Original paper Open Access

Nitrogen scheduling in maize in relation to tillage interventions and planting methods in Indian Punjab

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Keywords: *Bed planting, economics, maize, nitrogen scheduling, zero tillage.*

Abstract

Climate change and faster depletion of natural resources highlighted the importance of conservation agriculture. To study the effect of different tillage interventions and planting methods on productivity, soil properties and profitability of maize and to optimize the time of nitrogen application in maize under different tillage and planting methods, a field experiment was conducted during *kharif seasons of* 2017 and 2018in split plot design with four combinations of tillage systems and planting methods [conventional tillage + flat sowing (T1), conventional tillage + bed sowing (T2), zero tillage + flat sowing (T3), zero tillage + bed sowing (T4)] in main plots and four schedules of nitrogen (N) application including recommended (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at pre-tasseling stage) (N1), 1/2 N as basal and 1/2 N at knee high stage (N2), 1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage (N3) and 1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage (N4) in sub-plots with three replications. Bed and flat sowing in combination with zero and conventional tillage resulted in similar maize grain yield. However, the bed sowing helped in achieving 33.3% higher water saving over flat sowing. The net returns were higher by 5816.44 and 2528.11 INR ha^{-1} under zero-till flat sowing as compared with conventional-till flat sowing in 2017 and 2018 respectively. Maize with N application as per N3, N4 and N2 treatments produced statistically at par grain yield as with the recommended schedule of N application. So, advanced time of N application along with permanent bed planting can be adopted profitably for improved productivity.

Abbreviations

B:C: Benefit to cost ratio
CT- Conventional tillage
$KMnO_4$- Potassium permanganate
N- Nitrogen
N1- recommended (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at pre-tasseling stage)
N2- 1/2 N as basal and 1/2 N at knee high stage
N3- 1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage
N4- 1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage,
NH_4OAc- Ammonium acetate solution
NUE- Nitrogen use efficiency
pH- Potential of hydrogen
SPR- Soil penetration resistance
T1-conventional tillage + flat sowing
T2- conventional tillage + bed sowing
T3- zero tillage + flat sowing
T4- zero tillage + bed sowing,
ZT- Zero-tillage

Introduction

Due to more ploughing, conventional tillage (CT) leads to soil erosion (Schneider *et al.*, 2012) and results in a decline in soil organic matter and biodiversity (Biamah *et al.*, 2000). The increase in land degradation has brought an interest among the stakeholders to develop and practice conservation agriculture interventions (Sarker *et al.*, 2012).

Maize (*Zea mays* L.) is an important cereal crop with various uses. Maize, which is the third vital cereal crop after rice and wheat, can play a chief role in the sustainability of agricultural production. It is one of the most genetically versatile emerging crops having wider flexibility under diverse agro-climatic conditions. Maize provides nutrients for humans (food) and animals (feed) and also serves as a raw material for the production of food sweeteners, starch, alcoholic beverages, protein, and oil (Ramesh *et al.*, 2014). The conventional practice of seedbed preparation in maize consumes a large amount (~25%) of the total farm operational energy input which can be optimized by minimizing the number of tillage operations (Sidhu *et al.*, 2004). Some of the agronomic practices like zero tillage (ZT), raised bed planting and residue management are found to be potential resource conservation technologies (RCT's) that can play a vast role in saving the energy and scarce natural resources like land and water.

The raised bed method improved the nitrogen use efficiency (NUE) by 10% as compared to flat method (Fahong *et al.*, 2004). Further, it is reported that less losses of N under a permanent bed planting system generally resulted into higher NUE in maize and wheat as compared to a conventional flat planting system (Sandhu *et al.*, 2019). At the same time, the crop should not suffer from deficiency of this nutrient and it becomes necessary to determine the optimum dose and time of nitrogen (N) application, which will meet the requirements of crop and ensure maximum grain yield and monetary returns. Therefore, the nitrogen schedule is anticipated to vary with different planting methods *viz.*, flat sowing, and bed planting method. However, no information is available on optimum time of nitrogen application in maize under Punjab conditions for different tillage and planting methods.

Furthermore, the recommended schedule of N application in maize is to apply one-third N as basal, one-third N at knee high stage and one-third N at pre-tasseling stage (Bhatti and Kaur, 2020). However, farmers feel it is difficult to apply N at the time of tasselling due to more height attained by the crop at this time.

