameters. Amare *et al.* (2014), also found that conventional tillage resulted in higher plant heights compared to zero tillage. Similar results were found by Sarma & Gautam (2010), who obtained significantly higher plant in conventional tillage (174.1 cm) as compared to zero tillage (145.5 cm) at Pantanagar, India. In the present investigation, the plant height significantly differed by leaf colour chart value only at 70 DAS and 90 DAS. Plant height increased with an increase in nitrogen dose when applied as split. Three standard split applications of nitrogen (120 kg ha^{-1}) and nitrogen application through LCC based on 4, 5 and 6 critical values result the statistically similar plant height at all other dates of observations (Table 1). LCC-6 exhibited significantly greater plant height than LCC-5, LCC-4, and the recommended nitrogen dose, attributable to the higher nitrogen levels in LCC-6. Singh & Singh (2019) also observed the tallest plant height at LCC-6 and reported that increased plant height in LCC-6 is likely due to higher nitrogen level that enhances vegetative growth. These findings were also aligned with those of Sarnaik (2010).

Leaf area index

Although conventional tillage produces a significantly higher leaf area index than zero tillage, the difference is statistically insignificant at all growth stages. Higher leaf area index in conventional tillage was also evidenced by Buczek *et al.* (2021) compared to reduced tillage and no-tillage in wheat. Pandey and Chaudhary (2014) also observed higher LAI in conventional tillage, although the difference was non-significant in spring-planted maize in Chitwan. Conventional tillage offers better soil aeration, improves seedling establishment, reduces the competition for resources, and accelerates the decomposition of organic matter releasing nutrients that ultimately result in proper growth and development of plants increasing LAI. At 30, 50, and 70 days, the recommended nitrogen dose resulted in a significantly higher leaf area index, which was statistically similar to nitrogen application based on LCC critical values of 4, 5, and 6. At 90 DAS, nitrogen application through LCC at critical value 5 recorded a significantly higher value of LAI (2.29) which was statically at par with recommended doses, and nitrogen application through LCC at critical values 4 and 6. At 110 DAS, the recommended dose of nitrogen recorded the highest LAI (2.17), which was similar to LCC values 5 and 6. Three standard splits recommended dose of nitrogen application (120kg ha^{-1}) and nitrogen application through LCC based on 4, 5, and 6 critical values result in statistically similar LAI during all dates of observations (Table 2). This result suggests that continuous application of nitrogen helps to maintain nitrogen content (dark green color in LCC-5 and LCC-6) resulting in higher leaf area.

Table 1. Plant height of maize as influenced by tillage and nitrogen management practice during winter season.

Treatments	Plant height (cm)			
	30DAS	50DAS	70DAS	90DAS
Tillage				
Zero tillage	95.23	123.66	168.26^{b}	197.39
Con. tillage	91.81	134.85	179.43^{a}	204.78
SEm (±)	1.83	2.12	0.9	1.93
LSD (0.05)	11.14	12.91	5.5	11.75
CV%	3.4	2.8	0.9	1.7
F-test	Ns	Ns	0.01	Ns
Nitrogen management practice				
Control (0 kg N ha^{-1})	85.19	104.94^{b}	140.36^{b}	163.17^{c}
Rec. Dose (120 kg N ha^{-1})	95.61	140.81^{a}	188.53^{a}	210.67^{ab}
LCC <3 (45 kg N ha^{-1})	89.86	123.17^{a}	162.00^{ab}	193.64^{b}
LCC <4(83.33 kg N ha^{-1})	99.36	138.22^{a}	181.39^{a}	206.42^{ab}
LCC <5(119.7 kg N ha^{-1})	93.17	129.61^{a}	179.78^{a}	215.92^{a}
LCC < 6(140 kg N ha^{-1})	97.94	138.78^{a}	191.00^{a}	216.69^{a}
SEm (±)	6.17	5.84	10.45	6.01
LSD (0.05)	18.19	17.23	30.83	17.74
CV%	16.1	11.1	14.7	7.3
F-test	Ns	0.002	0.02	0.001
Grand mean	93.52	129.25	173.84	201.08
Interaction	Ns	Ns	Ns	Ns

Note: LCC, Leaf color chart; DAS, Days after sowing; Rec. Dose, recommended dose; Ns, non-significance; Sem, standard error of the mean; LSD, least significant difference; CV, coefficient of variation; Treatment followed by different letters are significantly different among each other based on DMRT as 5% level of significance.

