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Influence of crop establishment methods and nutrient management on growth, yield, economics, and soil health of Wheat (*Triticum aestivum* L.)

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Abstract

A field experiment was conducted during the *rabi* season of 2024-25 and 2025-26 at the Agricultural Research Farm, Guru Kashi University, Talwandi Sabo (Bathinda), Punjab, India, to evaluate the effects of three sowing methods Standing Stubble (SS), Broadcasting (BC), and Dibbling (DB) combined with four fertilizer levels (80%, 100%, 120%, and 140% of the Recommended Dose of Fertilizer, RDF) on the growth, productivity, economics, and soil properties of wheat cv. PBW 872. Twelve treatments were arranged in a Randomized Block Design with three replications. Dibbling with 140% RDF (T₁₂) recorded the tallest plant height (111 cm), highest tiller density (139.5 m⁻¹), maximum dry matter accumulation (52.0 g m⁻¹ row length), and superior physiological traits including chlorophyll content (40.2 SPAD), crop growth rate (9.1 g m⁻² day⁻¹), and leaf area index (4.1). Yield components including effective tillers (124 m⁻¹), ear length (9.0 cm), grains per ear (44), and 1000-grain weight (41.1 g) were also highest under T₁₂. Grain yield reached 49.0 q ha⁻¹ under T₁₂, while the highest grain yield of 49.5 q ha⁻¹ was recorded under Broadcasting + 120% RDF (T₇) and Broadcasting + 140% RDF (T₈). T₇ achieved the maximum benefit-cost ratio (2.00) and net return (₹1,82,878 ha⁻¹). Soil pH and EC remained largely unaffected by treatments, while available N, P, and K increased with higher RDF. These findings suggest that Dibbling with 140% RDF maximizes productivity, while Broadcasting with 120% RDF offers the greatest economic return, supporting context-specific recommendations for wheat cultivation in Punjab's semi-arid agro-climatic zone.

Keywords: Wheat, sowing methods, fertilizer dose, grain yield, benefit-cost ratio, soil fertility, Punjab, dibbling, broadcasting

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most extensively cultivated cereal crops and constitutes a major component of global food and nutritional security. It contributes substantially to human caloric and protein intake and plays a crucial role in sustaining agricultural economies worldwide. In India, wheat is the principal *rabi* cereal cultivated across diverse agro-climatic regions and forms the backbone of the rice-wheat production system in north-western states including Punjab (Food and Agriculture Organization, 2025.; Kumar *et al.*, 2021) [1, 10]. Nevertheless, wheat productivity is often constrained by inappropriate crop establishment techniques and imbalanced nutrient management practices. Sowing method markedly influences seed placement, crop emergence, root proliferation, nutrient uptake, and resource-use efficiency, thereby affecting yield and profitability. Conventional broadcasting generally results in poor crop geometry and uneven plant stand, whereas improved methods such as dibbling and sowing under standing stubble conditions enhance moisture conservation, residue utilization, and soil health (Hobbs *et al.*, 2022; Sharma *et al.*, 2023) [6, 17]. Balanced fertilization is equally important for sustaining productivity and soil fertility. Nitrogen, phosphorus, and potassium are essential macronutrients regulating vegetative growth, root development, and stress tolerance in wheat (Foulkes *et al.*, 2020) [4]. Therefore, optimization of sowing methods along with suitable fertilizer levels is essential for achieving higher productivity and sustainability under the semi-arid conditions of Punjab.

