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Impact of Specific Nitrogen Management and Tillage Practices on Growth Parameters and Grain Quality of Wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during rabi 2025–26 at Farmer Field, Vivekananda Global University, Jaipur to evaluate the effect of nitrogen management and tillage practices on growth, yield and quality of wheat (*Triticum aestivum*). The experiment was laid out in split plot design with three replications, comprising four tillage practices in main plots viz., zero tillage, minimum tillage, conventional tillage and deep tillage and four nitrogen levels in sub-plots viz., 75% recommended dose of fertilizers, 100% recommended dose of fertilizers, 125% recommended dose of fertilizers and 150% recommended dose of fertilizers. Results revealed that tillage and nitrogen levels significantly influenced growth, yield and quality parameters of wheat. Among tillage practices, deep tillage recorded significantly higher growth attributes, dry matter accumulation, yield attributes and yields, followed by conventional tillage, whereas minimum and zero tillage remained inferior. Deep tillage resulted in maximum grain yield (4655.57 kg ha^{-1}), straw yield (7454.94 kg ha^{-1}) and biological yield (12110.51 kg ha^{-1}), along with higher protein content (12.16%) and protein yield (566.99 kg ha^{-1}). Among nitrogen levels, 125% recommended dose of fertilizers recorded higher grain yield (4372.20 kg ha^{-1}) and superior yield attributes, while 150% recommended dose of fertilizers resulted in maximum straw yield (6892.43 kg ha^{-1}), biological yield (11168.63 kg ha^{-1}), nutrient uptake and protein content (11.97%) with highest protein yield (515.37 kg ha^{-1}). The response beyond 125% recommended dose of fertilizers indicated diminishing returns in grain yield. Economic analysis revealed that 150% recommended dose of fertilizers recorded maximum net returns (₹63530.83 ha^{-1}), whereas 125% recommended dose of fertilizers recorded higher benefit to cost ratio (2.73). Based on one-year experimentation, deep tillage combined with 150% recommended dose of fertilizers improved overall productivity and biomass yield, while 125% recommended dose of fertilizers proved more economical under semi-arid conditions of Rajasthan.

Keywords: Wheat, tillage systems, nitrogen management, split plot design, yield attributes

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and serves as a staple food for a large proportion of the population. In India, it is the second most important food grain crop after rice and plays a crucial role in ensuring food and nutritional security [1]. However, sustaining wheat productivity under intensive cropping systems has become increasingly difficult due to declining soil fertility, deterioration of soil physical properties and imbalanced nutrient management practices [2, 3]. Nitrogen is the most critical and yield-limiting nutrient in wheat and plays a crucial role in regulating growth, yield attributes and grain quality, particularly protein content [4]. Adequate nitrogen supply enhances photosynthesis, biomass production and grain formation, whereas deficiency results in poor growth and yield. On the other hand, excessive nitrogen application reduces nitrogen use efficiency and increases losses through leaching and volatilization, thereby affecting both economic returns and environmental sustainability [5]. Therefore, optimization of nitrogen levels is essential to achieve higher productivity and better grain quality. Tillage practices significantly influence soil physical environment, moisture dynamics, root growth and nutrient availability. Conventional tillage, though widely practiced, often leads to soil degradation and higher cost of cultivation due to repeated soil disturbance. Conservation tillage practices such as zero and minimum tillage improve soil structure, moisture retention and reduce energy inputs, whereas deep tillage helps in

alleviating soil compaction and enhances root penetration, particularly under semi-arid conditions [6, 7, 8]. The response of wheat to nitrogen fertilization is closely associated with tillage practices, as soil disturbance affects nitrogen mineralization, availability and uptake. Efficient management of these factors is essential for improving productivity, nutrient use efficiency and profitability. Grain quality, especially protein content, is also largely governed by nitrogen nutrition and plays an important role in determining the end-use value of wheat [9].

Although several studies have reported the individual effects of tillage and nitrogen management, limited information is available on their combined influence under graded nitrogen levels in the semi-arid conditions of Rajasthan. Therefore, the present investigation was undertaken to evaluate the effect of different tillage practices and nitrogen levels on growth, yield, quality and economics of wheat.