Keeping these considerations in view, the present investigation was planned: 1) to study the effect of different tillage interventions and planting methods on the growth, productivity and profitability of maize, 2) to optimize the time of nitrogen application in maize under different tillage and planting methods, and 3) to identify best feasible N schedule under the advanced time of last dose of N application from pre-tasseling to early stage in maize.

Material and methods

Experimental site details

The field experiment was conducted at Punjab Agricultural University, Ludhiana during *kharif* seasons of 2017 and 2018 in India. The experimental site is situated at 30° 56' N latitude and 75° 52' E longitude at a height of 247 m above the mean sea level in the central plain region of Punjab falling under the Trans-Gangetic agro-climatic zone of India and is characterized by thesub-tropical and semi-arid type of climate with annual rainfall of 500-750 mm. The soil of the experimental field was sandy loam. The surface soil layer (0-15 cm) was normal in pH (7.3) and electrical conductivity (0.24 dS m^{-1}) with medium in Walkley-Black organic carbon (4.6 g kg^{-1}), $KMnO_4$-oxidizable nitrogen (283.9 kg ha^{-1}) and Olsen-phosphorus (20.8 kg ha^{-1}) and high in NH_4O-Ac-extractable potassium (291.2 kg ha^{-1}).

Treatments and experimental design

The experiment was conducted in split plot design with four combinations of tillage systems and planting methods including conventional tillage + flat sowing (T1), conventional tillage + bed sowing (T2), zero tillage + flat sowing (T3), zero tillage + bed sowing (T4) in main plots and four schedules of nitrogen application *viz.*, recommended (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at pre-tasseling stage) (N1), 1/2 N as basal and 1/2 N at knee high stage (N2), 1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage (N3) and 1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage (N4) in sub-plots with three replications.

Crop management

The field was not cultivated in the case of zero tillage flat and zero tillage bed (reshape only) planting system. In a conventional tillage flat planting system, the field was cultivated twice with disc harrow and a fine seed bed was obtained by giving two ploughings with a tractor-drawn cultivator followed by planking. In a conventional tillage bed planting method, the same tillage operations were done as in conventional tillage flat planting and afterwards, beds were made. The maize hybrid 'PMH1' was sown on 12^{th} and 14^{th} June during 2017 and 2018, respectively. The sowing was done by dibbling two seeds per hill keeping row to row spacing of 60 cm and plant to plant spacing of 20 cm. In bed planting, row-to-row spacing was kept as 67.5 cm and plant-to-plant spacing was 18 cm. The recommended dose of N (125 kg ha^{-1}) was applied through urea at different times as per treatment and whole of recommended dose of phosphorus (62.5 kg P_2O_5 ha^{-1}) was applied as basal through single super phosphate (16% P). Crop was harvested manually on September 26 and 18 during 2017 and 2018, respectively when husk of more than 80 % of the cobs turned yellowish brown and grains became hard. The cobs along with the stalk were stacked in a upright position in the field for 15 days and thereafter cobs were dehusked manually and then threshing was done using plot maize dehusker cum thresher.

Agronomic and morphological traits

The data on growth and yield attributing traits *viz.*, plant height, cobs per plant, cob length, grains per cob, and 1000-grain weight and biological, cob, grain ,and stover yields of maize were recorded at harvest. Before threshing, the bundle weight was recorded and expressed as biological yield in q ha^{-1}. All the cobs from each net plot were dehusked and weight was expressed as cob yield in q ha^{-1}. Then, cobs were shelled and weight of grains was recorded and expressed as grain yield in q ha^{-1}. The stover weight was computed after deducting the weight of grains from bundle weight.

Irrigation water applied and irrigation water productivity

Irrigation water applied was worked out by multiplying the number of irrigations applied with the depth of irrigation, assuming the depth of 50 mm in case of bed sowing and 75 mm for flat sowing treatment for each irrigation. The irrigation water productivity in kg m^{-3} was calculated by dividing the grain yield (kg ha^{-1}) obtained with irrigation water applied (m^3 ha^{-1}).

Grain and plant stover chemical analysis

The grain and stover samples were collected from each plot after harvesting and dried in an oven at 65°C for three days and then ground and kept in paper bags for subsequent analysis. To determine nitrogen content in grain and stover, ground samples from each plot were digested and analyzed separately adopting modified Kjeldahl's method given by Piper (1966). N uptake by grain and stover was calculated by multiplying percent N content of grain and stover with the grain and stover yield of the crop, respectively, and was expressed in kg ha^{-1}.