2. Materials and Methods

2.1. Experimental Site and Climate

The field experiment was conducted during the *rabi* seasons of 2024-25 and 2025-26 at the Agricultural Research Farm, Faculty of Agriculture, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India (29°59'N, 75°04'E; 213 m above mean sea level). The experimental site falls under the semi-arid agro-climatic region of south-western Punjab, characterized by hot summers and cool winters. During the crop seasons, maximum temperature ranged from 17.06 to 36.15°C in 2024-25 and 17.42 to 35.78°C in 2025-26, whereas minimum temperature varied between 4.98 to 24.74°C and 5.16 to 24.51°C, respectively. Relative humidity remained comparatively higher during winter months, ranging from 59.03 to 95.35% in 2024-25 and 60.14 to 94.88% in 2025-26. Rainfall distribution during the experimental period was low and erratic, with total rainfall of 96.8 mm during 2024-25 and 89.8 mm during 2025-26, most of which was received during September and April. The prevailing weather conditions during the crop growth period were generally favourable for wheat cultivation under irrigated semi-arid conditions. Meteorological observations recorded during the experimental period are presented in Table 1.

Table 1: Monthly meteorological data recorded during the 2024-25 and 2025-26 wheat crop season at Bathinda, Punjab

	T _{max} (°C)		T _{min} (°C)		RH (%)		Rainfall (mm)	
Month	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
September	36.15	35.78	24.74	24.51	85.73	84.92	66.6	58.4
October	34.34	33.92	15.85	15.41	77.35	76.18	0.0	2.4
November	26.58	27.04	9.21	9.48	82.60	81.92	6.8	4.6
December	20.56	19.88	6.00	5.74	91.26	92.14	0.4	1.2
January	17.06	17.42	4.98	5.16	95.35	94.88	4.2	6.0
February	24.84	25.12	8.60	8.94	94.21	93.65	2.0	3.4
March	30.32	31.05	13.81	14.22	79.45	78.60	0.0	1.6
April	35.15	35.72	16.52	16.88	59.03	60.14	16.8	12.2

Source: PAU Regional Research Station, Bathinda.

2.2. Soil Characteristics

Representative composite soil samples (0-15 cm depth) were collected from ten random locations before sowing and analysed using standard methods. The soil was sandy loam (sand 74.0%, silt 12.2%, clay 13.8%) with pH 8.12 (1:2.5 soil-water suspension; Black's glass electrode), EC 0.25 dS m⁻¹ (1:2 soil:water; Solubridge conductivity meter), organic carbon 0.46% (Walkley-Black method; Jackson, 1967) [7], available N 122.0 kg ha⁻¹ (alkaline permanganate method; Subbiah and Asija, 1956) [20], available P₂O₅ 17.9 kg ha⁻¹ (Olsen's NaHCO₃ method; Olsen *et al.*, 1954) [13], and available K₂O 114.0 kg ha⁻¹ (1 N ammonium acetate extraction, flame photometry; Jackson, 1967) [7]. The soil was classified as medium in K, low in N, and low in organic carbon.

The field experiment was conducted during the *rabi* seasons of 2024-25 and 2025-26 at the Regional Research Station, Bathinda, Punjab, using wheat variety PBW 872. The study was laid out in a Randomized Block Design (RBD) with three replications, consisting of twelve treatment combinations involving three sowing methods, viz., standing stubble, broadcasting, and dibbling, along with four fertilizer levels (80, 100, 120, and 140% RDF). The recommended dose of fertilizer (RDF) comprised 120 kg N, 60 kg P₂O₅, and 40 kg K₂O ha⁻¹. Rice stubbles of 20-25 cm height were retained under standing stubble treatment, while residues were removed from broadcasting and dibbling plots. Nitrogen was applied in split doses, whereas phosphorus and potassium were applied basally. Recommended agronomic and plant protection practices were followed uniformly in all

treatments (Punjab Agricultural University [PAU], 2025) [16].

Growth observations including plant height, tiller density, dry matter accumulation, leaf area index, chlorophyll content, and crop growth rate were recorded at different crop stages. Yield attributes, grain yield, straw yield, biological yield, and harvest index were measured at maturity. Post-harvest soil samples were analysed for pH, EC, soil organic carbon, and available N, P, and K using standard procedures (Jackson, 1973; Subbiah and Asija, 1956) [8,20]. Economic parameters such as gross return, net return, and benefit-cost ratio were calculated based on prevailing market prices. The experimental data were statistically analysed using analysis of variance (ANOVA), and treatment means were compared using the Least Significant Difference (LSD) test at 5% probability level (Gomez and Gomez, 1984) [5].

