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Enhancing maize yield in a conservation agriculture-based maize (*Zea mays*)-wheat (*Triticum aestivum*) system through efficient nitrogen management

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ABSTRACT

This study evaluated the impact of contrasting tillage and nitrogen management options on the growth, yield attributes, and yield of maize (*Zea mays* L.) in a conservation agriculture (CA)-based maize-wheat (*Triticum aestivum* L.) system. The field experiment was conducted during the rainy (*kharif*) seasons of 2020 and 2021 at the research farm of ICAR-Indian Agricultural Research Institute (IARI), New Delhi. The experiment was conducted in a split plot design with three tillage practices [conventional tillage with residue (CT), zero tillage with residue (ZT) and permanent beds with residue (PB)] as main plot treatments and in sub-plots five nitrogen management options [Control (without N fertilization), recommended dose of N @150 kg N/ha, Green Seeker-GS based application of split applied N, N applied as basal through urea super granules-USG + GS based application and 100% basal application of slow release fertilizer (SRF) @150 kg N/ha] with three replications. Results showed that both tillage and nitrogen management options had a significant impact on maize growth, yield attributes, and yield in both seasons. However, time to anthesis and physiological maturity were not significantly affected. Yield attributes were highest in the permanent beds and zero tillage plots, with similar numbers of grains per cob (486.1 and 468.6). The highest leaf area index (LAI) at 60 DAP was observed in PB (5.79), followed by ZT(5.68) and the lowest was recorded in CT (5.25) plots. The highest grain yield (2-year mean basis) was recorded with permanent beds plots (5516 kg/ha), while the lowest was observed with conventional tillage (4931 kg/ha). Therefore, the study highlights the importance of CA practices for improving maize growth and yield, and suggests that farmers can achieve better results through the adoption of CA-based permanent beds and use of USG as nitrogen management option.

Keywords: Green seeker, Maize, Urea super granules, Yield, Zero tillage

Maize (*Zea mays* L.) is one of the most important cereal crops grown globally. It is popular due to its versatility, adaptability to a range of soil types, and high genetic yield potential. Maize requires moderate moisture, warmth, and 4–6 irrigations during its growth period, with a temperature range of 21°C–32°C for seed germination. In India, maize is cultivated on 9.57 million hectares, with a total production of 28.77 million tonnes and a productivity of 3.01 tonnes per hectare. However, this productivity falls short of the global average of 5.82 tonnes/hectare. The top five maize-producing states in India, namely Madhya Pradesh, Karnataka, Tamil Nadu, Bihar and Telangana, account for 55% of the total production. Maize is predominantly used as poultry feed in India, with a significant portion also being used in the starch industry, as livestock feed, in processed foods, and for other purposes (IIMR 2021).

Recently, there has been a growing emphasis on conservation agriculture as a means to promote sustainable crop production and enhance soil health. Conservation agriculture (CA) involves practices such as minimizing soil disturbance, implementing crop rotation, and using cover crops to conserve soil moisture, boost soil fertility, and reduce soil erosion. The goal of CA is to increase crop yields while reducing the environmental impact of agriculture. Previous research has demonstrated the benefits of CA in cereal-based cropping systems, including improved resource efficiency, profitability, soil quality, and resilience to climate change (Parihar *et al.* 2016). Conservation agriculture has been shown to increase soil organic matter, improve water

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infiltration, and reduce evaporation (Patra *et al.* 2023). The maize-wheat (*Triticum aestivum* L.) cropping system, covering 1.85 million hectares, is the third most important cropping system in India (Parihar *et al.* 2017).

