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Impact of Advanced Planting System and Targeted Yield-Based Precision Nitrogen Management on Productivity of Wheat (*Triticum aestivum* L.) in Indo – Gangetic Plains

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ABSTRACT

A two-year field experiment was conducted during Rabi 2024-25 and 2025-26 at the Agronomy Field Laboratory, F.S. University, Shikohabad, Firozabad, Uttar Pradesh, India, to assess the impact of efficient planting methods and precision nitrogen management on growth and yield of wheat (*Triticum aestivum* L.). The experiment was laid out in a split-plot design with three replications. Five tillage and crop establishment methods (TCM) – Zero Tillage Wheat (ZTW), Conventional Tillage Wheat (CTW), Reduced Tillage (RT), Reduced Tillage with residue retention (RTW), and Furrow

Irrigated Raised Bed (FIRB) – were allocated to main plots. Five precision nitrogen management (PNM) practices – Control, Recommended Dose of Fertilizer (RDF), SPAD meter-based, Leaf Color Chart (LCC)-based, and Targeted Yield (TY) approach – were assigned to sub-plots. Wheat variety DBW-17 was sown in both years. Both planting method and nitrogen management significantly influenced plant height, tiller density, and yield attributes in both years. Among TCEM, FIRB recorded the highest plant height at harvest of 73.6 and 74.2 cm, maximum tillers m^{-2} at harvest of 367.9 and 368.7, grain yield of 53.1 and 53.9 q ha^{-1} , straw yield of 64.3 and 65.1 q ha^{-1} , and biological yield of 116.9 and 117.7 q ha^{-1} during 2024-25 and 2025-26, respectively. ZTW was statistically at par with FIRB for most parameters. RTW consistently produced the lowest values for plant height, tiller count, and all yield components. Among PNM treatments, the Targeted Yield approach recorded the highest plant height at harvest of 80.8 and 81.4 cm, maximum tillers m^{-2} at harvest of 368.5 and 369.3, grain yield of 52.3 and 53.0 q ha^{-1} , straw yield of 59.9 and 60.7 q ha^{-1} , and biological yield of 111.6 and 112.4 q ha^{-1} in the two years. SPAD-based N management was the next best treatment, while the control recorded the lowest values for all growth and yield parameters. Harvest index was also highest under FIRB and TY treatments. The study concludes that integration of FIRB or ZTW planting systems with Targeted Yield-based precision nitrogen management significantly enhances wheat growth, tiller production, and grain yield. Adoption of these resource-conserving practices can improve productivity and nitrogen use efficiency, offering a sustainable approach for wheat cultivation in the Indo-Gangetic Plains.

Keywords : Triticum aestivum, Furrow Irrigated Raised Bed, Zero tillage, Precision nitrogen management, Targeted Yield, Plant height, Tillers, Grain yield, Biological yield, Indo-Gangetic Plains

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India after rice and contributes approximately 35% to the total food grain production of the country (Government of India, 2024). It is predominantly grown during the rabi season and forms the backbone of food security in the Indo-Gangetic Plains. However, wheat productivity in this region has become stagnant at around 3.5 t ha^{-1} due to continuous adoption of conventional tillage, delayed sowing, imbalanced fertilizer use and deteriorating soil health (Jat, Singh, & Saharawat, 2020). Conventional flat sowing after 4-5 tillage operations increases cost of production, reduces irrigation efficiency and adversely affects soil physical properties. To address these constraints, resource conservation technologies have emerged as viable alternatives. Conservation Tillage Establishment Methods (TCEM) such as Zero Tillage Wheat (ZTW), Reduced Tillage (RT), Reduced Tillage with Residue (RTW),

