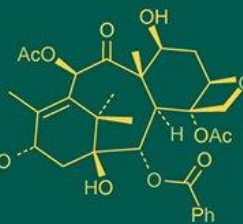
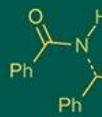


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Influence of tillage, hydrogel and Integrated Nutrient Management (INM) on growth performance of wheat (*Triticum aestivum* L.)

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Abstract

Triticum aestivum L. is a hexaploid species, evolved through natural hybridization events involving diploid and tetraploid ancestors (Dubcovsky & Dvorak, 2007). Government of India (GoI) data indicates that wheat output in the agricultural year 2024-25 is to be around 117-118 million tonnes. Tillage, soil moisture and nutrient availability interact closely in determining the growth and development of wheat. Integration of appropriate tillage practices with hydrogel and INM may create a favorable soil environment by improving moisture retention, nutrient availability and root activity. The field experiment was conducted at the Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (208002), Uttar Pradesh, India. Experiment was conducted during two consecutive *Rabi* seasons of 2024-25 and 2025-26. Wheat variety "DBW-187" (Karan Vandana) is used with Split Plot Design, comprising four main plot factors i.e., Tillage practices (T): Conventional Tillage (15 cm) (T₁), Deep Tillage (25 cm) (T₂), Conventional Tillage (15 cm) + Pusa Hydrogel 5 kg ha⁻¹ (T₃) and, Deep Tillage (25 cm) + Pusa Hydrogel 5 kg ha⁻¹ (T₄) and six sub-plot factors i.e., Integrated Nutrient Management (N): 100% Recommended dose of NPK (120:60:40 kg ha⁻¹) (N₁), 100% Recommended dose of NPK + Vermicompost @ 8 t ha⁻¹ (N₂), 100% Recommended dose of NPK + Farm Yard Manure @ 20 t ha⁻¹ (N₃), 100% Recommended dose of NPK + Vermicompost @ 8 t ha⁻¹ + FYM @ 20 t ha⁻¹ (N₄), 75% Recommended dose of NPK + Farm Yard Manure @ 20 t ha⁻¹ (N₅) and 75% Recommended dose of NPK + FYM @ 20 t ha⁻¹ + Vermicompost @ 8 t ha⁻¹ (N₆), which replicated thrice. Study was conducted considering, Initial (15 DAS) and Final Plant Population (m⁻²), Plant Height (cm), Plant Fresh and Dry Weight (g plant⁻¹), Leaf Area (cm plant⁻¹) and Number of Tillers (m⁻²), growth parameters. Results indicates that, combined application of Deep tillage (25 cm) + Pusa Hydrogel @ 5 kg ha⁻¹ and integrated nutrient management comprising 100% recommended dose of NPK (120:60:40 kg ha⁻¹) + Vermicompost @ 8 t ha⁻¹ + Farmyard Manure @ 20 t ha⁻¹ resulted in superior growth of wheat. Thus, deep tillage integrated with Pusa hydrogel and nutrient management may be considered an effective approach for enhancing the growth performance of wheat (*Triticum aestivum* L.).

Keywords: Wheat, tillage, hydrogel, INM, growth performance etc.

1. Introduction

Wheat (*Triticum aestivum* L.), commonly known as bread wheat, is one of the most important cereal crops globally, serving as a staple food for a large proportion of the world's population (Shewry, 2009 and Curtis *et al.*, 2002) [13, 3]. Among the various wheat species, *Triticum aestivum* is a hexaploid species (2n = 6x = 42 chromosomes), which evolved through natural hybridization events involving diploid and tetraploid ancestors (Dubcovsky & Dvorak, 2007) [4]. Morphologically, *Triticum aestivum* is an annual herb characterized by hollow stems (culms), narrow leaves, and a terminal spike inflorescence composed of spikelets. Each spikelet contains multiple florets that develop into grains (Bonjean & Angus, 2001) [2]. The wheat grain, botanically known as a caryopsis, consists of three main parts, i.e., the bran, endosperm, and germ (Wieser, 2007) [15]. Global production of wheat in 2025, has shown a steady increase, according to estimates by the Food and Agriculture Organization (FAO, 2025) [5] and the International Grains Council (IGC, 2025) [7]. Total world wheat production during 2025 is projected to range between 796 and 810 million tonnes, marking a slight increase compared to approximately 787 million tonnes in 2024.