Efficient use of inputs, particularly nitrogen (N) fertilizers, is crucial in modern agriculture (Nayak *et al.* 2022). The use of N fertilizers has increased significantly in the past 30 years to boost soil N supply to crops. However, low N use efficiency is common in cereal-based agro-ecosystems, with cereals absorbing only 40–60% of applied nitrogen (Herrera *et al.* 2016). Several options have been proposed to enhance the nitrogen use efficiency of nitrogenous fertilizers, including the use of Urea Deep Placement (UDP), which reduces nitrogen losses and improves nitrogen uptake through the use of large-sized fertilizer particles placed near the root zone (IFDC 2013; 2015). This technique has proven to be an effective soil nutrient management strategy with higher crop yields and lower fertilizer use compared to broadcast application. However, there is limited information available on the use of different nitrogen sources in combination with CA practices in India. The present study aims to investigate the effect of contrasting tillage (conservation agriculture and conventional) and nitrogen management options on the growth, yield attributes, and yield of maize under a maize-wheat system.

MATERIALS AND METHODS

The experiment was conducted during the rainy (*kharif)* seasons of 2020 and 2021 at the ongoing experimental site (block '9B') located at the ICAR-Indian Agricultural Research Institute (IARI) in New Delhi (28°38′ N, 77°10′ E), at 228 m amsl. The study site falls under the Indian Trans-Gangetic Plains Zone (Agro Climatic Zone-VI), which is characterized by a sub-tropical and semi-arid climate. At the start of this long-term experiment-*kharif*-2012, the soil of the study site was determined to have a sandy loam texture with a *p*H range of 7.9 (as determined using a 1:2 soil-water ratio), a bulk density of 1.63 mg/m^3, and a hydraulic conductivity of 0.835 cm/h (saturated). The organic carbon content was found to be 4.89 g/kg soil and the alkaline $KMnO_4$-N content was 152.0 kg/ha (Subbiah and Asija 1956). The experiment was arranged using a split plot design (SPD) with three replications. The specific treatments adopted are described in Table 1.

Description of imposed treatments and crop establishment: In the CA and CT plots, the preceding crop residue was retained/incorporated into the soil in different plots of imposed treatments. The zero tillage plots (ZT) were established in June 2012 and left undisturbed throughout the study period. In contrast, the CT plots were tilled with one deep tillage followed by two cultivations. The maize variety 'PMH1' was planted in July at a spacing of 67.5 cm × 20 cm using a maize planter. A common dose of 60 kg P_2O_5 + 40 kg K_2O and 25 kg $ZnSO_4$ heptahydrate per hectare was applied to all plots as a basal fertilizer (at the time of mechanical seeding). The control plot (without nitrogen) received only P_2O_5 and K_2O, while the N150 plot received 150 kg N as a 50 kg basal dose, with the remaining N was applied in two equal splits at 36 days after planting (DAP)

Table 1 Description of imposed treatments

Tillage and residue management	Nitrogen management	Treatment notations
Conventional tillage with residue incorporation-CT	Control (without-N application)-N0	CT-N0
Conventional tillage with residue incorporation-CT	Recommended dose of N-RDN @150 kg N/ha applied through urea-N150	CT-N150
Conventional tillage with residue incorporation-CT	1/3rd of RDN + Green Seeker-GS based application of split applied N-GS	CT-GS
Conventional tillage with residue incorporation-CT	Slow release fertilizer (SRF) @150 kg N/ha as basal application (SRF)	CT-SRF
Conventional tillage with residue incorporation-CT	50% of RDN applied as basal through urea super granules + GS based application of split applied N-USG	CT-USG
Permanent bed with residue retension-PB	Control (without-N application)-N0	PB-N0
Permanent bed with residue retension-PB	RDN @150 kg N/ha applied through urea-N150	PB-N150
Permanent bed with residue retension-PB	1/3rd of RDN + Green Seeker-GS based application of split applied N-GS	PB-GS
Permanent bed with residue retension-PB	SRF @150 kg N/ha as basal application-SRF	PB-SRF
Permanent bed with residue retension-PB	50% of RDN applied as basal through urea super granules + GS based application of split applied N-USG	PB-USG
Zero tillage flat with residue retension-ZT	Control (without-N application)-N0	ZT-N0
Zero tillage flat with residue retension-ZT	RDN @150 kg N/ha applied through urea-N150	ZT-N150
Zero tillage flat with residue retension-ZT	1/3rd of RDN + Green Seeker-GS based application of split applied N-GS	ZT-GS
Zero tillage flat with residue retension-ZT	SRF @150 kg N/ha as basal application-SRF	ZT-SRF
Zero tillage flat with residue retension-ZT	50% of RDN applied as basal through urea super granules + GS based application of split applied N-USG	ZT-USG