Furrow Irrigated Raised Bed (FIRB) and Conventional Tillage Wheat (CTW) are being promoted for sustainable wheat production (Govaerts, Sayre, & Deckers, 2007). These practices improve soil structure, conserve moisture, reduce fuel and labor requirement and facilitate timely sowing. Among these, FIRB system enhances root growth, improves drainage and reduces lodging, while ZTW helps in advancing sowing date and conserving soil moisture (Chaudhary, Jat, & Gathala, 2021). Previous studies have reported 10-15% higher yield under FIRB and ZTW compared to CTW due to better crop establishment and resource use efficiency (Kumar, Singh, & Sharma, 2022). Nitrogen is the key nutrient for wheat, but its use efficiency under blanket application of 120:60:40 NPK kg ha^{-1} is less than 35% (Dobermann, 2005). This leads to economic losses and environmental pollution. Precision Nitrogen Management (PNM) tools like SPAD chlorophyll meter, Leaf Colour Chart (LCC) and Targeted Yield (TY) approach have been developed to apply N based on crop need (Singh, Singh, & Timsina, 2018). These tools help in split application of N at critical stages, thereby improving N recovery to 45-55% and reducing losses (Singh, Singh, & Ladha, 2019). Integration of TCEM with PNM is expected to synchronize nutrient supply with crop demand and enhance productivity. Considering the above facts, the present investigation was carried out during rabi 2024-25 and 2025-26 to study the effect of different TCEM and PNM on growth and yield of wheat. Table-I shows plant height at 30, 60, 90 DAS and at harvest. Plant height is an important growth parameter that determines biomass and is significantly influenced by tillage and N management (Yadav, Singh, & Kumar, 2021). Improved aeration under FIRB and need-based N through SPAD/LCC are likely to increase plant height. Table-II presents number of tillers m^{-2} . Tillering is highly responsive to N and soil environment. Studies have shown that raised bed planting with real-time N management increases tiller density by 15-20% (Singh et al.,

2019). Table-III deals with grain yield, straw yield, biological yield and harvest index. Yield is the final expression of growth and is governed by interaction of establishment method and nutrient management (Jat et al., 2020). Therefore, integration of suitable TCEM with PNM may offer a sustainable option for improving wheat productivity in central Uttar Pradesh.

2. MATERIALS AND METHODS

A field experiment was conducted on sandy loam soil at FS University, Shikohabad, Uttar Pradesh, India to study the “Boosting crop performance and soil fertility: Leveraging precision Nitrogen management and advanced planting system for Wheat (*Triticum aestivum*) cultivation” during rabi season of the both years 2024-25 and 2025-26. The experiment comprising of 25 treatment combinations was laid out in Split Plot Design with three replications. The treatment-A consisted of five tillage and crop establishment methods (TCEM) T₁ (ZTW), T₂ (RT), T₃ (RTW), T₄ (FIRB),

T₅ (CTW) and Treatment –B consisted of five levels of precision N management (PNM) F₀ (control), F₁ (NPK), 120:60:40, F₂ (SPAD), F₃ (TY), F₄ (LCC). The soil of experimental plot was physical properties is sand percent is 46.7%, Clay 17.3%, Silt 32.7% during the experimentation of 2024-25 & 45.9%, 16.8%, 33.0% during the 2025-26. The soil was low organic carbon percent is 0.41% and 0.43%, & N 224.8 kg ha⁻¹ and 223.9 kg ha⁻¹ during the both years of study and medium available of phosphorus (P₂O₅) is 15.4 kg ha⁻¹ (2024-25) & 15.8 kg ha⁻¹ (2025-26) and potash

(K₂O) is 232.2 kg ha⁻¹ & 235.8 kg ha⁻¹ during the both experimentation. The DBW-17 wheat variety was developed at ICAR-II WBR in India and released in 2007 for its high yield, resistance to stripe and leaf rusts, and tolerance to terminal heat, replacing older cultivars like PBW343. Its development involved pedigree-bulk methods and shuttle breeding, and it showed superior, stable yields during multi-location trials between 2003 and 2006, with an average yield of 49 quintal per hectare. After all average yield across 50-55 quintal per hectare.

Key Aspects of DBW17 History and Development :

- High yield Potential
- Disease Resistance
- Terminal Heat Tolerance
- Superior Performance

3. RESULT & DISCUSSION

3.1: PLANT HEIGHT

Plant height is an important parameter which can be used to study the effect of different treatments on crop augmentation. The data on periodic plant height recorded at 30 DAS, 60 DAS, 90 DAS & at harvest as presented in this table –I & II and figure-I & II. showed that averaged over the different treatments the increase in plant height mean with successive intervals from 30-60 DAS, 60-90 DAS, and from 90 DAS to At harvest was 38.2cm, 18.4cm and 7.8cm during the session 2024-2025 & 39.0cm, 19.2cm and 8.6cm during the session 2025-2026 of both experimentation. Wheat plants attain their maximum height during early crop growth period and thereafter, a slow rate of increase in plant height was registered during the year of study. Due to tillage (TCEM) and nitrogen management (PNM) the improvement in moisture and nutrient supply resulted significant increase in plant height in T₄ (FIRB) furrow irrigated raised beds over all other treatments at 30 DAS, 60 DAS, 90 DAS stage and at harvest. The increase in plant height from 30DAS to 60DAS was found maximum under T₄ (FIRB) treatment during the two years 2024-25 and 2025-26 of study. At 60 days of crop growth stage, maximum height in 2024 -25 is 55.5cm & 2025-26 is 56.3cm of plants was obtained under treatment T₄ (FIRB) being significantly taller than those for the rest of the tillage crop establishment treatments except zero till T₁ (ZTW) and least (46.0cm in 2024-25 & 46.4cm in 2025-26) under reduced till T₃ (RTW). Treatment zero till T₁ (ZTW) was