Soil observations

The soil depth-wise data on bulk density was recorded with a core sampler and penetration resistance was measured with the help of a digital cone penetrometer from the two sites in each plot at the harvest of the second-year crop and then averaged values were taken.

Economic analysis

The gross returns were worked out by multiplying the prevailing market price of grain and stover with their respective yields and net returns were calculated by subtracting the cost of cultivation from the gross returns. The market prices of maize grain for calculation of gross returns were taken as INR 1365/- and 1700/- and that of stover were taken as INR 105/- and 120/- per quintal in 2017 and 2018 respectively. the benefit cost ratio was calculated by dividing the net returns with the cost of cultivation under the respective treatment (Gudadhe *et al.*, 2020).

Statistical analysis

All the data were subjected to statistical analysis as per split-plot design (Gomez and Gomez, 1984) using CPCS1 software with a 5% level of significance for comparing the treatment means.

Results and discussion

Yield and yield traits

The growth and yield traits *viz.*, plant height, cobs per plant, cob length, grains per cob, and 1000-grain weight were not significantly affected by tillage, planting method, and time of nitrogen application during both years (Table 1). Similarly, cob, grain, stover, and biological yield in both the years of study remained statistically similar under different tillage, planting methods, and time of N application (Table 2). The highest biological yield was recorded under conventional tillage + flat sowing (T1) (185.5 qha^{-1}), followed by conventional tillage + bed sowing (T2) (182.5 q ha^{-1}), zero tillage + flat sowing (T3) (179.8 qha^{-1}) and zero tillage + bed sowing (T4) (178.4 qha^{-1}) in 2017. Similarly, maximum biological yield in 2018 was obtained under conventional tillage + flat sowing (T1) which was 1.8, 7.2 and 9.5% higher than zero tillage + flat sowing (T3), zero tillage + bed sowing (T4) and conventional tillage + bed sowing (T2) respectively. Further, the data revealed that zero-tilled flat sown (T3) crop yielded 2.7, 2.7 and 3.4% higher grain yield than T4, T2 and T1 respectively in 2017. However, during 2018, grain yield was highestunder T1(49.7 qha^{-1}) followed by T3 (48.8 qha^{-1}), T4 (46.3 qha^{-1}) and T2 (45.4 qha^{-1}). Similar trends were observed in cob yield during both years. The results are in accordance with the findings of Ramesh *et al.* (2016); Islam *et al.* (2014); Monneveux and Quillerou (2006); Kapusta *et al.* (1996); Kler *et al.* (1992) who also observed no significant differences in maize yield under no tillage and conventional tillage operations. Ram *et al.* (2012) also reported that the tillage and planting method did not affect the yield attributes and yield. Contrarily, Kaur, and Kumar (2018) reported significantly higher grain and stover yields under bed sowing as compared to flat sowing in maize.

Among the different times of N application, highest biological yield in 2017 was recorded where1/2 N was applied as basal, 1/4 N at knee high stage and 1/4 N at waist high stage (N3) (187.2 q ha^{-1}); followed by1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage (N4) (184.2 q ha^{-1});1/3 N as basal, 1/3 N at knee high stage, 1/3 N at pre-tasseling stage (N1) (182.2 q ha^{-1}); and 1/2 N as basal, 1/2 N at knee high stage (N2) (172.6 q ha^{-1}). Whereas in 2018, crop with N1 treatment recorded maximum biological yield (185.2 q ha^{-1}) which was 4.1, 7.9, and 9.7% higher than N4, N3, and N2 respectively. Similarly, the highest grain yield was obtained with N3 (54.6 q ha^{-1}) which was 1.3, 1.9 and 9.9% higher than with N1, N4, and N2, respectively in 2017 and 2018, the grain yield was maximum under N1 (50.1 q ha^{-1}) which was 4.2, 8.0 and 9.9% higher than N1,

Table 1 - Effect of tillage system, planting methods and time of nitrogen application on growth and yield traits of maize

