



Effect of tillage and precision nutrient placement on enhanced yield, productivity and profitability of maize (*Zea mays*)

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In agriculture, the challenge of nutrient and upper soil layer depletion underscores the need for strategic management to ensure sustained productivity while preserving soil fertility and environmental sustainability. Precise nutrient placement is essential for improving maize (*Zea mays* L.) yields in India, where intensive farming faces diminishing soil productivity. Conventional tillage leads to issues like carbon depletion, soil erosion, and inefficient input utilization (Goddard *et al.* 2008). Conservation tillage, involving crop residue retention and minimal tillage, offers a sustainable alternative (Zhang *et al.* 2009). Minimum tillage produced higher crop growth as indicated by plant height, dry biomass production, CGR, RGR and root growth over conventional tillage, while remained statistically at par with zero tillage (Sonnad *et al.* 2024). Unlike conventional tillage, minimum tillage reduces soil disturbance while still facilitating seedbed preparation and optimal growing conditions (Rusu 2005). Residue retention acts as natural mulch, protecting soil, improved water infiltration capacity and minimized soil erosion (Bogunovic *et al.* 2018). The practice of zero tillage with retained crop residues contributes to improved soil organic carbon levels, increased microbial biomass, and greater soil aggregate stability (Saha *et al.* 2010). Point placement of nitrogen fertilizer in conservation agriculture increases crop productivity, nitrogen uptake, and efficiency (Nayak *et al.* 2022). Effective tillage methods are crucial for maximizing soil nitrogen recovery and enhancing nitrogen use efficiency (NUE) in maize cultivation, balancing fertilizer application to avoid overuse or deficiency. Variations in grain yields across tillage methods and nutrient placement highlight this complex relationship. This study seeks to explore how tillage practices and precise nutrient placement increase the yield, productivity and profitability of maize.

The field experiment was conducted during the rainy (*kharif*) season of 2022 at ICAR-Indian Agricultural

Research Institute, New Delhi. The field experiment was executed in a split-plot design (SPD) with 3 distinct tillages, viz. T₁, Conventional tillage (Field was ploughed 3-times with cultivator followed by rotavator and crop residues were retained on the soil surface without incorporation); T₂, Minimum tillage (Field was prepared with one rotavator and previous crop residue and weeds if any incorporated in the soil and T₃, Zero tillage (Field was not disturbed and 3 t/ha wheat residues were kept) in main plots and 4 methods of precise nutrients application methods viz. N₁, 50% RDF (1/3rd Point placement as basal, 30 DAS and 50 DAS); N₂, 75% RDF (1/3rd Band placement as basal, 30 DAS and 50 DAS); N₃, 100% RDF (1/3rd Band placement as basal, 30 DAS and 50 DAS) and N₄, 100% RDF (1/3rd basal + 2 Top dress broadcasting). The maize hybrid 'Kaveri 25K55' was sown on 16th July 2022, with rows spaced 60 cm apart and plants spaced 20 cm within rows, using a seed rate of 20 kg/ha. The recommended dose of fertilizers 150:60:50 kg/ha NPK was used for maize. The yield and economic parameters have been calculated with the following formula:

$$\text{Shelling (\%)} = \frac{\text{Grain yield (t/ha)}}{\text{Cob yield (t/ha)}} \times 100$$

$$\text{Harvest index} = \frac{\text{Economic yield (t/ha)}}{\text{Biological yield (t/ha)}} \times 100$$

$$\text{Gross returns (₹/ha)} = \text{Sum of monetary value of grain and stover yield}$$

$$\text{Net returns (₹/ha)} = \text{Gross returns (₹/ha)} - \text{Cost of production (₹/ha)}$$

$$\text{Net benefit cost ratio (NB:C)} = \frac{\text{Net returns (₹/ha)}}{\text{Cost of production (₹/ha)}}$$

The recorded data were subjected to analysis of variance (ANOVA) using the OPSTAT statistical software package (Sheron *et al.* 1998). The standard error of the mean (SEM±) and least significant difference (LSD) at the 5% significance

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level were computed for each treatment to facilitate statistical comparison of treatment means.