Official estimates from the Government of India (GoI) indicate wheat output in the agricultural year 2024-25 to be around 117-118 million tonnes.

1.1 Tillage

Tillage is an important agronomic practice that modifies soil physical conditions and influences crop establishment, root development and subsequent growth. Different tillage depths and intensities can alter soil structure, porosity, aeration, infiltration and moisture distribution, thereby affecting the availability of water and nutrients to growing plants. Suitable tillage practices can promote better root proliferation, plant establishment, tillering and dry matter accumulation, which may result in improved growth dynamics of wheat.

1.2 Hydrogel

Hydrogel is a water-absorbing polymer capable of retaining and gradually releasing water in the soil, thereby improving moisture availability in the crop root zone. Its application can help reduce fluctuations in soil moisture and maintain a more favorable moisture regime for plant growth. Improved moisture availability may enhance root activity, nutrient uptake, plant height, tiller production, leaf development and dry matter accumulation. Thus, hydrogel has potential to improve the growth dynamic of wheat, particularly under conditions of limited or irregular water availability.

1.3 Integrated Nutrient Management

Integrated Nutrient Management (INM) involves the balanced and judicious use of inorganic fertilizers along with organic nutrient sources such as farm yard manure (FYM) and vermicompost. The combined application of organic and inorganic nutrient sources can improve nutrient availability, soil fertility and nutrient-use efficiency, thereby promoting sustained crop growth. Consequently, suitable INM practices can positively influence different growth parameters and improves the overall growth dynamics of wheat.

Tillage, soil moisture and nutrient availability interact closely in determining the growth and development of wheat. Integration of appropriate tillage practices with hydrogel and INM may create a favorable soil environment by improving moisture retention, nutrient availability and root activity. However, the individual and interactive effects of these practices on the temporal growth performance of wheat need to be better understood. Therefore, the present study was undertaken to investigate the “Influence of tillage, hydrogel and integrated nutrient management (INM) on growth performance of wheat (*Triticum aestivum* L.)” with emphasis on changes in major growth attributes during different stages of crop development.

2. Materials and Methods

2.1 Experimental Site

The field experiment was conducted at the Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (208002), Uttar Pradesh, India. The experimental site is located at 26.49° North latitude and 80.29° East longitude, with an altitude of approximately 125.9 m above mean sea level. The region falls under the Central Plain Zone (Agro-climatic zone-III) of Uttar Pradesh and is characterized by a subtropical climate with hot summers and cool winters.

2.2 Treatment Details and Experimental Design

The experiment was carried out during two consecutive Rabi seasons of 2024-25 and 2025-26, for which, Wheat variety “DBW-187” (Karan Vandana) is used with Split Plot Design as described by Gomez and Gomez (1984) [6], comprising four main plot factors i.e., Tillage practices (T): Conventional Tillage (15 cm) (T₁), Deep Tillage (25 cm) (T₂), Conventional Tillage (15 cm) + Pusa Hydrogel 5 kg ha⁻¹ (T₃) and, Deep Tillage (25 cm) + Pusa Hydrogel 5 kg ha⁻¹ (T₄) and six sub-plot factors i.e., Integrated Nutrient Management (N): 100% Recommended dose of NPK (120:60:40 kg ha⁻¹) (N₁), 100% Recommended dose of NPK + Vermicompost @ 8 t ha⁻¹ (N₂), 100% Recommended dose of NPK + Farm Yard Manure @ 20 t ha⁻¹ (N₃), 100% Recommended dose of NPK + Vermicompost @ 8 t ha⁻¹ + FYM @ 20 t ha⁻¹ (N₄), 75% Recommended dose of NPK + Farm Yard Manure @ 20 t ha⁻¹ (N₅) and 75% Recommended dose of NPK + FYM @ 20 t ha⁻¹ + Vermicompost @ 8 t ha⁻¹ (N₆) making total combination of twenty-four treatments which replicated thrice.