Treatments	Plant height (cm) at harvest		No. of cobs per plant		Cob length (cm)		No. of grains per cob		1000-grain weight (g)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Main plot (Combination of tillage systems and planting methods)										
T1 (Conventional tillage + flat sowing)	215.0	230.5	1.0	1.0	17.6	18.2	434.4	424.3	251.7	257.7
T2 (Conventional tillage + bed sowing)	216.2	226.3	1.0	1.0	18.0	17.2	422.0	410.3	258.7	253.7
T3 (Zero tillage + flat sowing)	214.6	228.9	1.0	1.0	18.0	18.0	443.3	414.1	254.9	258.0
T4 (Zero tillage + bed sowing)	218.5	220.5	1.0	1.0	18.1	17.0	431.4	409.4	260.9	255.0
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot (Time of nitrogen application)										
N1 ((Recommended-⅓ N as basal, 1/3 N at knee high stage & 1/3 N at pre-tasseling stage)	217.1	213.6	1.0	1.0	18.1	17.9	448.0	423.8	253.5	260.2
N2 (½ N as basal & ½ N at knee high stage)	215.6	210.4	1.0	1.0	17.5	17.7	417.0	403.0	253.7	254.5
N3 (½ N as basal, ¼ N at knee high stage & ¼ N at waist high stage)	215.9	213.0	1.0	1.0	17.9	17.8	424.8	413.9	264.9	250.2
N4 (1/3 N as basal, 1/3 N at knee high stage & 1/3 N at waist high stage)	215.7	211.1	1.0	1.0	18.0	17.2	441.2	417.4	254.1	259.5
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

N4, and N2, respectively. The trends in cob and stover yields were also similar in both years. Lower biomass production with two-split N application as compared with three-splits in fodder maize was also reported by Hassan *et al.* (2010). Furthermore, Abebe and Feyisa (2017) recorded the highest maize grain yield at 3-split N application in heavy rainy seasons and at the 2-split application in good rainy seasons being statistically similar. Shelling percentage was also not significantly influenced by different treatments (Table 2).

Nitrogen uptake

The N uptake by grain and stover was similar under all the combinations of tillage system and planting methods, but N uptake by grains was maximum under zero tillage in combination with flat sowing (T3) whereas N uptake by stover was highest under T1 in 2017. During 2018, N uptake by grain and stover was highest in T1 followed by T3 treatment. The total N uptake by crop was maximum under T1 during both years. However, the differences among the treatments were non-significant. Tiwari *et al.* (2018) also reported the highest nitrogen uptake by maize grain and stover under flat sowing with zero tillage. During the time of nitrogen application treatments, the highest N uptake by maize grains was achieved with N3 and the lowest with N2 treatment during both years. The total N uptake was significantly higher in N3 (17.3%) than in N2 treatment but statistically at par with N1 and N4 treatments in the first year of study, though the total N uptake was not significantly affected by the time of N application in the second year and it was highest in N1 treatment and lowest in N2 treatment (Table 3). Similar findings were reported by Hassan *et al.* (2010).

Irrigation water applied and irrigation water productivity

The irrigation water applied varied due to different sowing methods. Bed sowing saved 33.3% of irrigation water over the flat sowing method during both years (Table 3). The data showed that a combination of tillage and planting methods affected the irrigation water productivity significantly. It was maximum under T4 (2.11 and 2.32 kg m^{-3}) which was significantly higher than T1 (1.40 and 1.66 kg m^{-3}) and T3 (1.44 and 1.63 kg m^{-3}) but statistically at par with T2 (2.11 and 2.27 kg m^{-3}) in 2017 and 2018 respectively. Higher irrigation water productivity in bed sowing is attributed to less irrigation water applied. Ram *et al.* (2012) also reported higher water use efficiency of maize planted on raised beds. N2 treatment exhibited the lowest irrigation water productivity owing to the lowest grain yield in both years.

Table 2 - Effect of tillage system, planting methods and time of nitrogen application on yield and shelling percentage of maize

Treatments	Biological yield (q ha^{-1})		Cob yield (q ha^{-1})		Grain yield (q ha^{-1})		Stover yield (q ha^{-1})		Shelling (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Combination of tillage systems and planting methods										
T1 (Conventional tillage + flat sowing)	185.5	183.8	83.2	69.6	52.3	49.7	102.4	114.3	63.2	71.7
T2 (Conventional tillage + bed sowing)	182.5	167.8	79.7	63.5	52.7	45.4	102.8	104.3	66.2	71.2
T3 (Zero tillage + flat sowing)	179.8	180.6	84.2	68.3	54.1	48.8	95.6	112.3	64.2	70.6
T4 (Zero tillage + bed sowing)	178.4	171.4	81.0	64.9	52.7	46.3	97.3	106.5	65.2	70.6
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Time of nitrogen application										
N1 (Recommended- 1/3 N as basal, 1/3 N at knee high stage & 1/3 N at pre-tasseling stage)	182.2	185.2	81.7	70.1	53.9	50.1	100.6	115.1	66.1	71.0
N2 (½ N as basal & ½ N at knee high stage)	172.6	168.8	79.4	63.9	49.7	45.6	93.3	104.9	62.8	71.3
N3 (½ N as basal, ¼ N at knee high stage & ¼ N at waist high stage)	187.2	171.7	85.0	65.0	54.6	46.4	102.2	106.8	64.4	71.1
N4 (1/3 N as basal, 1/3 N at knee high stage & 1/3 N at waist high stage)	184.2	177.9	82.2	67.3	53.6	48.1	102.0	110.6	65.5	70.7
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Soil physical properties

