



Impact of diverse tillage and nitrogen management on growth and yield of conservation agriculture-based wheat (*Triticum aestivum*)

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ABSTRACT

A study was carried out during the winter (*rabi*) seasons of 2020–21 and 2021–22 at ICAR-Indian Agricultural Research Institute, New Delhi to assess the effects of diverse tillage and nitrogen management scenarios on growth, development, and yield of a conservation agriculture (CA)-based wheat (*Triticum aestivum* L.) crop grown in sequence with maize (*Zea mays* L.). Experiment was conducted in split plot design (SPD) comprised of 3 different tillage practices in main plots [Conventional tillage + residue (CT); Zero tillage + residue (ZT); and Permanent beds + residue (PB)] and 5 nitrogen (N) options in sub plots [Control (zero nitrogen); Recommended dose of N-RDN @150 kg N/ha (50 kg N/ha Basal + 2-equal splits at 37 days after sowing (DAS) and 84 DAS); Green Seeker (GS) based application of N @148 kg N/ha (GS); Urea super granules applied as basal @75 kg N/ha + GS based N application (USG); and Slow release fertilizer as 100% basal application @150 kg N/ha (SRF)] with 3-replications. The findings revealed that in both the seasons, both tillage and nitrogen management approaches significantly affected wheat growth, yield characteristics, and overall yield, whereas the time to anthesis and physiological maturity, and test weight remained unaffected. Within the spectrum of tillage practices, leaf area index (LAI) and yield attributes exhibited the trend PB>ZT>CT. PB recorded the highest grain yield (5159 kg/ha), followed by ZT (4916 kg/ha) and the lowest grain yield was observed with CT (4578 kg/ha). The wheat grain yields were 12.7% and 7.4% higher in PB and ZT, respectively, over to CT. Among nitrogen management options, the grain yield exhibited the pattern USG>N₁₅₀>SRF>GS>N₀. This study emphasizes that adopting conservation agriculture (CA) practices, particularly CA-based permanent beds using urea super granules (USG) for nitrogen management can improve wheat growth and yield.

Keywords: Crop yield, Permanent bed, Physiological maturity, Urea super granules, Zero tillage

Wheat (*Triticum aestivum* L.) stands as a cornerstone of our food supply, playing a pivotal role in ensuring food security. In India, it is cultivated across an expanse of ~30.47 million hectares, yielding an impressive production output of 106.84 million tonnes, and the productivity of wheat varies across agro-ecologies, ranging from as high as 4533 kg/ha in Trans-Gangetic Plains zone (Haryana, Punjab and Delhi) to 1250 kg/ha in southern plateau and hill zone (Karnataka, Andhra Pradesh and Tamil Nadu) (DACNET 2021). In recent years the rice-wheat system in Indo-Gangetic plains region of India is facing multiple challenges, such as difficulty in

sowing of wheat after puddled rice harvesting, deterioration of soil quality, natural resources degradation, rapid fall in water table and low nitrogen use efficiency, which have posed significant threats to wheat yields (Parihar *et al.* 2016a)

The CA-based maize (*Zea mays* L.)-wheat (M-W) system has shown sustainable approach to cereal-based cropping systems (Jat *et al.* 2019, Sidhu *et al.* 2019). In 2019, the maize-wheat cropping system covered 1.85 million hectares area in India (Parihar *et al.* 2020). By applying the principles of zero tillage, residue retention, and crop diversification, CA can improve crop yield, farm profitability, input use efficiency (Jat *et al.* 2020), soil organic matter (Parihar *et al.* 2020), and improve soil water storage (Patra *et al.* 2023). Nitrogen is the element that is frequently found deficient in agricultural soils because plants require nitrogen in substantial quantities, and only a small fraction of the nitrogen is present in soils in the form (NH₄⁺ and NO₃⁻) that plants can readily absorb. The use of nitrogen fertilizers is essential for increasing the availability of nitrogen to

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crops in soil. Projections from FAO (2011) suggest that the worldwide consumption of nitrogenous fertilizers will approach approximately 180 million tonnes by the year 2030. Nevertheless, it is noteworthy that cereal-based agro-ecosystems often exhibit low nitrogen use efficiency, with cereals assimilating just 40–60% of the used nitrogen (Herrera *et al.* 2016).