and 61 DAP. USG briquettes were placed near the root zone of the crop at a depth of 7–10 cm, followed by split application of prilled urea, slow-release plots received full N as basal. Irrigation was applied if there was a moisture stress through surface irrigation at critical stages (Seedling, Knee-high, Tasseling, Silking, Milking, and Grain filling).

Measurement of growth parameters, yield attributes and yields: The leaf area was measured at periodic intervals using a leaf area meter (Model LI-COR-3100). The leaf area index (LAI) was calculated by dividing the total leaf area by the ground area occupied by the crop. The crop was harvested manually, and two border rows in both directions and 0.5 m in the lengthwise direction were left unharvested (plot size: 30 m^2). The maize grain was collected, oven-dried at 65–70°C for 48 hours, and weighed. The stover was cut from the ground level, sun-dried, weighed using a spring balance, and expressed in kg/ha. The number of cobs per 1.0 m^2 was counted from three randomly selected spots in each plot and averaged. The length of five randomly selected cobs from each plot was measured from base to tip and the mean value was calculated in cm. The girth (circumference) of the same five cobs was measured from the middle portion with the help of a verniercalliper scale, and the mean value was expressed in cm. The number of grains per row was recorded for the same cobs that were used for cob length measurements and expressed as the average value for each plot. The total number of grains in a cob was calculated by multiplying the number of grain rows by the number of grains per row. A random sample of 100 grains was taken from the final yield of each plot, weighed, and expressed as 100-grain weight. The harvest index was calculated by dividing the economic yield by the biological yield and expressed as a percentage:

Harvest index (HI) = (Economic yield) /(Biological yield) × 100

Statistical analysis: All the experimental data were statistically analyzed using analysis of variance (ANOVA) as applicable to split plot design (Gomez and Gomez 1984) using SAS software. The significance of the treatment effects was determined using F-test and the difference between the means was estimated by using least significant difference at 5% probability level.

RESULT AND DISCUSSION

Crop phenology: The timing of the developmental stages, such as days after planting (DAP) to anthesis and physiological maturity, is of great importance in field experiments as it has a significant impact on crop productivity. In this study, the results showed that the days to emergence, anthesis, and physiological maturity were primarily determined by the maize variety used. The treatments applied did not have a significant effect on these stages. However, it was observed that treatments without nitrogen application resulted in a delayed anthesis but an earlier physiological maturity. This is consistent with the established idea that stress experienced before anthesis prolongs the pre-anthesis duration, while stress experienced after anthesis shortens the post-anthesis duration (Chisanga *et al.* 2015). These findings align with previous studies by Gungula *et al.* (2007). On the other hand, treatments with nitrogen application resulted in a longer time to reach physiological maturity due to an extended post-anthesis duration, caused by a longer grain filling duration due to the prolonged availability of nitrogen. This observation is also in agreement with the findings of Squire *et al.* (1990). It is important to note that the crop yield is a function of crop duration (pre- and post-anthesis) and the photosynthetic area of the crop, represented by the leaf area. Therefore, the accurate determination of the phenological stages is critical in field experiments to understand the impact on crop productivity.