2.3 Growth Parameters

2.3.1 Initial (15 DAS) and Final Plant Population (m⁻²)

A 1m × 1m quadrat was randomly placed in each plot. Emerged seedlings were counted at full emergence for the initial plant population, and surviving plants were counted at maturity for the final population. Counts were expressed as plants per m², averaged for each treatment, and recorded carefully.

[Plant Population (plants m⁻²) = Number of plants counted in 1m² area]

2.3.2 Plant Height (cm)

Five plants were randomly selected and tagged in each plot for recording plant height. Plant height was measured using a meter scale in centimeters from the ground surface to the tip of the main shoot. Observations were taken at 30, 60, 90 days after sowing (DAS) and at harvest.

2.3.3 Plant Fresh and Dry Weight (g plant⁻¹)

Five plants were randomly selected and tagged in each plot for recording fresh weight. The whole plant was carefully uprooted and weighed immediately using a digital balance, and the results were expressed in g plant⁻¹. Observations were taken at 30, 60, 90 days after sowing (DAS) and at harvest. The same tagged plants used for fresh weight were oven-dried at 65-70 °C until a constant weight was achieved. After drying, samples were weighed using a digital balance and expressed as g plant⁻¹.

2.3.4 Leaf Area (cm plant⁻¹)

Five plants were randomly selected and tagged in each plot for recording leaf area. Leaf area was measured by the graph paper method and their area calculated in cm², and expressed as cm² plant⁻¹. Observations were taken at 30, 60, 90 days after sowing (DAS) and at harvest.

[Leaf Area (cm² plant⁻¹) = Full squares + (k × Partial squares)]

*k = constant (0.75)

2.3.5 Number of Tillers (m^{-2})

The number of tillers was recorded by counting all tillers within a 1m^2 area in each plot. Counts were taken at 30, 60, 90 days after sowing (DAS) and at harvest, and expressed as number of tillers m^{-2} .

3. Results and Discussion

3.1 Initial (15 DAS) and Final Plant Population (m^{-2})

The data presented in Table 01. represents that during 2024-25, Initial plant population was significantly influenced by tillage practices, with T_4 recording the highest plant population of 225.52. Among INM, plant population was found to be non-significant. Although, N_4 recorded the highest plant population of 222.31. During 2025-26, Initial plant population was found to be non-significant. Although, T_4 recording the highest plant population of 229.27. Among INM, plant population was found to be non-significant. Although, N_4 recorded the highest plant population of 224.47. In 2024-25, Final plant stand at harvest was found to be non-significant. Although, T_3 recording the highest plant population of 212.67. Among INM, plant population was found to be non-significant. Although, N_6 recorded the highest value 212.08. In 2025-26, Final plant stand at harvest was significantly influenced by tillage practices, with T_4 treatment 212.15. Among INM, plant population was found to be non-significant. Although, N_4 recorded the highest value 210.83 among INM.

3.2 Plant Height (cm)

The data presented in Table 02. represents that during 2024-25, Plant height was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant height of 23.46, 60.55, 100.58 and 98.28 at 30, 60, 90 DAS and at harvest, respectively. Among INM treatments, N_4 recorded the highest plant height of 22.35, 53.43, 96.05 and 93.75 at the respective growth stages. During 2025-26, Plant height was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant height of 23.27, 61.52, 102.39 and 100.09 at 30, 60, 90 DAS and at harvest, respectively. Among INM treatments, N_4 recorded the highest plant height of 22.10, 58.28, 96.75 and 94.45 at the respective growth stages.