significantly superior remaining of the treatments. The difference in plant height between reduced till T_2 (RT) and conventional till T_5 (CTW) was at par at 90DAS and at harvest during the both years 2024-25 and 2025-26 of experimentations. Crop receiving targeted yield F_3 (TY) based nutrients had produced significantly taller plants than those growth with other nutrients management strategies at all the growth stages except at 90 days after sowing and at harvest where crop receiving SPAD based (F_2) nutrients which was at par with it. Plant height at harvest registered at increased 4.4% over F_1 (RDF) with all the nutrients management strategies, except F_4 (LCC) approach. The increase was however significant only with targeted yield F_3 (TY) and F_2 (SPAD) based nutrients applications at all the stages during the both crop season 2024 -25 and 2025-26 of experimentation study. The differences between the two (targeted 5.0 t/ha { F_3 =TY} and { F_2 =SPAD} fertilizer based nutrients) were significant only at initial stages of growth (30DAS & 60DAS).

Table –I : The Performance of various tillage and crop establishment methods (TCM) and precision nitrogen management (PNM) on plant height (cm) of wheat at the various crop growth stages both are the crop season 2024-25 & 2025-26

Treatments	PLANT HEIGHT (CM)							
	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest
	CROP SEASON 2024-2025				CROP SEASON 2025-2026			
➤ Tillage and Crop Establishment Methods (TCEM- Main Plot)								
T ₁ (ZTW)	14.9	54.1	72.0	73.6	15.1	54.9	72.8	74.2
T ₂ (RT)	14.3	51.2	70.3	70.2	14.8	52.2	70.7	71.1
T ₃ (RTW)	13.5	46.0	63.4	63.2	14.0	46.4	64.1	64.2
T ₄ (FIRB)	16.2	55.5	73.3	77.5	17.2	56.3	73.9	77.8
T ₅ (CTW)	14.2	52.4	71.2	71.6	14.8	52.9	71.6	71.9
<u>SEm±</u>	<u>0.14</u>	<u>0.48</u>	<u>0.68</u>	<u>0.73</u>	<u>0.19</u>	<u>0.54</u>	<u>0.76</u>	<u>0.81</u>
<u>C.D. at 5%</u>	<u>0.46</u>	<u>1.56</u>	<u>2.22</u>	<u>2.38</u>	<u>0.62</u>	<u>1.76</u>	<u>2.48</u>	<u>2.64</u>
➤ Precision Nitrogen Management (PNM-Sub Plot)								
F0 (Control)	11.8	47.7	65.1	72.2	12.2	47.9	66.8	73.3
F1 (RDF)	16.1	51.2	70.2	75.8	16.8	52.8	71.3	76.1
F2 (SPAD)	15.7	53.8	72.9	78.2	16.1	54.2	73.3	78.8
F3 (TY)	17.4	57.2	74.1	80.8	18.3	57.9	74.9	81.4
F4 (LCC)	15.0	53.1	71.3	75.6	15.8	53.5	71.8	75.8
<u>SEm±</u>	<u>0.37</u>	<u>0.94</u>	<u>1.26</u>	<u>1.33</u>	<u>0.41</u>	<u>1.10</u>	<u>1.38</u>	<u>1.47</u>
<u>C.D. at 5%</u>	<u>1.06</u>	<u>2.69</u>	<u>3.60</u>	<u>3.80</u>	<u>1.17</u>	<u>3.15</u>	<u>3.95</u>	<u>4.20</u>

(Source: Field experiment conducted during rabi 2024-25 and 2025-26 at FSU, Shikohabd, U.P.)