Numerous strategies have been projected to improve the efficiency of N fertilizers. Urea deep placement (UDP) is one such method that utilizes larger sized fertilizer particles strategically placed in close proximity to the root zone. This approach has demonstrated effectiveness in augmenting crop yields while reducing fertilizer need, as opposed to the conventional broadcast application technique (IFDC 2013, Kumar *et al.* 2023). However, it is crucial to acknowledge the limited availability of information regarding the utilization of diverse N sources in conjunction with CA in India. The current investigation aims to scrutinize the influence of distinct tillage methods and N management strategies on the growth, yield attributes, and overall production of wheat.

MATERIALS AND METHODS

The present experiment was conducted during the winter (*rabi*) seasons of 2020–21 and 2021–22 at ICAR-Indian Agricultural Research Institute, New Delhi (28° 38' N, 77° 10' E, at an altitude of 228 m amsl). This location falls within the Indian Trans-Gangetic plains zone, known for its sub-tropical and semi-arid climatic conditions. The soil at the research site, initially classified as sandy loam, was analyzed with a pH of 7.9. Furthermore, the soil exhibited a bulk density of 1.63 mg/m³ and a hydraulic conductivity of 0.835 cm/h under saturated conditions. Soil organic carbon content was measured as 4.89 g/kg soil, while the alkaline KMnO₄-N was determined to be 152 kg/ha, as per the method outlined by Subbiah and Asija (1956). Experiment was conducted in split plot design (SPD) comprised of 3 different tillage practices in main plots, viz. Conventional tillage + residue (CT); Zero tillage + residue (ZT); and Permanent beds + residue (PB)] and 5 nitrogen (N) options in sub plots, viz. Control (zero nitrogen); Recommended dose of N-RDN @150 kg N/ha (50 kg N/ha Basal + 2-equal splits at 37 days after sowing (DAS) and 84 DAS); Green Seeker (GS) based application of N @148 kg N/ha (GS); Urea super granules applied as basal @75 kg N/ha + GS based N application (USG); and Slow release fertilizer as 100% basal application @150 kg N/ha (SRF) with 3-replications.

Experiment details: A quantity of 2.8–3.3 t/ha of the previous crop residue was retained/incorporated in the CA and CT, respectively, across various plots. The ZT plots were set up in June 2012 and remained unchanged during the entire study duration. Conversely, the CT treatment was initially ploughed with the help of disc harrow and subsequently complemented by a spring-tine cultivator. The wheat variety HD 2967 was sown in October with a seed rate of 100 kg/ha. An even application of 60 kg P₂O₅ + 40 kg K₂O per hectare, was administered as a basal

fertilizer to all plots during mechanical seeding of wheat. In the control plot (with no nitrogen), solely P₂O₅ and K₂O were applied. On the other hand, the N₁₅₀ plot received a total of 150 kg N/ha, with 50 kg administered as a basal dose, and the remaining N was applied in 2-equal splits at 37 DAS and 84 DAS. The USG (Urea Super Granules) briquettes were positioned within the crop's root zone at a depth of 7–10 cm. Subsequently, prilled urea was applied in split doses. In case of SRF plots, entire N was applied as basal application. To mitigate the impact of moisture stress, irrigation was administered during critical growth stages, including crown root initiation, tillering, jointing, flowering, and milking stages.

Measurement of anthesis, physiological maturity, leaf area index (LAI), yield attributing characters and yield: Days to 50% anthesis and physiological maturity were recorded from the sowing of crop. Leaf area measurements were systematically taken using a leaf area meter (Model LI-COR-3100) at regular intervals. The leaf area index was computed by dividing the cumulative leaf area by the ground area occupied by the crop. The crop was manually harvested, leaving two border rows unharvested in both lateral directions and 0.5 m along the length, resulting in a plot size of 30 m². Wheat grains were collected, subjected to oven-drying at temperatures ranging from 65 to 70°C for 48 h, and then weighed to work out the grain yield. The grain yield of wheat was calculated at a moisture content of 15% and expressed as kg/ha. The straw was harvested from ground level, sun-dried, and weighed, and expressed in kg/ha. The total number of tillers (effective tillers-bearing spike + non-effective tillers-tillers not bearing spike) was counted from 1.0 m row length at harvest and expressed as the total number of tillers/m². The number of tillers bearing spike-effective tillers was counted from 1.0 m row length at harvest and expressed as the number of effective tillers/m². Randomly 10 spikes selected from each plot, were split into grains and chaff. The number of grains was averaged and expressed as the grains/spike. Random grain samples representing each plot were collected, weighed, and expressed as (g) of 1000-grain weight. The harvest index (HI) was calculated as described by Parihar *et al.* (2016a).