Table 2. Leaf area index of maize as influenced by tillage methods and nitrogen management practice during winter season.

Treatments	Leaf Area Index (LAI)				
	30DAS	50DAS	70DAS	90DAS	110DAS
Tillage					
Zero tillage	0.66	1.34	1.85	1.66	1.62
Con. tillage	0.88	1.97	2.38	2.2	2.12
SEm (±)	0.06	0.2	0.1	0.15	0.84
LSD (0.05)	0.37	1.23	0.59	0.91	0.51
CV%	13.8	21.2	8	13.2	7.9
F-test	Ns	Ns	Ns	Ns	Ns
Nitrogen management practice					
Control (0 kg N ha^{-1})	0.46^{b}	1.19^{b}	1.60^{c}	1.40^{c}	1.38^{d}
Rec. Dose (120 kg N ha^{-1})	0.97^{a}	2.11^{a}	2.58^{a}	2.25^{a}	2.17^{a}
LCC <3 (45 kg N ha^{-1})	0.78^{a}	1.32^{b}	1.75^{bc}	1.68^{bc}	1.60^{cd}
LCC <4(83.33 kg N ha^{-1})	0.84^{a}	1.74^{a}	2.13^{abc}	2.05^{ab}	1.79^{bc}
LCC <5(119.7 kg N ha^{-1})	0.73^{ab}	1.81^{a}	2.42^{a}	2.29^{a}	2.00^{ab}
LCC < 6(140 kg N ha^{-1})	0.83^{a}	1.76^{a}	2.23^{ab}	2.07^{ab}	2.14^{a}
SEm (±)	0.09	0.12	0.19	0.15	0.11
LSD (0.05)	0.28	0.36	0.57	0.44	0.31
CV%	30.1	18.2	22.3	18.6	14
F-test	0.03	0.001	0.02	0.002	0.01
Grand mean	0.77	1.66	2.09	1.92	1.92
Interaction	Ns	0.03	Ns	Ns	Ns

Note: LCC, Leaf color chart; DAS, Days after sowing; Rec. Dose, recommended dose; Ns, non-significance; Sem, standard error of the mean; LSD, least significant difference; CV, coefficient of variation; Treatment followed by different letters are significantly different among each other based on DMRT as 5% level of significance.

Table 3. Total dry matter accumulation of maize as influenced by tillage methods and nitrogen management practice during the winter season.

Treatments	Total dry weight (g m^{-2})				
	30DAS	50DAS	70DAS	90DAS	110DAS
Tillage					
Zero tillage	18.33	48.35	90.64	160.88	240.609
Con. tillage	21.37	63.61	128.41	200.73	295.979
SEm (±)	1.63	9.44	12.01	12.49	19.88
LSD (0.05)	9.93	57.45	73.06	76.02	120.97
CV%	14.2	29.2	19	12	12.8
F-test	Ns	Ns	Ns	Ns	Ns
Nitrogen management practice					
Control (0 kg N ha^{-1})	11.07^{b}	34.66^{c}	73.47^{c}	124.44^{c}	189.28^{b}
Rec. Dose (120 kg N ha^{-1})	24.55^{a}	81.17^{a}	151.49^{a}	192.67^{ab}	320.89^{a}
LCC <3 (45 kg N ha^{-1})	21.29^{a}	44.29^{bc}	78.22^{c}	146.35^{bc}	223.22^{b}
LCC <4(83.33 kg N ha^{-1})	22.18^{a}	59.64^{b}	114.67^{b}	189.82^{ab}	277.35^{a}
LCC <5(119.7 kg N ha^{-1})	19.11^{ab}	56.93^{b}	125.68^{ab}	224.82^{a}	298.55^{a}
LCC < 6(140 kg N ha^{-1})	20.90^{a}	59.17^{b}	113.63^{b}	206.73^{a}	300.47^{a}
SEm (±)	49	6.07	10.25	18.3	16.39
LSD (0.05)	8.3	17.92	30.24	54	48.36
CV%	34.7	26.6	22.9	24.8	15
F-test	0.001	0.001	0.001	0.01	0.001
Grand mean	19.85	55.98	109.53	180.8	268.29
Interaction	Ns	Ns	Ns	Ns	Ns