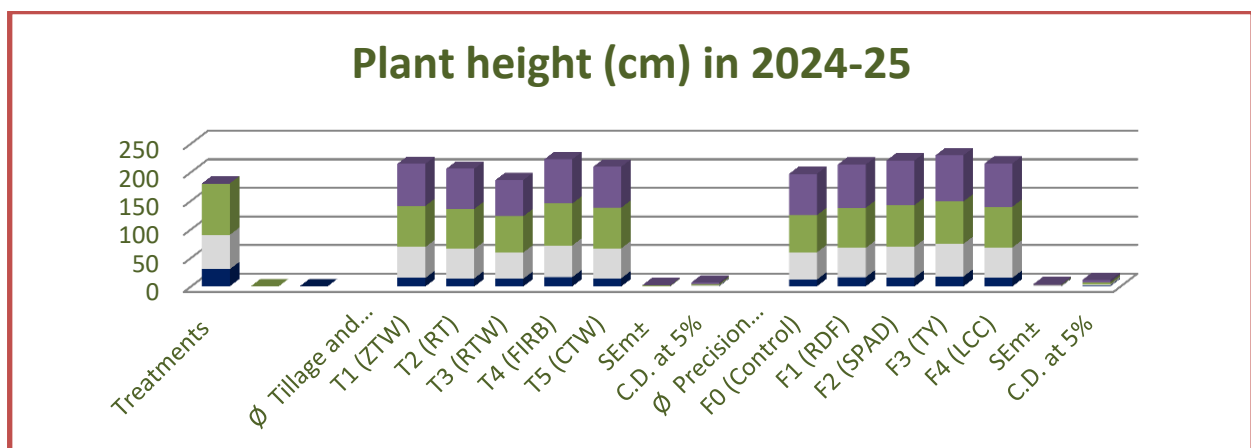


Figure – Ia : Experimental wheat plant height affected various treatments of TCEM & PNM

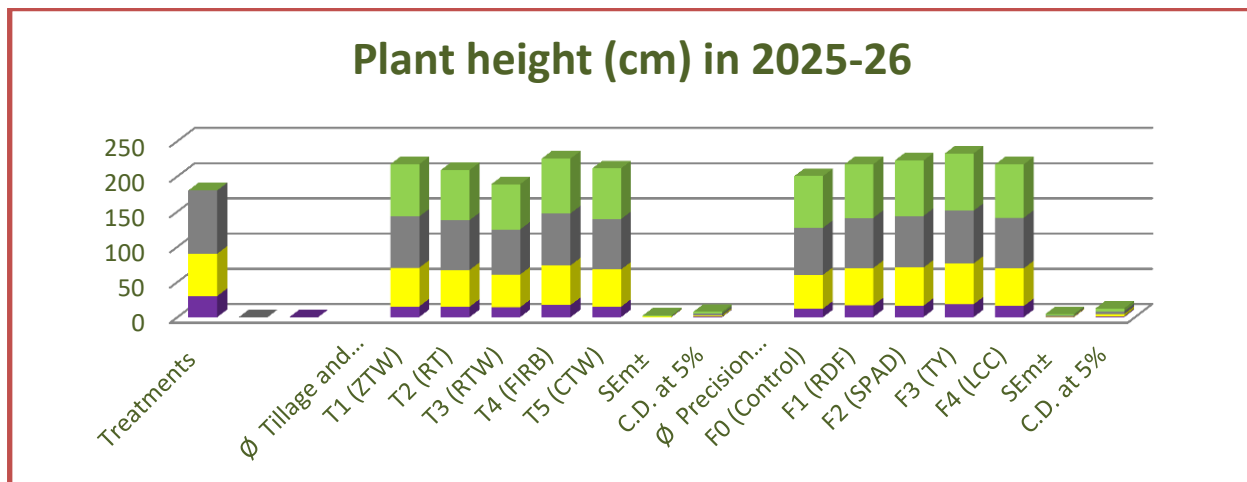


Figure – Ib : Experimental wheat plant height affected various treatments of TCEM & PNM