3.3 Plant Fresh Weight (g plant^{-1})

The data presented in Table 03. represents that during 2024-25, Plant fresh weight was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant fresh weight of 37.07, 200.04, 497.18 and 361.49 at 30, 60, 90 DAS and harvest, respectively. Among INM treatments, N_4 recorded the highest plant fresh weight of 35.18, 196.61 and 345.25 at 30, 60 DAS and at harvest, while N_2 has highest 495.49 fresh weight at 90 DAS. The interaction effect was significant at 30 and 90 DAS. During 2025-26, Plant fresh weight was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant fresh weight of 37.55, 200.84, 499.03 and 354.04 at 30, 60, 90 DAS and harvest, respectively. Among INM treatments, N_4 recorded the highest plant fresh weight

of 35.78, 196.58 and 334.68 at 30, 60 DAS and at harvest, while N_2 has highest 495.49 fresh weight at 90 DAS. The interaction effect was significant at 30 DAS (2024-25) and 90 DAS (2024-25 and 2025-26) which was represented in interaction Table 07, 08 and 09.

3.4 Plant Dry Weight (g plant^{-1})

The data presented in Table 04. represents that during 2024-25, Plant dry weight was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant dry weight of 6.67, 42.17 and 313.49 at 30, 60 DAS and at harvest, while T_2 has highest 136.27 at 90 DAS, respectively. Among INM treatments, N_4 recorded the highest plant dry weight of 6.33, 40.36 and 296.25 at 30, 60 and at harvest, while N_2 is 126.49 dry weight. During 2025-26, Plant dry weight was significantly influenced by tillage practices and INM at all growth stages. T_4 recorded the highest plant dry weight of 6.72, 42.34 and 314.36 at 30, 60 and at harvest, respectively. While, T_2 has 144.39 at 90 DAS. Among INM treatments, N_4 recorded the highest plant dry weight of 6.48, 41.46, 141.48 and 297.12 g plant^{-1} at the respective growth stages.

3.5 Leaf Area (cm plant^{-1})

The data presented in Table 05. represents that during 2024-25, Leaf area was significantly influenced by tillage practices and INM at 30 DAS and 60 DAS. Highest values are as follows T_3 , T_3 , T_2 and T_2 with 276.20, 961.70, 852.83 and 752.83 for 30, 60, 90 DAS and at harvest. Among INM treatments, N_4 recorded the highest leaf area of 232.93, 816.07, 846.92 and 746.92 $\text{cm}^2 \text{ plant}^{-1}$ at the respective growth stages. In 2025-26, Leaf area was significantly influenced by tillage practices and INM at 30 DAS and 60 DAS. T_3 , T_3 , T_1 and T_2 with 272.20, 970.20, 850.57 and 750.57 at 30, 60, 90 DAS and harvest, respectively. Among INM treatments, N_4 recorded the highest leaf area of 233.93 and 818.74 at 30 and 60 DAS while, N_6 has highest values of 854.15 and 754.15 for 90 DAS and at harvest.

3.6 Number of Tillers (m^{-2})

The data presented in Table 06. represents that during 2024-25, Number of tillers was significantly influenced by tillage practices at 60 and 90 DAS. T_4 recorded the highest number of tillers at 30 DAS (289.06), 60 DAS (449.50) while T_2 recorded the highest number of tillers at 90 DAS and at harvest (499.83 & 451.83) respectively. Among INM treatments, N_6 recorded the highest number of tillers at 30 DAS (280.83), whereas N_4 recorded the highest values at 60 DAS (414.17), N_1 recorded highest at 90 DAS (456.75) and N_6 at harvest (452.08). During 2025-26, Number of tillers was significantly influenced by tillage practices at 60 DAS and 90 DAS. T_4 recorded the highest number of tillers at 30 DAS (289.28), 60 DAS (450.67) and T_2 at 90 DAS (499.28), while T_1 recorded the highest number of tillers at harvest (450.50). Among INM treatments, N_6 recorded the highest number of tillers at 30 DAS (281.67) and at harvest (452.92), whereas N_4 recorded the highest values at 60 DAS (406.00) and N_6 at 90 DAS (457.75).