Yield attributes and yield: All the yield-related attributes were the highest with minimum tillage closely followed by zero tillage (Table 1). Minimum tillage (6.22 t/ha) achieved 11.6% higher maize grain yield compared to conventional tillage yield 5.57 t/ha but remained statistically comparable to zero tillage yield 6.13 t/ha. Notably, 100% RDF band placement (6.20 t/ha) achieved 4.90% and 8.39% higher grain yield compared to 75% RDF band placement (5.91 t/ha) and 100% RDF broadcasting (5.72 t/ha), respectively. However, 50% RDF point placement (6.06 t/ha) exhibited comparable results to 100% RDF band placement. The lowest grain yield was observed with 100% RDF broadcasting at 5.72 t/ha. Minimum tillage (10.07 t/ha) achieved 17.22% higher stover yield compared to conventional tillage yield 8.59 t/ha but remained statistically at par with zero tillage yield 9.95 t/ha. Notably, 100% RDF band placement (10.26 t/ha) achieved 13.24%, 15.54% and 3.53% higher stover yield compared to 75% RDF band placement (9.06 t/ha), 100% RDF broadcasting (8.88 t/ha) and 50% RDF point placement (9.91 t/ha), respectively. The lowest stover yield was observed with 100% RDF broadcasting at 8.88 t/ha. Biological, grain and straw yield were statistically at par among minimum tillage and zero tillage. Harvest index remained unaffected by the variations in main plot treatments, with no significant differences detected. The improved performance of maize with minimum tillage and zero tillage can be associated with several factors. These include reduced soil erosion decreased compaction, increased porosity increased nutrient availability due to residue retention and enhanced soil structure, which collectively result in better water infiltration, improved root penetration and higher water retention and also accumulation biomass enhances mineral nutrient uptake and boosts productivity. As a consequence of these favourable conditions, all the yield-contributing characteristics and overall productivity reach their peak with the adoption of minimum tillage practices. Maize grain yield improved in response to higher total biomass accumulation (Lorenz *et al.* 2010). The embellished grain yield with enhanced biomass production and nitrogen uptake under tillage practices may be explained by creating an optimal and expanding microenvironment with enhanced soil physical characteristics, soil biochemical properties, increased infiltration rate and favourable dynamics of soil water availability (Govaerts *et al.* 2007). The improvement in crop growth resulting from residue retention may be associated with increased soil moisture, reduced weed population and enhanced soil health (Choudhary *et al.* 2019).

Among methods of nutrient application treatments, all the yield attributing characters were significantly higher in case of 100% RDF band placement treatment as compared to other treatments but in case of cob length, grain yield and biological yield were statistically comparable to that obtained with 50% RDF applied through point placement. Here point placement of nutrients was more efficient than band placement of nutrients but that's why here 50% RDF point

Table 1 Effect of tillage and precision nutrient placement on yield parameters and yield of maize

Treatments	No. of cob bearing plants/m ²	No. of cobs/plant	Cob weight (g)	Cob length (cm)	Cob girth (cm)	No. of seed-rows/ cob	No. of seeds/cob	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Shelling (%)	Harvest index
Tillage													
T ₁ , CT	7.50	1.19	106.76	12.0	11.26	13.12	305	254.0	5.57	8.59	14.16	72.6	0.40
T ₂ , MT	7.79	1.74	129.30	14.3	12.99	15.66	402	254.6	6.22	10.07	16.30	78.7	0.38
T ₃ , ZT	7.72	1.44	115.53	12.9	11.59	14.52	350	257.8	6.13	9.95	16.07	75.2	0.37
SEM±	0.02	0.02	1.45	0.28	0.29	0.22	3.85	5.58	0.12	0.24	0.36	1.62	0.006
LSD ($p=0.05$)	0.10	0.10	5.85	1.14	1.19	0.89	15.55	NS	0.49	0.99	1.48	NS	NS
Precise nutrient application methods													
N ₁ , 50% RDF PP	7.76	1.46	119.01	14.1	12.43	14.72	357.77	250.93	6.06	9.91	15.96	75.8	0.38
N ₂ , 75% RDF BP	7.65	1.44	116.81	12.5	11.80	14.30	346.88	252.91	5.91	9.06	15.00	75.8	0.39
N ₃ , 100% RDF BP	7.88	1.58	122.03	14.6	12.78	15.10	377.11	259.20	6.20	10.26	16.44	77.9	0.37
N ₄ , 100% RDF FP	7.40	1.33	110.94	11.0	10.77	13.61	327.44	258.82	5.72	8.88	14.63	72.5	0.39
SEM±	0.08	0.03	1.72	0.3	0.22	0.31	5.39	4.68	0.08	0.11	0.16	3.07	0.004
LSD ($p=0.05$)	0.23	0.11	5.17	1.0	0.66	0.91	16.15	NS	0.25	0.33	0.48	NS	0.01

Refer to methodology for treatment details. LSD, least significant difference.

placement getting at par with 100% RDF band placement of nutrients. Here getting of higher growth attributes in maize directly contributes higher yield attributes to maize so higher maize grain, stover and biological yield in 100% RDF band placement of nutrients. Implementing appropriate nitrogen fertilizer placement enhances the accessibility of nitrogen, promoting robust vegetative growth in cultivated crops (Kraska *et al.* 2021). This elevation in vegetative growth enhances the source capacity of the crop by fostering the development of more green leaves and the formation of increased biomass (Gungula *et al.* 2005). Similarly, Nkebiwe *et al.* (2016) and Johnson *et al.* (2017) reported a significant enhancement in grain yield with the application of nitrogen through point placement. No significant interaction effects of tillage and precision nutrient application techniques were observed on the yield and yield components of maize.