3.2 : NUMBER OF TILLERS

Tillers count per unit area is an important parameter for determining the effect of any treatment on augmentation and yield of a crop like wheat. The mean data of tillers were counted at 30DAS, 60DAS, 90DAS and at harvest is presented in the table & figure. The perusal of data revealed that wheat plants produced maximum tillers m^{-2} at 60 DAS and later on tiller m^{-2} decreased with the advancement of crop age. Average decrease in tillers m^{-2} from 60 DAS to 90 DAS was 38 tillers m^{-2} during 2024-25 & 40 tillers m^{-2} during 2025-26 experimentation. Wheat sown on furrow irrigated raised beds T₄ (FIRB) produced more tillers followed by wheat sown under zero tillage T₁ (ZTW) method. Wheat sown on T₄ (FIRB) recorded maximum tillering at 30 DAS, 60 DAS, 90 DAS stages and at harvest being significantly higher than those for the rest of the tillage crop establishment methods and lowest (101.8, 287.6, 283.3 & 275.1 in 2024-25 & 102.6, 288.4, 284.1, 275.9 in 2025-26) under 'wheat had sown by T₃ (RTW) during the two years of study. Treatment T₁ (ZTW) was significantly superior over rest of the treatments at 30 DAS, 60 DAS, and 90 DAS and at harvest during experimentation. Treatment T₂ (RT) was significantly more number of tiller m^{-2} than T₃ (RTW) at all stages and at harvest which recorded lowest tillers during the both year's 2024-25 & 2025-26 of experimental study. Precision nitrogen management (PNM) practices had significant effect on number of tillers m^{-2} throughout the crop augmentation period. Treatment F₃ (TY) recorded significantly higher tillers m^{-2} over all other treatments at 30DAS, 60DAS, 90DAS and at harvest during the both of years of study. Moreover, F₂ (SPAD based nitrogen management significantly superior over rest of the treatments at 30DAS and at harvest but it was statistically at par with F₄ (LCC) treatment during the both year's 2024-25 & 2025-26 of experimental study. But 60DAS and 90DAS F₂ (SPAD) based nitrogen management was at par with F₄ (LCC) based nitrogen management during experimentation.

Table – II : Performance of various tillage and crop establishment methods (TCEM) and precision nitrogen management (PNM) on tillers m^{-2} of experimental wheat during to the crop season 2024-25 & 2025-25

NUMBER OF TILLER'S	
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Treatments	30	60	90	At	30	60	90	At
	DAS	DAS	DAS	Harvest	DAS	DAS	DAS	Harvest
	CROP SEASON 2024-2025				CROP SEASON 2025-2026			
➤ Tillage and Crop Establishment Methods (TCEM- Main plot)								
T ₁ (ZTW)	133.3	438.9	378.7	353.6	134.1	439.7	379.5	354.4
T ₂ (RT)	116.1	320.6	318.3	307.9	116.9	321.4	319.1	308.7
T ₃ (RTW)	101.8	287.6	283.3	275.1	102.6	288.4	284.1	275.9
T ₄ (FIRB)	133.0	455.7	391.4	367.9	133.8	456.5	392.2	368.7
T ₅ (CTW)	125.4	425.9	366.9	347.6	126.2	426.7	367.7	348.4
<u>SEm±</u>	<u>1.60</u>	<u>3.82</u>	<u>3.48</u>	<u>3.40</u>	<u>2.40</u>	<u>4.62</u>	<u>4.28</u>	<u>4.20</u>
<u>C.D. at 5%</u>	<u>5.22</u>	<u>12.45</u>	<u>11.34</u>	<u>11.08</u>	<u>7.82</u>	<u>15.06</u>	<u>13.95</u>	<u>13.69</u>
➤ Precision Nitrogen Management (PNM-Sub plot)								
F0 (Control)	103.3	293.1	288.4	282.1	104.1	293.3	289.2	282.9
F1 (RDF)	117.9	355.3	327.3	321.6	118.7	356.1	328.1	322.4
F2 (SPAD)	129.2	427.3	373.7	346.5	130.0	428.1	374.5	347.3
F3 (TY)	135.9	459.2	394.6	368.5	136.7	460.0	395.4	369.3
F4 (LCC)	124.3	393.8	354.5	333.4	125.1	394.6	355.3	334.2
<u>SEm±</u>	<u>2.52</u>	<u>7.12</u>	<u>6.36</u>	<u>6.03</u>	<u>3.32</u>	<u>7.92</u>	<u>7.16</u>	<u>6.83</u>
<u>C D (P=0.05)</u>	<u>7.21</u>	<u>20.36</u>	<u>18.19</u>	<u>17.25</u>	<u>9.50</u>	<u>22.65</u>	<u>20.48</u>	<u>19.53</u>

(Source: Field experiment conducted during rabi 2024-25 and 2025-26 at FSU, Shikohabd, U.P.)