3. Results

Growth Parameters

Growth and physiological parameters of wheat were markedly influenced by the interaction between sowing methods and fertilizer levels. Progressive enhancement in fertilizer dose significantly improved plant height, tiller density, dry matter accumulation, chlorophyll content, crop growth rate (CGR), and leaf area index (LAI) (Table 2). Among the treatments, Dibbling with 140% RDF (T₁₂) produced the tallest plants, maximum tiller population, and greater dry matter accumulation, indicating superior crop establishment and efficient utilization of nutrients. The precision placement of seed under dibbling ensured better soil-seed contact, uniform germination, and reduced inter-plant competition, thereby promoting vigorous root growth and nutrient absorption. Higher nitrogen availability under elevated RDF levels enhanced photosynthetic activity, chlorophyll synthesis, and assimilate production, resulting in increased vegetative growth and biomass accumulation. Similarly, Standing Stubble with 140% RDF (T₄) recorded comparatively higher SPAD values, CGR, and LAI, which may be attributed to improved soil moisture conservation and moderated soil temperature under residue-retained conditions. These findings are in close conformity with the reports of Singh *et al.*, (2020) [18], Kumar *et al.*, (2018) [11], Chen *et al.*, (2024) [2], and Hobbs *et al.*, (2022) [6], who emphasized the positive role of balanced fertilization and improved crop establishment techniques in enhancing wheat growth and physiological efficiency.

Yield Attributes and Yield

Yield attributes and productivity of wheat responded significantly to different sowing methods and fertilizer levels (Table 2). Dibbling with 140% RDF (T₁₂) recorded the highest effective tillers, ear length, grains ear⁻¹, and test weight, reflecting superior translocation of assimilates towards reproductive structures under adequate nutrient supply. However, maximum grain yield was recorded under Broadcasting with 120% RDF (T₇) and 140% RDF (T₈), which remained statistically at par with T₁₂. The higher grain yield under these treatments was primarily associated with improved spike density, enhanced grain filling, and better utilization of available resources. Increased fertilizer levels, particularly nitrogen, promoted higher photosynthetic efficiency and sink capacity, ultimately leading to greater grain production. The comparatively lower yield under Standing Stubble treatments may be attributed to slower initial crop establishment and temporary nitrogen immobilization due to residue decomposition. Nevertheless, residue-retained treatments demonstrated the potential for sustaining crop productivity while improving soil health in the long term. Similar observations have also been documented by Patel *et al.*, (2017) [15], Singh *et al.*, (2019) [19], Abbas *et al.*, (2009) [1], and Khan *et al.*, (2007) [10], who reported that optimum nutrient management coupled with efficient sowing

methods significantly enhances wheat productivity and resource-use efficiency under semi-arid conditions.

Economics

Economic evaluation revealed substantial variation among treatments with respect to profitability and economic efficiency (Table 3). Broadcasting with 120% RDF (T₇) emerged as the most economically viable treatment, recording the highest gross return, net return, and benefit-cost ratio. The superior economic performance of T₇ was mainly due to higher grain yield coupled with comparatively balanced input costs. Although treatments receiving 140% RDF produced comparable yields, the additional expenditure incurred on fertilizer application reduced net profitability, indicating diminishing economic returns beyond the optimum fertilizer level. Dibbling with 120-140% RDF also generated higher returns owing to improved crop performance and yield realization. In contrast, Standing Stubble treatments recorded relatively lower economic returns because of reduced grain yield despite improvements in soil organic carbon and physiological traits. The findings clearly indicate that optimum fertilizer application integrated with suitable sowing practices can significantly improve farm profitability and input-use efficiency in wheat-based production systems. Similar economic advantages of balanced fertilization and improved crop establishment methods have been reported by Tilman *et al.*, (2021)^[21], Khan *et al.*, (2007)^[10], and Singh *et al.*, (2020)^[18].