Bulk density was not significantly affected by the different combinations of tillage system and planting methods after two years (Table 4). However, the bulk density of 0-15 cm soil layer was lowest in conventional tillage + bed sowing (1.32 g cm^{-3}) and highest in zero tillage + flat sowing (1.38 g cm^{-3}). The trend was similar for the 15-30 cm soil layer. Ram *et al.* (2012) also reported lower bulk density under conventional tillage and bed planting.

Soil penetration resistance (SPR) increased with an increase in depth up to 20 cm and then it declined i. e. at 30 cm soil depth. The perusal of data showed that the soil penetration resistance was minimum under conventional tillage + bed sowing (T2) and highest in zero tillage + flat sowing (T3). SPR followed the same trend at 10, 20, and 30 cm soil layers (Table 4). Similar results were reported by Varsa *et al.* (1997).

Economics

The data related to economic analysis (Table 5) indicated that the cost of cultivation was lowest in zero-tillage flat sowing and highest in conventional tillage bed sowing during both years due to no field preparation in zero tillage and more cost incurred on bed formation. The gross returns in 2017 were highest in T3 followed by T1 and lowest in T2, whereas in 2018, these were highest in T1 followed by T3. The highest net returns were obtained in T3 (INR 59075.71 and 68290.27 ha^{-1}) but lowest in T2 (INR 51569.54 and 55759.67 ha^{-1}) in 2017 and 2018 respectively. Similarly, the B:C ratio was highest in T3 (2.23) followed by T2 (2.06) in 2017. A similar trend was observed in 2018. Higher net returns and B:C ratio under zero tillage sowing of maize are also recorded by Singh and Singh (2019); Ram *et al.* (2012). During the time of N application, the lowest cost of cultivation was involved in the N2 treatment due to fewer N splits than in N1, N3, and N4 treatments. However, gross returns, net returns, and B:C were higher in N1 than N2 but closely followed by N3 and N4 treatments. Maximum net benefit was obtained with a 3-split N application in heavy rainy seasons and with a 2-split application in good rainy seasons (Abebe and Feyisa, 2017).

Conclusions

The present investigation showed that the maize grain yield recorded was similar irrespective of tillage and planting methods. However, higher water productivity of maize was achieved with bed sowing. Zero tillage in maize registered maximum economic returns. Fur-

Table 3 - Effect of tillage system, planting methods and time of nitrogen application on nitrogen uptake, irrigation water applied and irrigation water productivity of maize

Treatments	Nitrogen uptake (kg ha^{-1})						Irrigation water applied (cm)		Irrigation water productivity (kg m^{-3})	
	Grain	Stover	Total	Grain	Stover	Total	2017	2018	2017	2018
	2017			2018						
Combination of tillage system and planting methods										
T1 (Conventional tillage + flat sowing)	60.7	55.6	116.4	58.1	62.9	121.1	37.5	30.0	1.40	1.66
T2 (Conventional tillage + bed sowing)	60.7	53.8	114.5	52.8	55.3	108.1	25.0	20.0	2.11	2.27
T3 (Zero tillage + flat sowing)	63.5	51.3	114.8	57.6	61.0	118.6	37.5	30.0	1.44	1.63
T4 (Zero tillage + bed sowing)	61.2	50.8	112.1	54.4	56.6	110.9	25.0	20.0	2.11	2.32
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	-	-	0.15	0.29
Time of nitrogen application										
N1 (Recommended- 1/3 N as basal, 1/3 N at knee high stage & 1/3 N at pre-tasseling stage)	60.2	54.5	114.7	56.5	62.5	118.9	31.3	25.0	1.80	2.08
N2 (1/2 N as basal & 1/2 N at knee high stage)	56.2	47.3	103.6	53.5	56.4	110.0	31.3	25.0	1.66	1.89
N3 (1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage)	67.0	54.6	121.5	56.6	57.0	113.7	31.3	25.0	1.82	1.92
N4 (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage)	62.8	55.2	118.0	56.3	59.8	116.1	31.3	25.0	1.79	1.99
LSD (p=0.05)	NS	NS	10.1	NS	NS	NS	-	-	NS	NS