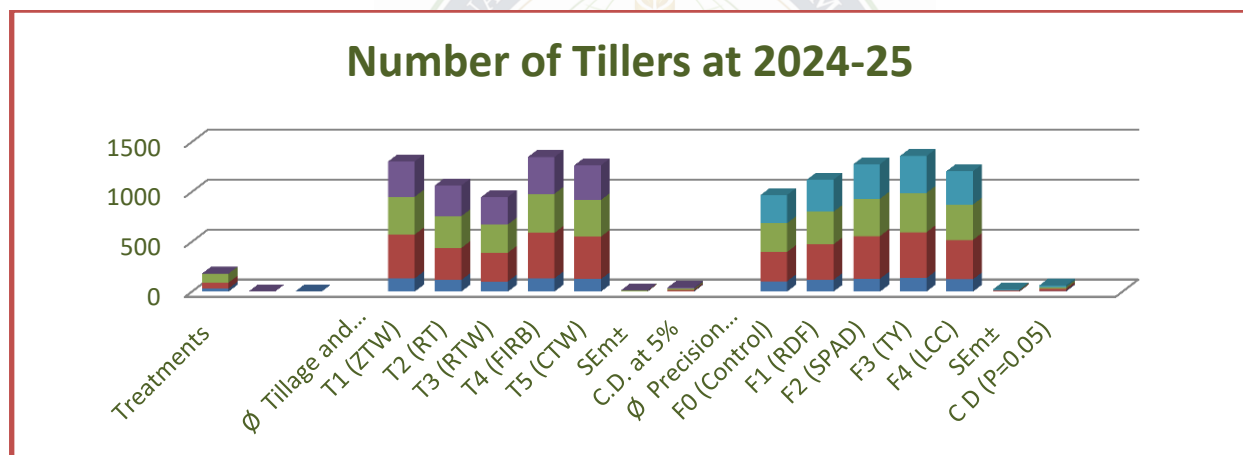


Figure – II a : Number of Tillers affected through various treatments of TCEM & PNM

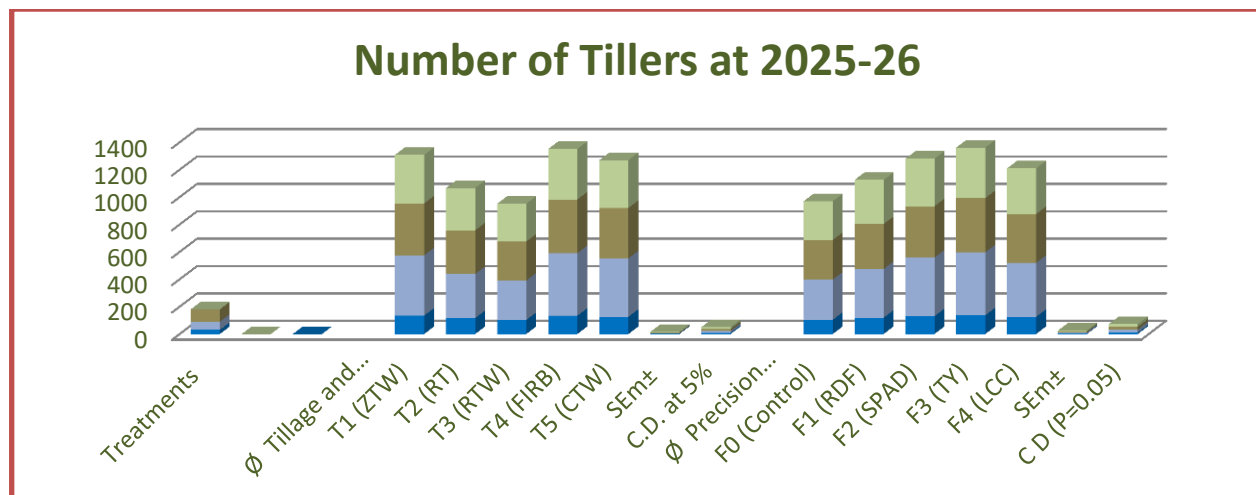


Figure – II b : Number of Tillers affected through various treatments of TCEM & PNM

4. GRAIN YIELD

Grain yield is the most important criteria for evaluating the effects of applied treatments. Crop productivity is the rate at which a crop accumulate biomass which depends primarily on the photosynthesis and conversion of light energy into chemical energy by green plants. The data on grain yield is presented in Table III and Fig. III*, III** revealed that grain yield increased with each increment in moisture retention level. The variations in grain yield due to main effects of various treatments were statistically significant during the two years of the experimentation study 2024-25 and 2025-26. The interaction effect of nitrogen management and tillage practices on grain yield was found significant during the both years of 2024-25 and 2025-26 under the experimentations in Table III. The nitrogen management F_0 =control and F_1 (RDF) were not so much influenced by tillage practices as F_2 (SPAD) and F_3 (TY). The grain yield of T_3 (TY) was significantly higher than various tillage practices except T_0 =control and T_4 (LCC) during the both years of experimentations. But in case of nitrogen management F_3 (TY), all the modes of tillage practices registered significantly higher yield over T_2 (RT) reduced tillage. However, T_0 (control) was superior over T_2 (SPAD), but T_1 (RDF) and T_4 (LCC) was at par with each other during the two years of 2024-25 and 2025-26 of study.