Soil Chemical Properties

Post-harvest soil analysis revealed that soil pH and electrical conductivity remained statistically unaffected by different sowing methods and fertilizer levels, indicating that the applied nutrient doses did not adversely influence soil chemical balance during the experimental period (Table 3). However, soil organic carbon (SOC) content showed noticeable improvement under Standing Stubble treatments due to decomposition and incorporation of crop residues, which contributed to enhanced organic matter buildup in the soil. Available nitrogen, phosphorus, and potassium contents increased progressively with higher fertilizer application levels, with Dibbling + 140% RDF (T₁₂) recording maximum available nitrogen and phosphorus, whereas higher potassium availability was observed under dibbling with 100% RDF. Enhanced nutrient availability under higher RDF treatments may be attributed to greater nutrient addition and improved nutrient cycling within the soil system. The retention of crop residues under standing stubble also contributed positively to soil fertility improvement and long-term sustainability of the rice-wheat production system. These findings corroborate the observations of Singh *et al.*, (2018)^[18], Ladha *et al.*, (2023)^[12], Patel and Tanaka (2023)^[14], and Zhai *et al.*, (2018)^[22], who reported that integrated residue and nutrient management practices improve soil fertility status and sustain soil health under intensive cereal-based cropping systems.

Table 2: Effect of sowing methods and fertilizer dose on Growth parameter, Yield attributes and Yield of wheat at different growth stages (pooled data 2024-25 and 2025-26)

Treatment	Plant height (cm)				Effective Tillers (m ⁻²)	Ear Length (cm)	Grains Ear ⁻¹	1000-Grain Wt (g)	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Harvest Index (%)
	30 DAS	60 DAS	90 DAS	At Harvest								
T ₁ (SS + 80% RDF)	13.5	34.0	99.5	102.0	110.0	8.1	37.0	37.5	41.0	62.5	103.5	39.6
T ₂ (SS + 100% RDF)	14.1	39.4	99.0	104.0	116.0	8.3	40.0	39.5	43.0	63.5	106.5	40.4
T ₃ (SS + 120% RDF)	19.2	38.4	100.2	102.5	118.0	8.4	41.2	39.7	43.5	62.5	106.0	41.0
T ₄ (SS + 140% RDF)	19.6	38.3	102.4	104.0	117.0	8.4	42.4	39.8	44.0	65.3	109.3	40.3
T ₅ (BC + 80% RDF)	15.1	38.5	99.2	104.0	117.0	8.3	40.2	39.5	42.5	62.2	104.7	40.6
T ₆ (BC + 100% RDF)	19.2	38.5	101.5	103.3	118.0	8.4	41.2	39.7	44.3	63.0	107.3	41.3
T ₇ (BC + 120% RDF)	24.1	42.0	101.1	106.0	115.0	8.6	44.0	40.6	49.5	70.3	119.8	41.3
T ₈ (BC + 140% RDF)	26.1	43.2	100.5	106.0	119.0	8.7	43.6	40.5	49.5	71.5	121.0	40.9
T ₉ (DB + 80% RDF)	15.1	38.1	99.5	103.0	117.0	8.4	40.5	39.6	42.5	62.0	104.5	40.7
T ₁₀ (DB + 100% RDF)	20.4	41.0	101.0	103.0	119.0	8.4	42.0	39.8	46.5	65.3	111.8	41.6
T ₁₁ (DB + 120% RDF)	25.0	43.3	101.4	108.0	120.0	8.6	43.5	40.1	46.0	65.8	111.8	41.1
T ₁₂ (DB + 140% RDF)	26.8	43.8	101.5	111.0	124.0	9.0	44.0	41.1	49.0	73.6	122.6	40.0
CV (%)	9.0	6.5	3.9	5.9	3.37	2.0	6.1	1.6	5.27	6.13	4.98	0.76
LSD (p = 0.05)	12.0	9.2	1.6	2.7	7.5	0.47	4.7	1.05	4.85	8.64	11.5	0.54