Economics: For farmers, the economic aspect of cultivation is of paramount importance. They consistently, choose the most profitable and cost-effective treatment, even if it does not always maximize yield. In this study, maximum cost of cultivation was incurred in conventional tillage (49.77×10^3 ₹/ha), followed by minimum tillage (47.87×10^3 ₹/ha) (Table 2). The lowest cost of cultivation was in case of zero tillage (47.07×10^3 ₹/ha) and the maximum gross and net return were computed with minimum tillage (152.39×10^3 and 104.52×10^3 ₹/ha) and found significantly higher over conventional tillage (140.21×10^3 and 90.44×10^3 ₹/ha) but remained at par with zero tillage (149.21×10^3 and 102.14×10^3 ₹/ha), respectively. Minimum tillage and zero tillage performed better (net B:C 2.18 and 2.16, respectively) as compared to CT as both produced the higher grain and stover yield. Minimum and zero tillage practices resulted in lower cultivation costs relative to conventional tillage, primarily due to reduced frequency of mechanical operations and overall machinery usage. Zero tillage is statistically at par with minimum tillage in terms of gross

return, net returns and net B:C. Least profitable treatment was the conventional tillage treatment. Similarly, Sharma *et al.* (2011) supported our results.

In case methods of nutrients application treatment, the highest cost of cultivation was found with 100% RDF band placement (49.22×10^3 ₹/ha) followed by 50% RDF point placement (48.55×10^3 ₹/ha). The minimum cultivation cost was recorded under in case of 75% band placement (47.17×10^3 ₹/ha) because placement of nutrients needs more labours than broadcasting of nutrients. The 100% band placement nutrient application recorded the maximum gross and net return while the minimum gross and net return obtained with 100% RDF broadcasting.

Gross return was significantly higher with 100% band placement over rest of the treatments and it has been seen that the yield maximized with 100% RDF band placement and found more economical with a net B: C of 2.16. But the 50% RDF point placement, in spite of being the second highest yielded with net B:C of 2.12 which is statistically at par with 100% RDF band placement. Here adoption of 50%-point placement nutrients treatments, 50% of nutrients can be saved Similarly, Singh *et al.* (2020) supported our results.

SUMMARY

Minimum tillage led to improved growth and yield attributes, resulting in significantly higher grain and straw yields compared to conventional tillage, while being statistically similar to zero tillage. Band placement of 100% recommended dose of fertilizer (RDF) significantly higher yield attributes, productivity, and profitability of maize compared to band placement of 75% RDF and conventional 100% RDF, though it was statistically similar to point placement of 50% RDF. Band placement of 100% RDF led to markedly superior net returns and B:C ratio over 75% RDF applied through band placement and conventional

Table 2 Effects of tillage and methods of nutrients application on economics of maize

Treatments	Cost of Cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Net B:C
T ₁ , CT	49.77	140.21	90.44	1.81
T ₂ , MT	47.87	152.39	104.52	2.18
T ₃ , ZT	47.07	149.21	102.14	2.16
SEM±		2.39	2.39	0.05
LSD (p=0.05)		9.66	9.66	0.20
Precise nutrient application methods				
N , 50% RDF PP	48.55	151.27	102.72	2.12
N , 75% RDF BP	47.17	144.56	97.39	2.06
N , 100% RDF BP	49.22	155.61	106.39	2.16
N , 100% RDF FP	48.02	137.64	89.62	1.87
SEM±		1.02	1.02	0.02
LSD (p=0.05)		3.07	3.07	0.06

Refer to methodology for treatment details. LSD, least significant difference.

100% RDF, but showed no significant difference when compared with 50% RDF applied through point placement. Minimum tillage and zero tillage practices demonstrated clear economic superiority over conventional tillage, as evidenced by significantly greater net returns and improved benefit-cost (B:C) ratios, highlighting their potential for cost-effective and sustainable maize production. Therefore, adopting point placement of 50% RDF and 75% RDF band placement can save 50% and 25% of fertilizers, respectively, compared to conventional 100% RDF broadcasting.

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