Leaf area index: The results of our study on leaf area index (LAI) indicate that LAI is a crucial indicator of the extent of a plant's assimilatory system, which drives dry matter accumulation and partitioning (Ahmad *et al*. 2010). Our data showed that the PB and ZT treatments produced significantly higher LAI than CT, with no significant differences between the two treatments at 30, 60, and 90 days after sowing (DAS). At 60 DAS, the stage corresponding to the crop's maximum LAI, the highest LAI was found in the

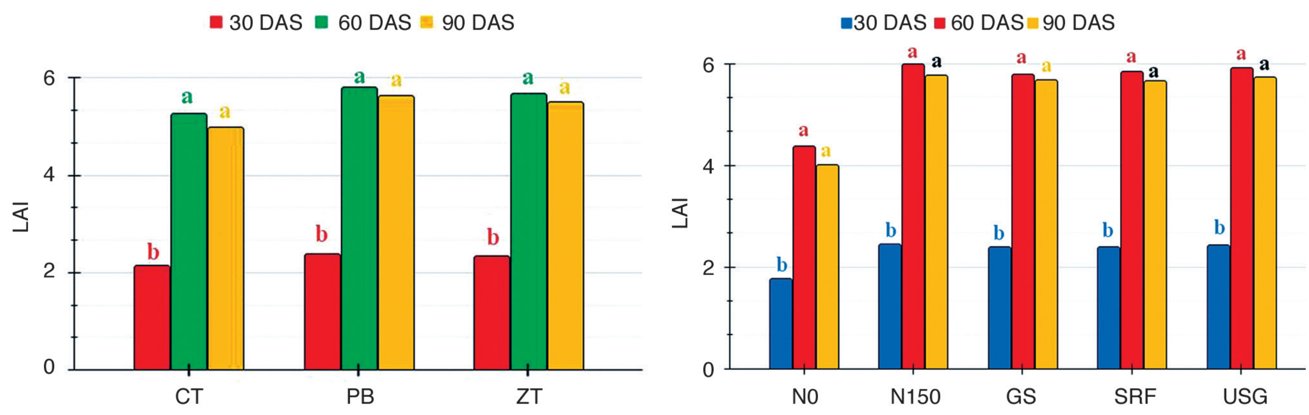

Fig 1 Effect of contrasting tillage and crop establishment techniques (A) and nutrient management option (B) on leaf area index (LAI) of maize. CT, Conventional tillage; PB, Permanent bed; ZT, Zero tillage, GS, Green seeker; SRF, Slow release fertilizer; USG, Urea super granules.

PB treatment (5.79), followed by ZT (5.68), and the lowest LAI was recorded under CT (5.25) (Fig 1).

This higher LAI in PB and ZT can be attributed to improved nitrogen availability and more favourable growing conditions, including lower bulk density and better root growth, as confirmed by Kumar *et al*. (2014). In the sub-plots, the highest LAI was found with CT-N150 (5.98), which was statistically at par to the other N management treatments, while the lowest LAI was recorded under CT-N0 (4.36) (Fig 1). This difference can be attributed to the direct effect of nitrogen on the growth and LAI of the crop. Besides CT-N0, the other treatments did not significantly differ in terms of observed LAI. The results showed that the leaf area increased until the grain formation stage and then declined as the source started transferring its photosynthates to the sink. These findings are consistent with previous research by De Jonge *et al*. (2012).

Yield attributes and yield: The results of this study indicate that tillage and nitrogen management options have a significant effect on the yield attributes and yield of maize under CA (Table 2 and Table 3). Over a two-year period, it was found that the permanent bed system in conservation agriculture was the most favourable tillage option for maize yield attributes and yield. Meanwhile, the use of the recommended rate of nitrogen fertilization (N150) was the efficient nitrogen management practice.

The cob length was found to be significantly influenced by nitrogen management options over the two years of study. The highest cob length was recorded with the recommended rate of nitrogen fertilization (N150), while the lowest was observed in the control treatment with no nitrogen fertilization (N0). Test weight did not differ with respect to tillage but was significantly impacted by nitrogen sources, with the highest cob yields coming from treatments using N150 followed by uniform USG placement. The number of grains per cob was found to be significantly affected by tillage (14.7 and 10.6% higher in PB and ZT, respectively, compared to CT) and nitrogen management, with the highest number of grains per cob recorded for the recommended rate of nitrogen fertilization (N150) (Table 2).