Table III: Performance of various tillage and crop establishment methods (TCEM) and precision nitrogen management (PNM) on Grain, Straw, Biological yield & Harvest index of experimental wheat during the both years of 2024-25 & 2025-26.

Treatments	YIELD AND HARVEST INDEX							
	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)
	CROP SEASON 2024-2025				CROP SEASON 2025-2026			
➤ Tillage and Crop Establishment Methods (TCEM-main plot)								
T ₁ (ZTW)	49.2	58.0	106.7	46.3	50.0	58.8	107.5	47.1
T ₂ (RT)	42.4	51.4	93.3	45.7	43.2	52.2	94.1	46.5
T ₃ (RTW)	37.9	45.3	82.7	45.5	38.7	46.1	83.5	46.3
T ₄ (FIRB)	53.1	64.3	116.9	45.7	53.9	65.7	117.7	46.5
T ₅ (CTW)	44.1	57.1	100.7	44.0	44.9	57.9	101.5	44.8
<u>SEm±</u>	<u>0.56</u>	<u>0.58</u>	<u>3.48</u>	<u>0.50</u>	<u>0.64</u>	<u>0.66</u>	<u>3.56</u>	<u>0.58</u>
<u>C.D. at 5%</u>	<u>1.83</u>	<u>1.89</u>	<u>11.34</u>	<u>1.63</u>	<u>2.09</u>	<u>2.15</u>	<u>11.61</u>	<u>1.89</u>
➤ Precision Nitrogen Management (PNM-sub plot)								
F ₀ (control)	34.3	45.5	79.3	43.4	35.1	46.3	80.1	44.2
F ₁ (RDF)	45.9	55.8	101.2	45.6	46.7	56.6	102.0	46.4
F ₂ (SPAD)	47.6	58.7	105.8	45.2	48.4	59.5	106.6	46.0
F ₃ (TY)	52.3	59.9	111.6	47.0	53.0	60.7	112.4	47.8
F ₄ (LCC)	46.7	56.2	102.4	45.9	47.5	57.0	103.2	46.7
<u>SEm±</u>	<u>0.83</u>	<u>1.06</u>	<u>3.18</u>	<u>0.79</u>	<u>0.91</u>	<u>1.14</u>	<u>3.26</u>	<u>0.87</u>
<u>C.D. at 5%</u>	<u>2.37</u>	<u>3.03</u>	<u>9.09</u>	<u>2.26</u>	<u>2.60</u>	<u>3.26</u>	<u>9.32</u>	<u>2.49</u>

(Source: Field experiment conducted during rabi 2024-25 and 2025-26 at FSU, Shikohabd, U.P.)

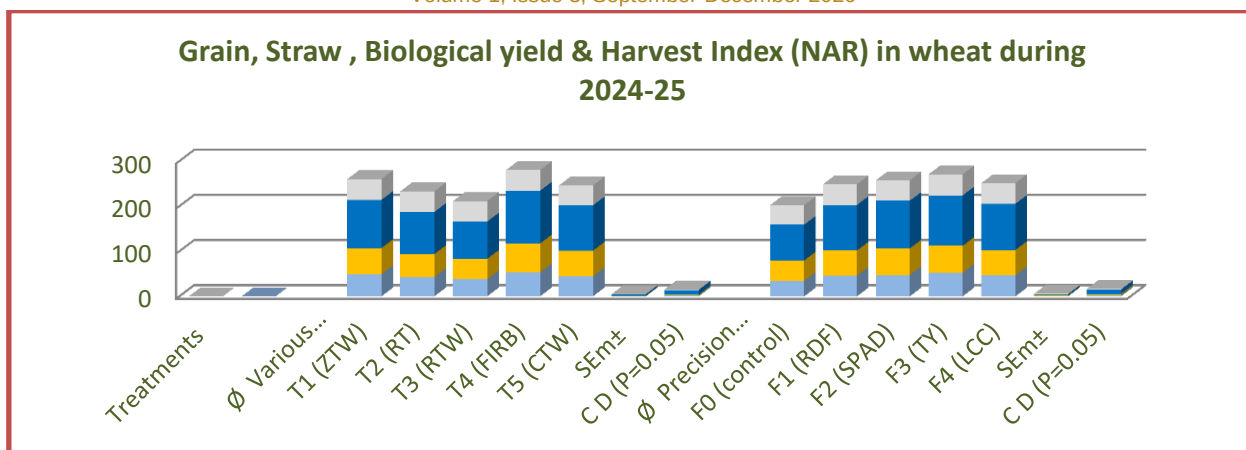


Figure III a : Yield and Harvest Index affected by various TCEM with different levels of PNM