Materials and Methods

A field experiment was conducted during rabi 2025–26 at Farmer Field, Vivekananda Global University, Jaipur, Rajasthan. The experimental soil was loamy sand in texture with a pH of 8.22, electrical conductivity (EC) of 0.39 dS m^{-1}, organic carbon of 0.28%, and available nitrogen, phosphorus and potassium of 132.87, 20.64 and 238.10 kg ha^{-1}, respectively. The experiment was laid out in split plot design with three replications, comprising four tillage practices in main plots viz., zero tillage (T_1), minimum tillage (T_2), conventional tillage (T_3) and deep tillage (T_4) and four nitrogen levels in sub-plots viz., 75% RDF of N (F_1), 100% RDF of N (F_2), 125% RDF of N (F_3) and 150% RDF of N (F_4). Wheat variety Raj 4238 (developed by Rajasthan Agricultural Research Institute, Durgapura) was sown by line sowing using a seed rate of 100 kg ha^{-1} with a row spacing of 22.5 cm. The recommended dose of fertilizers (100:60:40 kg $N:P_2O_5:K_2O$ ha^{-1}) was applied through urea, DAP (Di-Ammonium Phosphate) and MOP (Muriate of Potash). Full dose of phosphorus and potassium along with half the dose of nitrogen was applied as basal, and the remaining nitrogen was top-dressed as per treatments. Four irrigations were applied at critical growth stages. Weed control was carried out through pre-emergence application of pendimethalin. All other agronomic practices were kept uniform across all treatments. Observations on growth, yield attributes and yield were recorded as per standard procedures. The data were statistically analyzed using analysis of variance (ANOVA) appropriate for split plot design and treatment means were compared at 5% level of significance using critical difference (CD).

Results

Effect of Tillage Practices

Data presented in Table 1 revealed that tillage practices significantly influenced growth, yield attributes, yield and economics of wheat. Among the treatments, deep tillage (T_4) recorded significantly higher dry matter accumulation at all growth stages, with values of 4.65, 24.0 and 36.3 g $plant^{-1}$ at 45 DAS (Days After Sowing), 85 DAS and at harvest, respectively (Table 2), as compared to conventional (T_3), minimum (T_2) and zero tillage (T_1). The improvement in growth under deep tillage may be attributed to better soil aeration, enhanced root proliferation and improved moisture retention, which ultimately resulted in higher nutrient uptake and biomass accumulation. Yield attributes were significantly influenced by tillage practices. Deep tillage (T_4) recorded the highest number of effective tillers per metre row length (104.69), number of grains per spike (51.64), spike length (10.57 cm) and test weight (41.84 g) as compared to other tillage treatments (Table 3). These superior yield attributes ultimately resulted in higher grain yield under deep tillage. Grain, straw and biological yields were significantly influenced by tillage practices. The highest grain yield (4655.57 kg ha^{-1}), straw yield (7454.94 kg ha^{-1}) and biological yield (12110.51 kg ha^{-1}) were recorded under deep tillage (T_4), which was significantly superior to other treatments (Table 1). Economic analysis indicated that conventional tillage (T_3) recorded the highest benefit:cost ratio (2.76), followed by deep tillage (2.71), whereas the lowest was recorded under zero tillage (2.49) (Table 1). Observations on quality parameters revealed that protein content and protein yield of wheat grain were influenced by tillage practices, wherein deep tillage (T_4) recorded the highest values, while the lowest were observed under zero tillage (T_1) (Table 2).

Effect of Nitrogen Management

The data presented in Table 2 indicated that nitrogen levels significantly influenced dry matter accumulation at all growth stages. Application of 150% RDF (F_4) recorded significantly higher dry matter accumulation (4.35, 22.5 and 34.1 g $plant^{-1}$ at 45 DAS, 85 DAS and at harvest, respectively), followed by 125% RDF (F_3), whereas the lowest was recorded under 75% RDF (F_1). Yield attributes were also significantly influenced by nitrogen levels. The maximum number of effective tillers, grains per spike and spike length were recorded under 125% RDF (F_3), while test weight was highest under 125% RDF (40.57 g), indicating optimum nitrogen supply at this level (Table 3). Quality parameters were also influenced by nitrogen levels. The highest protein content and protein yield were recorded under 150% RDF (F_4), followed by 125% RDF (F_3), whereas the lowest values were observed under 75% RDF (F_1) (Table 2). Grain yield was significantly influenced by nitrogen levels and the highest grain yield (4372.20 kg ha^{-1}) was recorded under 125% RDF (F_3), which was significantly superior to other treatments (Table 1). However, maximum straw yield (6892.43 kg ha^{-1}) and biological yield (11168.63 kg ha^{-1}) were recorded under 150% RDF (F_4), indicating that higher nitrogen levels favoured biomass production. The response beyond 125% RDF indicated diminishing returns in grain yield. Economic analysis revealed that maximum net returns were recorded under 150% RDF (F_4), whereas the highest benefit:cost ratio (2.73) was observed under 125% RDF (F_3), followed by 150% RDF (2.68) (Table 1).