Table 3: Economic analysis and soil chemical properties and nutrient availability of sowing methods and fertilizer dose treatments for wheat production (Pooled data 2024-25 and 2025-26)

Treatment	Cost of Cultivation (₹ ha ⁻¹)	Gross Return (₹ ha ⁻¹)	Net Return (₹ ha ⁻¹)	B:C Ratio	pH	EC (dS m ⁻¹)	SOC (%)	Avail. N (kg ha ⁻¹)	Avail. P ₂ O ₅ (kg ha ⁻¹)	Avail. K ₂ O (kg ha ⁻¹)
T ₁ (SS + 80% RDF)	63,714	1,78,446	1,14,732	1.80	7.73	0.275	0.71	155.2	18.1	114.4
T ₂ (SS + 100% RDF)	64,047	1,51,985	87,938	1.37	7.55	0.276	0.72	156.0	21.3	120.6
T ₃ (SS + 120% RDF)	64,370	1,74,130	1,09,760	1.70	7.50	0.275	0.72	162.0	22.0	131.2
T ₄ (SS + 140% RDF)	63,492	1,54,229	90,737	1.43	7.69	0.285	0.73	189.2	20.8	134.3
T ₅ (BC + 80% RDF)	64,040	1,51,978	87,938	1.37	7.55	0.249	0.47	156.5	21.5	125.5
T ₆ (BC + 100% RDF)	64,380	1,74,137	1,09,757	1.70	7.58	0.252	0.48	187.0	20.5	132.4
T ₇ (BC + 120% RDF)	92,019	2,74,897	1,82,878	2.00	7.36	0.247	0.48	212.3	22.8	124.2
T ₈ (BC + 140% RDF)	91,242	2,55,394	1,64,152	1.80	7.35	0.246	0.50	215.4	26.9	130.2
T ₉ (DB + 80% RDF)	63,700	1,78,400	1,14,700	1.80	7.73	0.247	0.52	156.5	21.5	126.0
T ₁₀ (DB + 100% RDF)	64,047	1,63,995	99,948	1.56	7.48	0.256	0.63	192.5	24.8	134.6
T ₁₁ (DB + 120% RDF)	91,575	2,62,087	1,70,512	1.86	7.45	0.262	0.64	210.6	22.5	112.4
T ₁₂ (DB + 140% RDF)	91,797	2,63,462	1,71,665	1.87	7.32	0.264	0.60	225.7	29.2	132.4
CV (%)	-	-	-	-	3.26	4.22	23.08	14.14	13.46	6.69
LSD (p = 0.05)	-	-	-	-	0.48	0.016	0.27	39.5	6.41	23.9

5. Conclusion

The present investigation demonstrated that optimization of sowing methods along with appropriate fertilizer levels significantly improved wheat growth, productivity, profitability, and soil fertility under the semi-arid conditions of Punjab. Among the treatments, Dibbling with 140% RDF (T_{12}) exhibited superior performance in terms of growth parameters, physiological efficiency, yield attributes, grain yield, and biological yield due to improved crop establishment and enhanced nutrient utilization. However, Broadcasting with 120% RDF (T_7) recorded the highest grain yield (49.5 q ha^{-1}), maximum net return ($\text{₹}1,82,878 \text{ ha}^{-1}$), and benefit-cost ratio (2.00), indicating its greater economic feasibility for farmers under existing production conditions. Although Standing Stubble treatments produced comparatively lower yields, they contributed positively to soil organic carbon buildup, suggesting potential long-term benefits for soil health and sustainability. Soil pH and EC remained unaffected by treatments, while available nitrogen and phosphorus increased with higher fertilizer application, indicating that fertilizer levels up to 140% RDF were agronomically safe during the study period. Overall, the findings suggest that Broadcasting with 120% RDF may be recommended for maximizing economic returns, whereas Dibbling with 140% RDF may be preferred for achieving higher productivity under precision crop management systems.

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