Note: LCC, Leaf color chart; DAS, Days after sowing; Rec. Dose, recommended dose; Ns, non-significance; Sem, standard error of the mean; LSD, least significant difference; CV, coefficient of variation; Treatment followed by different letters are significantly different among each other based on DMRT as 5% level of significance.

Gupta *et al.* (2011) reported that increased nitrogen at LCC-5 enhanced auxin activity, carbohydrate accumulation, and meristematic growth at the shoot apex, which led to increased leaf area.

Total dry matter accumulation

The result determined that the total amount of dry matter accumulated for tillage was non-significant but it was found significant to nitrogen management practice (Table 3). During all dates of observations conventional tillage showed superior performance on total dry matter than zero tillage. Memon *et al.* (2012), Sarma & Gautam (2010), and Beyaert *et al.* (2002) reported significantly higher dry matter accumulation in conventional tillage compared to zero tillage. The result was in contrast to Shrivastav (2014) who stated that higher total dry matter was recorded in zero tillage compared to conventional tillage during the spring season of 2013 at Rampur, Chitwan, Nepal. For all observation dates, the recommended nitrogen dose led to a higher total dry matter accumulation. However, at 90 days, the nutrient management practice using the Leaf Color Chart (LCC) at a critical value of 5 resulted in a significantly greater total dry matter accumulation of 224.82 g m^{-2}. The LCC 5 treatment effectively increases dry matter production by enhancing leaf area and chlorophyll content, which improves photosynthetic activity. This leads to greater biomass accumulation, particularly at 90 DAS. Maiti (2006) pointed out that increased dry matter production in plants is due to an increased leaf area.

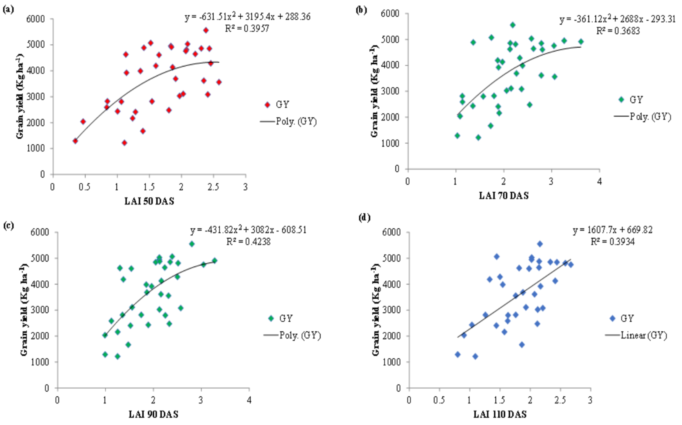

Figure 1. *Relationship between leaf area index at different days after sowing and grain yield of winter maize.*