Table 1: Plant population (No. m⁻²) in wheat at initial and final growth stage as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Plant Population (No. m ⁻²)					
	Initial (15 DAS)			Final (At harvest)		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)						
T ₁	212.49	216.04	214.27	164.83	205.14	184.98
T ₂	218.79	222.26	220.53	201.88	208.19	205.03
T ₃	221.44	225.00	223.22	212.67	210.11	211.39
T ₄	225.52	229.27	227.40	204.50	212.15	208.32
S.Ed.±	1.85	3.77	2.81	7.95	8.14	8.04
C.D. (P = 0.05)	6.41	NS	NS	27.51	NS	NS
Integrated Nutrient Management (N)						
N ₁	218.81	222.88	220.85	175.58	208.13	191.85
N ₂	220.78	223.39	222.09	200.16	209.06	204.61
N ₃	218.19	222.93	220.56	196.63	208.57	202.60
N ₄	222.31	224.47	223.39	204.19	210.83	207.51
N ₅	218.48	222.72	220.60	187.16	208.49	197.82
N ₆	218.80	222.48	220.64	212.08	208.33	210.20
S.Ed.±	2.36	1.21	1.79	9.72	8.43	9.07
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (T × N)						
S.Ed.±	4.72	2.42	7.14	19.43	16.86	18.14
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS

Table 2: Plant height (cm) in wheat at various stages of crop growth as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Plant Height (cm)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)												
T ₁	18.33	17.95	18.14	30.28	46.90	38.59	79.58	79.73	79.66	77.28	77.43	77.36
T ₂	20.80	20.52	20.66	53.43	54.20	53.82	89.87	91.12	90.50	87.57	89.38	88.48
T ₃	21.55	21.33	21.44	55.58	56.43	56.01	93.25	93.95	93.60	90.95	91.09	91.02
T ₄	23.46	23.27	23.37	60.55	61.52	61.04	100.58	102.39	101.49	98.28	100.09	99.19
S.Ed.±	0.46	0.48	0.47	1.15	0.96	1.06	1.92	1.51	1.72	1.67	1.73	1.70
C.D. (P = 0.05)	1.60	1.66	1.63	3.96	3.33	3.65	6.66	5.23	5.95	5.77	6.00	5.89
Integrated Nutrient Management (N)												
N ₁	20.87	20.60	20.74	48.78	54.25	51.52	89.80	90.50	90.15	87.50	88.20	87.85
N ₂	21.89	21.58	21.74	52.25	57.00	54.63	93.63	95.99	94.81	91.33	92.03	91.68
N ₃	21.59	21.30	21.45	51.54	56.23	53.89	92.33	93.03	92.68	90.03	90.73	90.38
N ₄	22.35	22.10	22.23	53.43	58.28	55.86	96.05	96.75	96.40	93.75	94.45	94.10
N ₅	20.23	20.00	20.12	48.04	52.60	50.32	87.73	88.43	88.08	85.43	86.13	85.78
N ₆	19.28	19.03	19.16	45.73	50.23	47.98	85.40	86.10	85.75	83.10	85.47	84.29
S.Ed.±	0.73	0.59	0.66	1.47	1.49	1.48	1.75	2.27	2.01	2.07	2.22	2.15
C.D. (P = 0.05)	2.08	1.68	1.88	4.19	4.26	4.23	5.00	6.48	5.74	5.93	6.33	6.13
Interaction (T × N)												
S.Ed.±	1.46	1.18	1.32	2.93	2.98	2.96	3.50	4.53	4.02	4.15	4.43	4.29
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Plant fresh weight (g plant⁻¹) in wheat at various stages of crop growth as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Plant Fresh Weight (g plant ⁻¹)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)												
T ₁	23.18	23.45	23.32	129.97	130.77	130.37	327.16	328.46	327.81	217.65	217.63	217.64
T ₂	30.04	30.52	30.28	171.77	171.46	171.62	449.48	452.71	451.10	294.00	294.32	294.16
T ₃	33.18	33.77	33.48	191.02	192.37	191.70	478.14	480.03	479.09	354.86	351.11	352.99
T ₄	37.07	37.55	37.31	200.04	200.84	200.44	497.18	499.03	498.11	361.49	354.04	357.77
S.Ed.±	0.62	0.60	0.61	2.57	2.90	2.74	5.40	7.67	6.54	6.70	8.03	7.37
C.D. (P = 0.05)	2.15	2.07	2.11	8.89	10.03	9.46	18.70	26.55	22.63	23.17	27.77	25.47
Integrated Nutrient Management (N)												
N ₁	29.81	30.18	30.00	168.15	168.95	168.55	420.47	424.88	422.68	293.73	296.10	294.92
N ₂	33.29	33.78	33.54	185.73	186.53	186.13	495.49	495.95	495.72	331.96	331.83	331.90
N ₃	32.26	32.66	32.46	179.87	180.67	180.27	449.70	454.33	452.02	323.09	322.13	322.61
N ₄	35.18	35.78	35.48	196.61	196.58	196.60	484.60	484.15	484.38	345.25	334.68	339.97
N ₅	28.62	28.96	28.79	159.53	160.33	159.93	399.68	400.95	400.32	282.28	280.98	281.63
N ₆	26.05	26.56	26.31	149.32	150.12	149.72	378.00	380.08	379.04	265.68	259.93	262.81
S.Ed.±	0.61	0.92	0.77	2.89	2.85	2.87	5.35	6.00	5.68	7.67	7.08	7.38
C.D. (P = 0.05)	1.74	2.63	2.19	8.26	8.13	8.20	15.30	17.13	16.22	21.93	20.23	21.08
Interaction (T × N)												
S.Ed.±	1.22	1.84	1.53	5.78	5.69	5.74	10.71	11.99	11.35	15.35	14.16	14.76
C.D. (P = 0.05)	3.47	NS	NS	NS	NS	NS	30.6	34.27	32.44	NS	NS	NS