Statistical analysis: Statistical analysis was carried out utilizing SAS 9.3 software (SAS Institute, Cary, NC, USA) to perform the analysis of variance (ANOVA) on the data collected from the split plot design, following the principles outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Leaf area index (LAI): The variation in leaf area index among different tillage methods were not statistically significant at the initial crop stage (30 DAS). At the later stages (45 DAS onwards), tillage methods significantly affected the LAI. PB recorded the maximum LAI which was statistically at par with ZT, while CT recorded the least LAI at all the stages. At 90 DAS, which corresponds to the stage of maximum leaf area index for the crop, the PB treatment exhibited the highest LAI (4.52), followed

Table 1 Effect of tillage and N management practices on leaf area index (LAI) of wheat (2-year mean basis)

Treatment	30 DAS	45 DAS	60 DAS	90 DAS	120 DAS	At harvest
<i>Tillage and crop establishment techniques</i>						
CT	0.775	0.996	1.293	4.149	4.046	1.745
PB	0.819	1.066	1.396	4.517	4.402	1.894
ZT	0.797	1.055	1.373	4.462	4.344	1.849
SEm±	0.017	0.012	0.011	0.071	0.017	0.024
LSD ($P=0.05$)	0.057	0.039	0.034	0.231	0.055	0.079
<i>Nitrogen management options</i>						
N ₀	0.474	0.686	0.888	2.848	2.717	1.115
N ₁₅₀	0.877	1.126	1.470	4.763	4.683	2.007
GS	0.874	1.125	1.470	4.734	4.641	2.003
SRF	0.877	1.136	1.469	4.761	4.629	2.008
USG	0.883	1.122	1.474	4.766	4.650	2.015
SEm±	0.031	0.028	0.062	0.089	0.112	0.060
LSD ($P=0.05$)	0.091	0.083	0.180	0.260	0.326	0.175

Treatment details are given under Materials and Methods.

closely by ZT (4.46), though the least LAI was observed in CT, recorded 4.20 (Table 1).

The increased LAI noted in the PB and ZT treatments can be attributed to higher nitrogen accessibility and better soil health. These conditions encompass reduced bulk density and enhanced root development, which align with the conclusions drawn by Kumar *et al.* (2023) in their study. Among the nitrogen management options, aside from N₀, the other treatments showed no significant differences in observed LAI. The highest LAI at 90 DAS was achieved with USG (4.77), a value statistically equivalent to the other nitrogen options. The N₀ treatment exhibited the lowest LAI (2.85) recorded (Table 1), highlighting the direct impact

of nitrogen on crop growth and LAI. The data suggests an initial surge in leaf area until the grain formation phase, followed by a subsequent decline as photosynthates are allocated from source to sink. These results align with prior research conducted by DeJonge *et al.* (2012).

Crop phenology: Days to anthesis and physiological maturity are important stages as pre and post anthesis duration are important determinants of crop yield. In this study, the outcomes revealed that the timing of anthesis, and physiological maturity were primarily dictated by the specific wheat variety employed. Interestingly, treatments without nitrogen application exhibited a delay in anthesis but achieved physiological maturity earlier (Table 2).

Table 2 Effect of tillage and N management practices on growth and yield attributes of wheat (2-year mean basis)

Treatment	Days to 50% anthesis	Days to physiological maturity	Tillers/m ² (60 DAS)	Spikes/m ²	Grains/spike	Weight of spike (g)	Grain weight (g)/spike	1000-grain weight (g)
<i>Tillage and crop establishment techniques</i>								
CT	87.6	136.1	473.1	434.0	59.6	3.24	2.38	40.1
PB	86.9	135.1	492.2	470.8	65.2	3.40	2.56	41.0
ZT	87.6	136.2	487.0	465.9	65.0	3.36	2.49	40.5
SEm±	0.19	0.38	5.22	4.51	0.38	0.039	0.025	0.77
LSD ($P=0.05$)	0.62	1.24	17.02	14.71	1.25	0.13	0.08	2.51
<i>Nitrogen management options</i>								
N ₀	89.7	133.5	348.9	291.7	51.5	2.71	2.00	33.3
N ₁₅₀	85.3	136.8	519.5	492.9	65.8	3.53	2.58	42.3
GS	86.9	136.8	516.0	499.9	65.5	3.44	2.54	42.3
SRF	88.0	135.9	508.9	498.7	67.8	3.47	2.65	42.9
USG	86.9	135.8	527.2	501.2	65.8	3.52	2.60	41.9
SEm±	0.27	0.31	11.28	10.74	0.96	0.036	0.041	0.40
LSD ($P=0.05$)	0.80	0.91	32.91	31.36	2.79	0.10	0.12	1.16

Treatment details are given under Materials and Methods.