Interaction Effect

A perusal of data presented in Table 4 revealed that the interaction effect between tillage practices and nitrogen levels on grain yield of wheat was non-significant. However, numerical variations were observed among different treatment combinations. The highest grain yield (4796.09 kg ha^{-1}) was recorded under T_4F_3 (deep tillage with 125% RDF), followed by T_4F_4 (4737.49 kg ha^{-1}) and T_4F_2 (4663.82 kg ha^{-1}). Among other combinations, T_3F_3 (4594.26 kg ha^{-1}) also recorded higher grain yield, whereas the lowest grain yield (3368.15 kg ha^{-1}) was observed under T_1F_1 (zero tillage with 75% RDF).

Table 1: Effect of tillage practices and nitrogen management on yield and economics of wheat (*Triticum aestivum* L.)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Tillage					
Zero Tillage	3653.11	5178.67	8831.78	49929.25	2.49
Minimum Tillage	3947.53	5631.91	9579.44	54224.08	2.50
Conventional Tillage	4420.79	6470.65	10891.51	63607.75	2.76
Deep Tillage	4655.57	7454.94	12110.51	68126.33	2.71
SEm ±	64.78	126.31	136.81	1136.08	0.04
CD (P=0.05)	224.14	437.06	473.38	3930.89	0.13
Nitrogen Management					
75% RDF of Nitrogen	3899.75	5461.55	9361.30	53122.92	2.46
100% RDF of Nitrogen	4128.85	5989.77	10118.61	56635.17	2.59
125% RDF of Nitrogen	4372.20	6392.43	10764.63	62598.5	2.73
150% RDF of Nitrogen	4276.20	6892.43	11168.63	63530.83	2.68
SEm ±	98.73	143.14	187.59	2021.4	0.06
CD (P=0.05)	288.13	417.77	547.47	5899.44	0.16

RDF: Recommended Dose of Fertilizers; SEm ±: Standard Error of Mean; CD: Critical Difference; B:C: Benefit:Cost

Table 2: Effect of tillage practices and nitrogen management on dry matter accumulation and quality parameters of wheat (*Triticum aestivum* L.)

Treatments	Dry matter accumulation (g plant^{-1})			Protein content (%)	Protein yield (kg ha^{-1})
	45 DAS	85 DAS	At harvest		
Tillage					
Zero Tillage	3.15	16.80	26.00	10.07	369.03
Minimum Tillage	3.60	19.20	29.60	10.81	428.15
Conventional Tillage	4.20	22.00	33.60	11.59	513.49
Deep Tillage	4.65	24.00	36.30	12.16	566.99
SEm ±	0.06	0.35	0.45	0.08	6.81
CD (P=0.05)	0.22	1.22	1.57	0.28	23.56
Nitrogen Management					
75% RDF of Nitrogen	3.45	18.50	28.60	10.15	398.55
100% RDF of Nitrogen	3.75	19.82	30.45	10.98	457.16
125% RDF of Nitrogen	4.06	21.18	32.35	11.53	506.57
150% RDF of Nitrogen	4.35	22.50	34.10	11.97	515.37
SEm ±	0.07	0.39	0.69	0.07	11.42
CD (P=0.05)	0.21	1.14	2.03	0.20	33.32

RDF: Recommended Dose of Fertilizers; DAS: Days After Sowing; SEm ±: Standard Error of Mean; CD: Critical Difference

Table 3: Effect of tillage practices and nitrogen management on yield attributes of wheat (*Triticum aestivum* L.)

Treatments	Effective Tillers per metre row length	No. of Grains per spike	Spike length (cm)	Test weight (g)
Tillage				
Zero Tillage	86.53	40.98	8.78	37.89
Minimum Tillage	94.60	44.14	9.26	40.68
Conventional Tillage	102.50	45.20	10.08	39.11
Deep Tillage	104.69	51.64	10.57	41.84
SEm ±	1.69	0.69	0.25	0.49
CD (P=0.05)	5.86	2.40	0.88	1.70
Nitrogen Management				
75% RDF of Nitrogen	95.67	44.42	9.32	39.17
100% RDF of Nitrogen	92.75	44.67	9.58	40.27
125% RDF of Nitrogen	103.92	47.92	10.31	40.57
150% RDF of Nitrogen	95.98	44.95	9.49	39.52
SEm ±	2.14	1.02	0.18	0.70
CD (P=0.05)	6.26	2.97	0.53	2.04

RDF: Recommended Dose of Fertilizers; SEm ±: Standard Error of Mean; CD: Critical Difference

Table 4: Interaction effect of tillage practices and nitrogen management on grain yield of wheat (*Triticum aestivum* L.)