Table 4: Plant dry weight (g plant⁻¹) in wheat at various stages of crop growth as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Plant Dry Weight (g plant ⁻¹)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)												
T ₁	4.17	4.22	4.20	27.30	27.41	27.36	86.47	89.25	87.86	185.80	192.23	189.02
T ₂	5.41	5.50	5.46	35.95	36.12	36.04	136.27	144.39	140.33	258.56	259.42	258.99
T ₃	5.97	6.09	6.03	39.43	40.39	39.91	118.06	121.00	119.53	306.98	307.29	307.14
T ₄	6.67	6.72	6.70	42.17	42.34	42.26	116.71	119.93	118.32	313.49	314.36	313.93
S.Ed.±	0.14	0.09	0.12	0.88	0.99	0.94	1.91	4.22	3.07	5.81	5.61	5.71
C.D. (P = 0.05)	0.47	0.30	0.39	3.05	3.41	3.23	6.62	14.59	10.61	20.09	19.41	19.75
Integrated Nutrient Management (N)												
N ₁	5.37	5.28	5.33	35.31	35.48	35.40	112.60	111.67	112.14	258.93	258.94	258.94
N ₂	5.99	6.03	6.01	39.00	39.15	39.08	126.49	132.64	129.57	283.36	292.57	287.97
N ₃	5.81	5.91	5.86	37.77	37.94	37.86	120.38	118.93	119.66	281.55	282.43	281.99
N ₄	6.33	6.48	6.41	40.36	41.46	40.91	119.64	141.48	130.56	296.25	297.12	296.69
N ₅	5.15	5.23	5.19	33.54	33.83	33.69	108.57	106.50	107.54	248.88	249.75	249.32
N ₆	4.69	4.86	4.78	31.30	31.53	31.42	98.59	100.65	99.62	228.28	229.15	228.72
S.Ed.±	0.18	0.14	0.16	0.91	1.17	1.04	4.09	5.77	4.93	7.31	7.5	7.41
C.D. (P = 0.05)	0.51	0.41	0.46	2.60	3.35	2.98	11.7	16.48	14.09	20.89	21.44	21.17
Interaction (T × N)												
S.Ed.±	0.35	0.29	0.32	1.82	2.35	2.09	8.19	11.53	9.86	14.62	15.01	14.82
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Leaf Area (cm plant⁻¹) in wheat at various stages of crop growth as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Leaf Area (cm plant ⁻¹)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)												
T ₁	154.97	155.97	155.47	542.94	545.88	544.41	848.68	850.57	849.63	748.68	750.57	749.63
T ₂	175.32	176.76	176.04	613.05	617.11	615.08	852.83	847.43	850.13	752.83	747.43	750.13
T ₃	276.20	272.20	274.20	961.70	970.20	965.95	843.81	849.68	846.75	743.81	749.68	746.75
T ₄	208.20	198.03	203.12	686.28	693.12	689.70	848.41	848.89	848.65	748.41	748.89	748.65
S.Ed.±	7.20	6.04	6.62	26.80	18.43	22.62	19.40	17.83	18.62	14.33	12.67	13.50
C.D. (P = 0.05)	24.91	20.89	22.90	92.72	63.75	78.24	NS	NS	NS	NS	NS	NS
Integrated Nutrient Management (N)												
N ₁	191.58	192.58	192.08	662.18	674.01	668.10	851.48	848.66	850.07	751.48	748.66	750.07
N ₂	221.73	223.39	222.56	776.04	779.54	777.79	846.25	846.88	846.57	746.25	746.88	746.57
N ₃	223.98	200.73	212.36	725.29	728.79	727.04	843.36	845.09	844.23	743.36	745.09	744.23
N ₄	232.93	233.93	233.43	816.07	818.74	817.41	846.92	851.38	849.15	746.92	751.38	749.15
N ₅	182.75	183.75	183.25	634.63	643.13	638.88	849.60	848.71	849.16	749.60	748.71	749.16
N ₆	169.08	170.08	169.58	591.76	595.26	593.51	852.98	854.15	853.57	752.98	754.15	753.57
S.Ed.±	11.84	7.67	9.76	29.36	25.00	27.18	13.82	15.46	14.64	12.177	16.90	14.54
C.D. (P = 0.05)	33.85	21.92	27.89	83.89	71.45	77.67	NS	NS	NS	NS	NS	NS
Interaction (T × N)												
S.Ed.±	23.69	15.34	19.52	58.71	50.00	54.36	27.65	30.93	29.29	24.35	33.79	29.07
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Number of tillers (m⁻²) in wheat at various stages of crop growth as influenced by tillage practices and integrated nutrient management (INM) during *rabi* 2024-25 and 2025-26