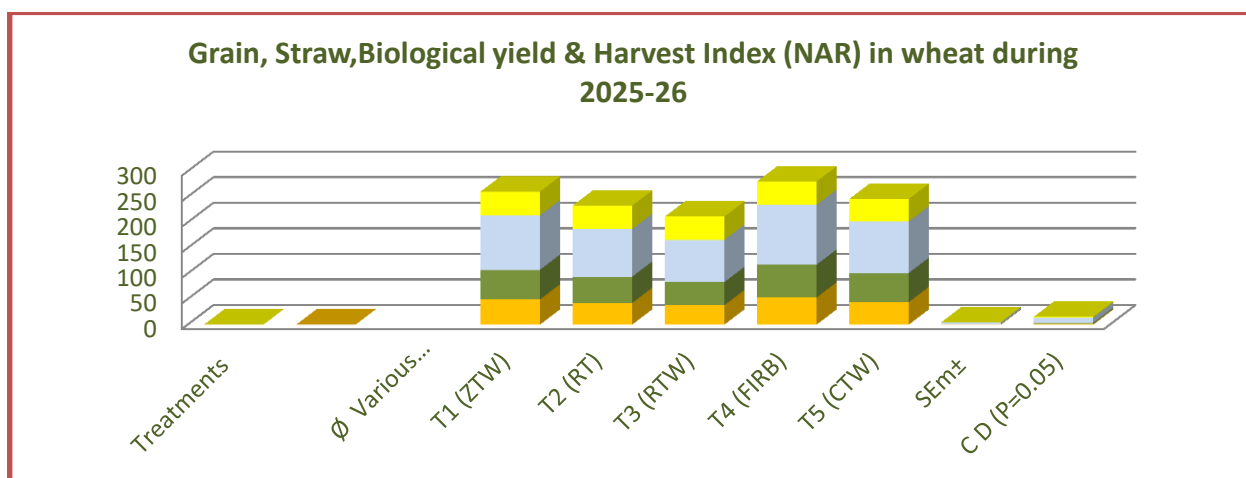


Figure III b : Yield and Harvest Index affected by various TCEM with different levels of PNM

5. CONCLUSION

The two-year (2024-25 & 2025-26) study revealed that both tillage crop establishment methods (TCEM) and precision nitrogen management (PNM) significantly influenced growth and yield attributes of wheat.

I. Effect of Tillage Crop Establishment Methods (TCEM) :

Among the five establishment methods, Furrow Irrigated Raised Bed (T4, FIRB) and Zero Tillage Wheat (T₁, ZTW) consistently outperformed other methods. FIRB recorded the highest grain yield (53.1 and 53.9 q/ha), biological yield (116.9 and 117.7 q/ha), plant height at harvest (73.6 and 74.2 cm), and number of tillers at harvest (367.9 and 368.7/m²) during 2024-25 and 2025-26, respectively. ZTW was statistically at par with FIRB for most parameters. In contrast, RTW (T3) gave the lowest grain

yield, plant height, and tiller count in both years. This indicates that FIRB and ZTW provide better soil aeration, root growth, and resource use efficiency, leading to improved vegetative and reproductive growth.

II. Effect of Precision Nitrogen Management (PNM) :

Among nitrogen management practices, the Targeted Yield approach (F3, TY) was superior to all other treatments. TY recorded the maximum grain yield (52.3 and 53.0 q/ha), biological yield (111.6 and 112.4 q/ha), plant height at harvest (80.8 and 81.4 cm), and number of tillers at harvest (368.5 and 369.3/m²) in 2024-25 and 2025-26. SPAD-based N management (F2) was the next best, while the Control (F0) gave the lowest values for all parameters. This confirms that real-time, demand-based N application through TY synchronizes N supply with crop growth stages, promoting better tillering, plant height, and yield.

6. OVERALL RECOMMENDATION

The study concludes that integration of FIRB or ZTW planting method with Targeted Yield-based precision nitrogen management is the most effective combination for maximizing grain yield, biological yield, plant height, and productive tillers in wheat under the tested conditions. Adoption of these practices can enhance wheat productivity and nitrogen use efficiency in the Indo-Gangetic Plains (IGP).

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