Table 3 Effect of tillage and N management practices on yields of wheat (2-year mean basis)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
<i>Tillage and crop establishment techniques</i>				
CT	4578	6757	11335	40.6
PB	5159	7596	12755	40.6
ZT	4916	7368	12284	40.1
SEm±	94.4	43.4	109.9	0.4
LSD ($P=0.05$)	307.7	141.6	358.3	1.3
<i>Nitrogen management options</i>				
N ₀	3459	4765	8225	42.1
N ₁₅₀	5268	7907	13175	39.9
GS	5187	7834	13021	39.8
SRF	5238	7841	13079	40.1
USG	5269	7855	13125	40.2
SEm±	131.9	172.8	233.0	0.7
LSD ($P=0.05$)	384.8	504.3	680.1	2.1

Treatment details are given under Materials and Methods.

This observation is consistent with the well-known understanding that stress prior to anthesis tends to prolong the pre-anthesis phase, while stress shortens the post-anthesis period, as previously reported by Chisanga *et al.* (2015). Furthermore, our study revealed that the timing of anthesis and physiological maturity was primarily influenced by the specific wheat variety utilized, reinforcing the well-established concept regarding stress effects before and after anthesis, as previously noted by Gungula *et al.* (2007).

Conversely, treatments incorporating nitrogen application exhibited a prolonged duration to achieve physiological maturity. This delay was attributed to the prolonged post-anthesis phase, a consequence of the sustained nitrogen availability. This observation aligns with the results reported by Squire *et al.* (1990). It is essential to emphasize that crop yield is intricately linked to the duration of the crop's growth phases, encompassing both pre- and post-anthesis phases, as well as the photosynthetic area represented by leaf coverage. Hence, the accurate identification of phenological stages in field experiments holds paramount importance in comprehending their impact on crop productivity.

Yield attributes and yield: Significant difference were noted in tillers/m², spikes/m², grains/spike, and grain weight/spike as influenced by different tillage practices. Among the tillage practices, PB and ZT recorded significantly higher tillers/m², spikes/m², grains/spike, and grain weight/spike than CT and overall the trend was PB>ZT>CT (Table 2). The hereditary trait of test weight (1000-grain weight) remained consistent across various tillage practices and nitrogen management scenarios. With the exception of N₀, which recorded the lowest values, nitrogen management options showed no notable impact on tillers/m², spikes/m², grains/spike, and grain weight/spike. The *P*-values indicated an absence of significant

interaction between tillage and crop establishment techniques, as well as nitrogen management options, with regard to the yield attributes of the wheat crop over both years of experimentation. Both tillage and N management practices significantly influenced grain yield. Within the range of tillage practices, the progression for grain yield was as follows: PB>ZT>CT. Compared to CT (Table 3), grain yields were 12.7% and 7.4% higher in PB and ZT, respectively. Additionally, among N management treatments USG plots recorded with highest yield.

In terms of nitrogen management options, the progression of grain yield was as follows: USG>N₁₅₀>SRF>GS>N₀. Biological yield showed significant impacts from both tillage and nitrogen management practices, while the interaction between the (tillage × nitrogen management practices) proved non-significant. Over the course of the study period, plots with ZT and PB treatments recorded 12.4% and 9.1% higher straw yield, respectively, compared to those with CT plots. PB exhibited the highest biological yield followed by ZT, which outperformed CT by 12.5 and 8.4%, respectively (Table 3). The integration of PB and ZT, in conjunction with the application of urea super granules (USG) and N₁₅₀, resulted in 12% increase in biomass over CT. This increased biomass likely played a pivotal role in the superior grain yield observed in these treatment combinations.

The improved grain yield linked to increased biomass in CA-based PB and ZT plots can be attributed to the establishment of an ideal microclimate for plant growth. This microclimate, in turn, fosters improved soil physical properties, as well as favorable soil biochemical properties (Parihar *et al.* 2016b). Additionally, it promotes advantageous soil moisture dynamics (Govaerts *et al.* 2007), all of which collectively contribute to the observed yield enhancement. This study concludes that nitrogen management strategies in terms of USG in combination with PB was the best treatment combination for wheat.

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