Treatments	Number of Tillers (m ⁻²)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean	2024-25	2025-26	Mean
Tillage practices (T)												
T ₁	274.06	275.50	274.78	365.89	360.28	363.09	412.00	410.67	411.34	449.06	450.50	449.78
T ₂	276.83	273.33	275.08	388.67	389.00	388.84	499.83	499.28	499.56	451.83	448.33	450.08
T ₃	270.83	274.83	272.83	420.00	420.39	420.20	439.06	439.61	439.34	445.83	449.83	447.83
T ₄	289.06	289.28	289.17	449.50	450.67	450.09	470.83	471.17	471.00	449.06	449.28	449.17
S.Ed.±	10.37	8.07	9.22	12.55	9.57	11.06	15.21	14.45	14.83	15.12	8.31	11.72
C.D. (P = 0.05)	NS	NS	NS	43.44	33.13	38.29	52.61	49.98	51.30	NS	NS	NS
Integrated Nutrient Management (N)												
N ₁	279.67	277.92	278.80	403.25	405.33	404.29	456.75	454.42	455.59	450.92	449.17	450.05
N ₂	276.25	276.75	276.50	404.17	403.25	403.71	456.33	452.67	454.50	447.50	448.00	447.75
N ₃	274.33	275.50	274.92	401.67	405.33	403.50	455.25	453.08	454.17	445.58	446.75	446.17
N ₄	276.67	279.67	278.17	414.17	406.00	410.09	455.83	456.83	456.33	447.92	450.92	449.42
N ₅	278.42	277.92	278.17	405.08	405.08	405.08	454.08	456.33	455.21	449.67	449.17	449.42
N ₆	280.83	281.67	281.25	407.75	405.50	406.63	454.33	457.75	456.04	452.08	452.92	452.50
S.Ed.±	8.17	8.65	8.41	13.7	7.32	10.51	7.72	12.22	9.97	8.23	9.92	9.08
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (T × N)												
S.Ed.±	16.34	17.3	16.82	27.41	14.64	21.03	15.44	24.44	19.94	16.46	19.83	18.15
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 7: Interaction effect of tillage practices and integrated nutrient management (INM) on plant fresh weight (g plant⁻¹) at 30 DAS during 2024-25