Yield attributes

Tillage had no significant effect on plant population, number of cobs per plant, number of grains per cob, or thousand-grain weights. However, it was determined to be somewhat greater in conventional tillage than zero tillage (Table 4). The present finding was also supported by Shrivastav (2014) and Singh *et al.* (2009). The number of gains per cob was highest at nitrogen application through LCC at a critical value of 5 (321.04), and it was statically similar to the recommended dose of nitrogen (299.28) and nitrogen application through LCC at a critical value of 6 (291.16). The highest thousand grains weight was obtained at LCC 6 (313.15 g) followed by the recommended dose of nitrogen (313.03 g) and LCC 5 (306.81 g), and these groups of treatments were statistically similar. In the present research, LCC 6 (140 kg N ha^{-1}) and LCC 5 (119 kg N ha^{-1}) received more nitrogen split contributing to higher thousand-grain weight. Sorkhi & Fateh (2014) reported that maize treated with 250 kg nitrogen per hector yielded the highest grain weight (400.19 g), while 100kg nitrogen per hector produced the lowest (336.7 g).

Table 4. Yield attributes of maize as influenced by tillage methods and nitrogen management practices during winter season.

Treatments	Plant population per ha	Barrenness Percentage	Number of cobs per plant	Number of grains per cob	Thousand grain weight (g)
Tillage					
Zero tillage	59379.29	6.79	1.07	244.47	287.23
Con. tillage	60785.32	2.81	1.00	275.00	286.72
SEm (±)	285.10	0.95	0.03	10.80	1.70
LSD (0.05)	1734.90	5.81	0.16	65.70	10.34
CV%	0.80	34.50	4.50	7.20	1.00
F-test	Ns	Ns	Ns	Ns	Ns
Nitrogen management practice					
Control (0 kg N ha^{-1})	56532.92	11.33^{a}	0.97	181.33^{c}	253.12^{c}
Rec. Dose (120 kg N ha^{-1})	60185.19	1.78^{b}	1.08	299.28^{a}	313.03^{a}
LCC <3 (45 kg N ha^{-1})	58847.74	4.02^{b}	1.00	216.10^{bc}	258.91^{bc}
LCC <4 (83.33 kg N ha^{-1})	61831.28	3.06^{b}	1.03	249.51^{b}	276.85^{b}
LCC <5 (119.7 kg N ha^{-1})	62500.00	3.78^{b}	1.07	321.04^{a}	306.81^{a}
LCC <6 (140 kg N ha^{-1})	60596.71	4.81^{b}	1.06	291.16^{a}	313.15^{a}
SEm (±)	1459.80	1.61	0.05	12.93	6.57
LSD (0.05)	4306.40	4.74	0.15	38.15	19.37
CV%	6.00	82.00	12.30	12.20	5.60
F-test	Ns	0.01	Ns	0.002	0.001
Grand mean	60082.30	4.80	1.04	259.74	286.98

Note: LCC, Leaf color chart; Rec. Dose, recommended dose; Ns, non-significance; Sem, standard error of the mean; LSD, least significant difference; CV, coefficient of variation; Treatment followed by different letters are significantly different among each other based on DMRT as 5% level of significance

Table 5. Different parameters of maize as influenced by tillage methods and nitrogen management practices during winter season.

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Shelling percentage
Tillage				
Zero tillage	3326	3651.64	40.90	85.18
Con. tillage	3947	3887.14	42.97	86.02
SEm (±)	194.9	177.80	2.58	0.28
LSD (0.05)	1186.1	1082.00	15.68	1.80
CV%	9.3	8.20	10.60	0.60
F-test	Ns	Ns	Ns	Ns
Nitrogen management practice				
Control (0 kg N ha^{-1})	1981.24^{d}	2705.59^{b}	37.55	84.95
Rec. Dose (120 kg N ha^{-1})	4449.00^{a}	4186.55^{a}	44.83	86.44
LCC <3 (45 kg N ha^{-1})	2599.41^{c}	3079.09^{b}	39.33	85.32
LCC <4 (83.33 kg N ha^{-1})	3462.69^{b}	3149.86^{b}	44.98	85.79
LCC <5 (119.7 kg N ha^{-1})	4814.26^{a}	4541.41^{a}	44.20	85.52
LCC <6 (140 kg N ha^{-1})	4511.00^{a}	4953.83^{a}	40.73	85.57
SEm (±)	184.8	327.10	2.79	0.54
LSD (0.05)	545.2	965.10	8.23	1.59
CV%	12.4	21.30	16.30	1.50
F-test	0.001	0.001	Ns	Ns
Grand mean	3636	3769.39	41.94	85.60