Grain yield was also found to be impacted by tillage and nitrogen management practices. The highest grain yield was recorded in the permanent bed (PB) with recommended rate of nitrogen fertilization and the lowest numerical value with respect to grain yield was observed in the conventional tillage with recommended rate of nitrogen fertilization (CT). The grain yields were 11.9% and 8.6% higher in PB and ZT, respectively, compared to CT (Table 3). Nitrogen options also significantly affected grain yield, with the highest grain yield recorded for urea super granules (USG) and the lowest grain yield recorded for the control treatment with no nitrogen fertilization (N0). The biological yield was significantly affected by tillage and N management, whereas the interaction (tillage × N management) was non-significant. Across the years, the CA-based ZT and PB plots showed similar stover yield, which was significantly higher than CT plots. Highest biological yield was observed with PB (10.6% higher than CT) followed by ZT (8.3% higher than CT) and lowest biomass yield was observed with CT (Table 3). In the present study, CA-based practices (PB and ZT) and USG and N150 resulted in higher biomass, which could explain the higher grain yield in these treatments. The enhanced grain yield with higher biomass under CA-based systems could be explained by an efficient growing microclimate with better soil physical properties, soil biochemical properties (Parihar *et al*. 2016), and favourable soil moisture dynamics (Govaerts *et al*. 2007). In conclusion, this study highlights the importance of considering nitrogen management

Table 2 Effect of tillage and nitrogen management options on yield attributes of maize (2-year mean basis)

Treatment	Days to 50% anthesis	Days to physiological maturity	Cobs/ m^2	Cob length (cm)	Cob girth (cm)	Grain rows/cob	Grains/ row	Grains/ cob	100-grain weight (g)
Tillage and crop establishment techniques									
CT	53.3	93.9	7.3	17.4	14.3	14.1	30.0	423.7	26.8
PB	52.4	94.1	7.8	18.0	14.4	14.4	33.6	486.1	26.8
ZT	53.2	94.3	7.6	17.9	14.3	14.3	32.7	468.6	26.6
SEm±	0.367	0.359	0.112	0.254	0.089	0.237	0.301	9.25	0.206
LSD (P=0.05)	NS	0.411	0.365	NS	NS	NS	0.982	30.2	NS
Nitrogen management options									
N0	54.2	93.0	5.4	15.3	14.0	13.7	26.9	368.8	24.6
N150	52.8	94.4	8.3	18.9	14.2	14.6	34.1	499.5	27.0
GS	52.6	94.1	7.9	17.9	14.4	14.5	32.7	474.0	27.2
SRF	52.7	94.4	7.9	18.2	14.7	14.4	32.7	471.4	27.7
USG	52.6	94.6	8.3	18.7	14.4	14.2	34.1	483.6	27.3
SEm±	0.474	0.464	0.170	0.231	0.100	0.161	0.578	11.18	0.203
LSD (P=0.05)	1.38	1.35	0.495	0.674	0.292	0.470	1.69	32.6	0.592

NS, Non-significant. Treatment details are given in Table 1.

Table 3 Effect of tillage and nitrogen management options on yield of maize (2 year mean basis)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Shelling (%)	Harvest index
Tillage and crop establishment techniques					
CT	4931	9282	15875	74.4	31.0
PB	5516	10343	17554	76.1	31.2
ZT	5355	9978	17200	73.7	30.9
SEm±	62.9	150.6	180.6	0.64	0.35
LSD (P=0.05)	205.2	491.1	589.0	NS	NS
Nitrogen management options					
N0	3459	7465	12497	68.7	27.8
N150	5736	10664	18201	76.1	31.5
GS	5737	10274	17810	76.1	32.2
SRF	5656	10287	17721	76.1	31.9
USG	5748	10646	18155	76.6	31.6
SEm±	59.4	162.6	164.2	0.58	0.39
LSD(P=0.05)	173.3	474.4	479.1	1.68	1.14

NS, Non-significant. Treatment details are given in Table 1.

practices in maize production under conservation agriculture. The findings of this study have implications for farmers, extension agents, and policymakers, as they can use the results to make informed decisions on tillage and nitrogen management practices that can improve maize production.