	T1	T2	T3	T4
F1	3368.15	3701.66	4104.28	4424.88
F2	3514.75	3863.53	4473.27	4663.82
F3	3895.91	4202.55	4594.25	4796.09
F4	3833.60	4022.35	4511.35	4737.48
SEm ±	279.23			
CD at 5%	NS			

T_1: Zero Tillage; T_2: Minimum Tillage; T_3: Conventional Tillage; T_4: Deep Tillage; F_1: 75% RDF of N; F_2: 100% RDF of N; F_3: 125% RDF of N; F_4: 150% RDF of N; NS: Non-Significant; SEm ±: Standard Error of Mean; CD: Critical Difference.

Discussion

The significantly superior performance of deep tillage in improving dry matter accumulation, yield attributes and grain yield may be attributed to better soil physical conditions, enhanced root development and efficient utilization of applied nutrients. The loosening of compacted soil layers under deep tillage facilitated greater root proliferation, improved water infiltration and moisture retention, thereby creating a favourable rhizosphere environment. These results are in conformity with the findings of Hobbs *et al.* [6] and Jat *et al.* [7], who reported that tillage-induced improvements in soil physical properties positively influence crop growth and productivity. The highest grain yield (4655.57 kg ha^{-1}) and biological yield (12110.51 kg ha^{-1}) under deep tillage corroborate the role of deep soil preparation in enhancing yield potential, particularly under the semi-arid conditions of Rajasthan where soil compaction often limits crop productivity.

The positive response to increasing nitrogen levels up to 125% RDF for grain yield and up to 150% RDF for biomass production is consistent with the well-established role of nitrogen in chlorophyll formation, photosynthesis and protein synthesis. The increase in dry matter accumulation with higher nitrogen levels, as observed in the present study, aligns with the findings of Raun and Johnson [4], who demonstrated that optimum nitrogen supply enhances photosynthetic efficiency and biomass production in cereal crops. The decline in grain yield beyond 125% RDF, despite a continued increase in biomass, suggests a shift in nitrogen utilization from productive to vegetative growth, reflecting diminishing returns in grain yield at higher nitrogen doses. Similar trends have been documented by Fageria *et al.* [10] and Ladha *et al.* [2].

The economic analysis revealed that while deep tillage and 150% RDF maximized gross and net returns, 125% RDF and conventional tillage recorded the highest benefit:cost ratios. This suggests that 125% RDF represents a more resource-efficient level of nitrogen application for smallholder farmers in semi-arid regions, where cost of inputs and risk of crop failure are critical considerations. The interaction between tillage and nitrogen management underscores the importance of adopting an integrated approach for improving wheat productivity, nutrient use efficiency and economic sustainability. However, the present findings are based on a single season of experimentation and require validation through multi-location and multi-year trials before wider recommendation.

Conclusion

Tillage practices and nitrogen levels significantly influenced growth, yield and economics of wheat under semi-arid conditions of Rajasthan. Among tillage practices, deep tillage (T_4) resulted in superior growth parameters, dry matter accumulation and yield attributes, which ultimately led to higher grain yield (4655.57 kg ha^{-1}), straw yield (7454.94 kg ha^{-1}) and biological yield (12110.51 kg ha^{-1}). Among nitrogen levels, 125% RDF (F_3) recorded the highest grain yield (4372.20 kg ha^{-1}) along with superior yield attributes, while 150% RDF (F_4) maximized biomass production, nutrient uptake and net returns (₹63530.83 ha^{-1}). Economic analysis indicated that 125% RDF recorded the highest benefit:cost ratio (2.73), making it the more economically efficient option. It may be concluded that adoption of deep tillage in combination with 150% RDF is beneficial for maximizing productivity, while 125% RDF is more economical for achieving higher returns per unit cost under the prevailing conditions. These findings are based on one season of experimentation and need further validation under multi-location and multi-year trials.

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