Note: LCC, Leaf color chart; Rec. Dose, recommended dose; Ns, non-significance; Sem, standard error of the mean; LSD, least significant difference; CV, coefficient of variation; Treatment followed by different letters are significantly different among each other based on DMRT as 5% level of significance.

Effect on grain yield, harvest index, and stover yield

Grain yield was not affected by tillage practice but it was significantly affected by the nitrogen management practice. Conventional tillage produces comparatively a higher grain yield (3947 kg ha^{-1}) than zero tillage (3326 kg ha^{-1}). Yield increase in conventional tillage might be due to its advantages (Table 5). A similar grain yield was obtained by Pandey & Chaudhary (2014), who recorded a higher yield in conventional tillage but the result was statistically at par with zero tillage. The result was in contrast with Karki *et al*. (2015), Khan & Parvej (2011) and Dahal *et al.* (2014) who noticed higher yield in zero tillage. The highest grain yield (4814.26 kg ha^{-1}) was achieved with LCC < 5 and it was significantly higher than other nitrogen management practices except LCC based nitrogen application at critical value 6 and recommended dose of nitrogen application. Favorable nutrition contributed to the increased yield in the LCC-5 treatment, as evidenced by the higher test weight and number of grains per cob. LCC-6 and LCC-5 plots received a higher split of nitrogen fertilizer. The superior yield at LCC 5 might be due to increased nitrogen application in multiple splits. These findings are also quite similar to those of Swamy *et al.* (2016), Maiti & Das (2006), Datturam (2011), Sen *et al.* (2011), and Sarnaik (2010). Porpavai *et al.* (2002) indicated that nitrogen application at LCC 5 met crop demand at various physiological stages and reduced nutrient losses through denitrification and volatilization. Mathukia *et al.* (2014) reported that real-time nitrogen application using LCC 5 in split doses results in higher grain yield in maize in Gujarat, India. In this experiment, nitrogen application using LCC as critical value 6 resulted in the highest Stover yield (4953.83 kg ha^{-1}), which was significantly higher than other nitrogen management practices except for recommended nitrogen dose (4186.55 kg ha^{-1}) and LCC application at critical value 5 (4541.41kg ha^{-1}). This result aligns with Sarnaik (2010), who concluded plots that received higher nitrogen doses obtained higher yields. Harvest index and shelling percentage were unaffected by either tillage or nitrogen management.

Conclusion

The findings signified that nitrogen management had a massive effect, whereas tillage methods had no significant outcome on the growth and yield attributes of winter maize. This suggests that further exploration into tillage practices could lead to improved outcomes in maize cultivation. Regarding nitrogen management, LCC critical value 5 proved to have the highest grain yield. LCC 5 also have significant result on the growth and yield attributes of maize. Hence, LCC critical value 5 can be used to meet the crop nitrogen demand. This research provides insight into the utilization of LCC as a precision tool for nitrogen application among farmers. The trial was carried out in a single season and location, which may limit their ability to accurately reflect the effects under varying environmental conditions. This study presents an opportunity to explore the effects of tillage systems on soil properties and the profitability of nitrogen application using LCC that was not addressed in the current research.

DECLARATIONS

Authors Contribution Statement

Conceptualization, D.T and S.M; Methodology, D.T, L.P.A and S.M; Software validation, D.T. and S.M, Formal analysis, D.T; Investigation, D.T; Data curation, D.T; Original draft preparation, D.T; review and editing, D.T, L.P.A and S.M; Supervision, S.M and L.P. All the authors have read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of manuscript.

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