thermore, the optimum time of N application was not affected by tillage and planting methods. The different schedules of N application did not affect the growth and yield of maize significantly. Nitrogen scheduling as N3 (½ N as basal, ¼ N at knee high stage & ¼ N at waist high stage), N4 (⅓ N as basal, ⅓ N at knee high stage & ⅓ N at waist high stage) and N2 (½ N as basal & ½ N at knee high stage) treatments gave statistical-

Table 4 - Effect of tillage system, planting methods and time of nitrogen application onbulk density and soil penetration resistance after two experimental years

Treatments	Bulk density (g cm^{-3})		Soil penetration (kPa)		
	Soil depth (cm)		Soil depth (cm)		
	0-15	15-30	10	20	30
Combination of tillage system and planting methods					
T1 (Conventional tillage + flat sowing)	1.38	1.35	439.8	1065.4	850.0
T2 (Conventional tillage + bed sowing)	1.34	1.32	433.3	1058.3	843.8
T3 (Zero tillage + flat sowing)	1.40	1.37	440.7	1066.0	851.2
T4 (Zero tillage + bed sowing)	1.37	1.34	435.3	1059.7	845.6
LSD (p=0.05)	NS	NS	NS	NS	NS
Time of nitrogen application					
N1 (Recommended-1/3 N as basal, 1/3 N at knee high stage & 1/3 N at pre-tasseling stage)	1.37	1.36	437.2	1062.4	847.5
N2 (1/2 N as basal & 1/2 N at knee high stage)	1.36	1.35	436.2	1061.5	846.7
N3 (1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage)	1.39	1.33	437.3	1062.2	847.8
N4 (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage)	1.36	1.34	438.2	1063.3	848.7
LSD (p=0.05)	NS	NS	NS	NS	NS

Table 5 -Effect of tillage system, planting methods and time of nitrogen application on economics of maize

Treatments	Cost of cultivation (INR ha^{-1})		Gross returns (INR ha^{-1})		Net returns (INR ha^{-1})		Benefit cost ratio	
	2017	2018	2017	2018	2017	2018	2017	2018
Combination of tillage system and planting methods								
T1 (Conventional tillage + flat sowing)	30106.00	32412.10	83365.27	98174.27	53259.27	65762.16	1.77	2.03
T2 (Conventional tillage + bed sowing)	31297.25	33868.40	82866.79	89628.07	51569.54	55759.67	1.65	1.65
T3 (Zero tillage + flat sowing)	26512.50	28155.00	85588.21	96445.27	59075.71	68290.27	2.23	2.43
T4 (Zero tillage + bed sowing)	27216.25	29042.50	83157.120	91538.20	55940.86	62495.70	2.06	2.15
Time of nitrogen application								
N1 (Recommended-1/3 N as basal, 1/3 N at knee high stage & 1/3 N at pre-tasseling stage)	28823.00	30914.50	85639.84	98915.27	56816.84	68000.77	1.99	2.22
N2 (1/2 N as basal & 1/2 N at knee high stage)	28663.00	30734.50	78868.30	90138.54	50205.30	59404.04	1.77	1.95
N3 (1/2 N as basal, 1/4 N at knee high stage and 1/4 N at waist high stage)	28823.00	30914.50	85681.75	91719.34	56858.75	60804.83	1.99	1.99
N4 (1/3 N as basal, 1/3 N at knee high stage and 1/3 N at waist high stage)	28823.00	30914.50	84787.50	95012.66	55964.50	64098.17	1.96	2.09

ly similar grain yield as achieved with recommended schedule (N1-⅓ N as basal, ⅓ N at knee high stage, ⅓ N at pre-tasseling stage). However, the net returns and B:C in N2 were considerably lower than N1, N3, and N4. Hence, it can be concluded that advanced time of N application for ease in N application operation in maize without sacrificing yield can be adopted along with permanent bed planting for improving water productivity and profitability.

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