Treatment	Plant Fresh Weight (g plant ⁻¹)						
	N ₁	N ₂	N ₃	N ₄	N ₅	N ₆	Mean
T ₁	22.46	24.43	23.80	26.16	21.46	20.73	23.18
T ₂	28.60	32.40	31.53	34.50	27.86	25.36	30.04
T ₃	30.66	35.83	34.86	42.20	28.60	26.90	33.18
T ₄	37.5	40.5	38.83	37.83	36.53	31.20	37.07
Mean	29.81	33.29	32.26	35.18	28.62	26.05	
Treatments	S.Ed.±				C.D. (P = 0.05)		
Tillage Practices (T)	0.62				2.15		
INM (N)	0.61				1.74		
Interaction of T × N	1.22				3.47		

Table 8: Interaction effect of tillage practices and integrated nutrient management (INM) on plant fresh weight (g plant⁻¹) at 90 DAS during 2024-25

Treatment	Plant Fresh Weight (g plant ⁻¹)						
	N ₁	N ₂	N ₃	N ₄	N ₅	N ₆	Mean
T ₁	318.53	345.80	332.40	365.20	305.60	295.40	327.16
T ₂	419.20	585.76	445.20	485.60	395.33	365.80	449.48
T ₃	462.06	515.20	495.60	555.20	435.60	405.20	478.14
T ₄	482.06	535.20	525.60	532.40	462.20	445.60	497.18
Mean	420.47	495.49	449.70	484.60	399.68	378.00	
Treatments	S.Ed.±			C.D. (P = 0.05)			
Tillage Practices (T)	5.40			18.70			
INM (N)	5.35			15.30			
Interaction of T × N	10.71			30.60			

Table 9: Interaction effect of tillage practices and integrated nutrient management (INM) on plant fresh weight (g plant⁻¹) at 90 DAS during 2025-26

Treatment	Plant Fresh Weight (g plant ⁻¹)						
	N ₁	N ₂	N ₃	N ₄	N ₅	N ₆	Mean
T ₁	316.50	347.10	333.70	366.50	310.23	296.70	328.46
T ₂	426.16	583.73	459.83	479.90	393.16	373.43	452.71
T ₃	470.13	516.46	496.90	556.50	436.90	403.30	480.03
T ₄	486.70	536.50	526.90	533.70	463.50	446.90	499.03
Mean	424.88	495.95	454.33	484.15	400.95	380.08	
Treatments	S.Ed.±			C.D. (P = 0.05)			
Tillage Practices (T)	7.67			26.55			
INM (N)	6.00			17.13			
Interaction of T × N	11.99			34.27			

4. Conclusion

Based on the experimental findings, the combined application of Deep tillage (25 cm) + Pusa Hydrogel @ 5 kg ha⁻¹ and integrated nutrient management comprising, 100% recommended dose of NPK (120:60:40 kg ha⁻¹) + Vermicompost @ 8 t ha⁻¹ + Farm Yard Manure @ 20 t ha⁻¹ resulted in superior growth of wheat. The treatment combination promoted better crop growth and development, indicating the beneficial effect of improved soil conditions, hydrogel application and balanced nutrient management. Thus, deep tillage integrated with hydrogel and nutrient management may be considered as an effective approach for enhancing the growth performance of wheat (*Triticum aestivum* L.).

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