REFERENCES

Ahmad M, Khaliq A, Ahmad R and Ranjha A M. 2010. Allometery and productivity of autumn planted maize hybrids under narrow row spacing. *International Journal of Agriculture and Biology* **12**(5): 661–67.

Chisanga C B, Phiri E, Shepande C, Sichingabula H and Lusaka Z. 2015. Evaluating CERES-maize model using planting dates and nitrogen fertilizer in Zambia. *Journal of Agricultural Science* **7**: 79–97.

De Jonge K, Ascough J, Andales A A, Hansen N, Garcia L and Arabi M. 2012. Improving evapotranspiration simulations in the CERES-maize model under limited irrigation. *Agricultural Water Management* **115**: 92–103.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research.* International Rice Research Institute, 2nd edn. Wiley-Inter-science Publication, John Wiley and Sons, New York.

Govaerts B, Fuentes M, Mezzalama M, Nicol J M, Deckers J, Etchevers J D, Figueroa-Sandoval B and Sayre K D. 2007. Infiltration, soil moisture, root rot and nematode populations after 12 years of different tillage, residue and crop rotation managements. *Soil Tillage Research* **94**: 209–19.

Gungula D T, Togun A O and Kling J G. 2007. The effects of nitrogen rates on phenology and yield components of early maturing maize cultivars. *Global Journal of Pure and Applied Sciences* **13**(3): 319–24.

Herrera J M, Noulas C, Stamp P and Pellet D. 2016. Little potential of spring wheat genotypes as a strategy to reduce nitrogen leaching in Central Europe. *Agronomy* **6**(2): 29.

IFDC (International Fertilizer Development Center). 2013. Fertilizer deep placement. IFDC solutions. IFDC, Muscle Shoals, Alabama **6**. http://issuu.com/ifdcinfo/docs/fdp_8pg_final_web?e=1773260/1756718

IFDC (International Fertilizer Development Center). 2015. Benefits of the fertilizer deep placement technology for smallholder rice farmers. IFDC Quarterly Magazine **40**(4). http://ifdc.org/ifdc-magazine/

IIMR. 2021. Indian Maize Scenario. PAU Campus, Ludhiana, Punjab. ICAR-Indian Institute of Maize research. https://iimr.icar.gov.in/india-maize-scenario/

Kumar V, Singh A K, Jat S L, Parihar C M, Pooniya V, Sharma S and Singh B. 2014. Influence of site-specific nutrient management on growth and yield of maize (*Zea mays*) under conservation tillage. *Indian Journal of Agronomy* **59**(4): 657–60.

Nayak H S, Parihar C M, Mandal B N, Patra K, Jat S L, Singh R, Singh V K, Jat M L, Garnaik S, Nayak J and Abdallah A M. 2022. Point placement of late vegetative stage nitrogen splits increase the productivity, N-use efficiency and profitability of tropical maize under decade long conservation agriculture. *European Journal of Agronomy* **133**: 126417.

Parihar C M, Jat S L, Singh A K, Majumdar K, Jat M L, Saharawat Y S, Pradhan S and Kuri B R. 2017. Bio-energy, biomass water-use efficiency and economics of maize–wheat–mungbean system under precision-conservation agriculture in semi-arid agro-ecosystem. *Energy* **119**: 245–56.

Parihar C M, Yadav M R, Jat S L, Singh A K, Kumar B, Pradhan S, Chakraborty D, Jat M L, Jat R K, Saharawat Y S and Yadav O P. 2016. Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. *Soil and Tillage Research* **161**: 116–28.

Patra S, Parihar C M, Mahala D M, Singh D, Nayak H S, Patra K, Reddy K S, Pradhan S and Sena D R. 2023. Influence of long-term tillage and diversified cropping systems on hydro-physical properties in a sandy loam soil of North-Western India. *Soil and Tillage Research* **229**: 105655.

Squire G R. 1990. *The physiology of tropical crop production*. CAB International, Wallingford, U K.

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**: 259–60.