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Influence of tillage practices and nutrient application rates on soil properties in a rice-mustard-black gram cropping system

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Abstract
An investigation entitled "Influence of Tillage Practices and Nutrient Application Rates on Soil Properties in a Rice-Mustard-Black Gram Cropping System" was conducted at Experimental Field Division of Soil Science and Agriculture Chemistry, SKUAST-Jammu, during the two successive years 2021-2022 and 2022-2023. The treatment comprises of four levels of tillage *viz*., T1 (Zero tillage), T2 (Conventional tillage), T3 (Zero tillage + residue addition) and T4 (Conventional tillage + residue addition) and five levels of fertilizer doses i.e. F1 (100% RDF), F2 (100% RDF + microbial consortia), F3 (100% RDF + 25% starter dose of N), F5 (75% RDF + FYM @ 5t ha^{-1}) and F5 (75% RDF + Microbial consortia) constituting 20 treatment combinations replicated thrice in factorial randomized block design. Results indicated that in case of rice crop maximum available nitrogen and soil porosity percentage was recorded highest under ZT+RA (Zero tillage + residue addition), while bulk density was recorded highest under CT (Conventional tillage). However, among nutrient doses highest available nitrogen was recorded under F3 nutrient dose, highest porosity percentage under F4 nutrient dose and highest bulk density under F1 and F3 nutrient dose.

Keywords: Tillage practices, nutrient application rates, soil properties, rice-mustard-black gram

Introduction
Tillage practices are fundamental in agriculture, influencing soil health, crop growth, and environmental sustainability. In the rice-mustard-black gram cropping system, the choice of tillage practices and nutrient application rates plays a crucial role in determining soil health and crop productivity in agricultural systems. CT involves plowing and mechanical soil disturbance (Busari *et al*., 2015) [1], while ZT minimizes soil disturbance, maintaining crop residues on the soil surface (Cunningham *et al*., 2004) [2]. Both practices have advantages and disadvantages that need to be considered for sustainable agricultural management. The choice Conventional tillage (CT) has been a traditional practice in agriculture, involving the mechanical disturbance of soil through plowing and cultivation. CT has several advantages, including improved soil aeration, effective weed control, and facilitation of nutrient incorporation. However, CT also has disadvantages, such as increased soil erosion, soil compaction, and loss of soil organic matter (Beare *et al*., 1994; Six *et al*., 2000) [6, 3].
On the other hand, zero tillage (ZT) has gained popularity in recent years due to its potential for soil conservation, reduced fuel and labor costs, and improved soil structure (Nciizah and Wakindiki, 2016) [4]. ZT helps conserve soil moisture (Jalota *et al*., 2001) and reduce erosion by maintaining crop residues on the soil surface. It also promotes soil biodiversity and microbial activity (González-Chávez *et al*., 2010; Mangalassery *et al*., 2015) [7, 8], enhancing soil fertility and nutrient cycling. Despite these benefits, ZT presents challenges in weed management, nutrient stratification, and disease and pest pressure. In the rice-mustard-black gram cropping system, the choice between CT and ZT can significantly impact soil properties such as nutrient content, soil structure, and microbial activity. Rice, mustard, and black gram are staple crops in many agricultural regions, and their cultivation in a cropping system presents a unique challenge in managing soil properties.

Rice, being a water-intensive crop, can lead to soil compaction and reduced soil aeration under conventional tillage practices. On the other hand, zero tillage, which minimizes soil disturbance, can improve soil structure and water infiltration but may require different nutrient management strategies to maintain crop productivity. Understanding the advantages and disadvantages of each tillage practice is essential for sustainable agricultural management in this cropping system. This study aims to investigate the influence of tillage practices and nutrient application rates on soil properties in the rice-mustard-black gram cropping system.

Materials and Methods

The study was conducted at the agricultural farm Chatha, SKUAST-J from the year 2021-2023. The soil texture was clay loam having 4.30 g kg^{-1} organic carbon, 239.28 kg ha^{-1} available nitrogen, 14.10 kg ha^{-1} available Phosphorus and 143.93 kg ha^{-1} of available K, 1.40 g cm^{-3} initial bulk density and 47.17% initial soil porosity. The rice variety used in the study was Pusa -1121. The experiment was laid out in factorial design with two factors. Factor A was tillage practices with 4 levels and the factor B was nutrient doses with 5 levels. Each treatment had three replications and the size of each plot was 10 m^2. The treatment combination of tillage practices and nutrient doses were 20 and are as follows: T1F1:Zero tillage + 100% RDF, T1F2: Zero tillage + 100% RDF + Microbial consortia, T1F3: Zero tillage + 100% RDF + 25% starter dose of N, T1F4: Zero tillage + 75% RDF + FYM @ 5t ha^{-1}, T1F5: Zero tillage + 75% RDF + Microbial consortia, T2F1: Conventional tillage + 100% RDF, T2F2: Conventional tillage + 100% RDF + Microbial consortia, T2F3: Conventional tillage + 100% RDF + 25% starter dose of N, T2F4: Conventional tillage + 75% RDF + FYM @ 5t ha^{-1}, T2F5: Conventional tillage + 75% RDF + Microbial consortia, T3F1: Zero tillage + residue addition +100% RDF, T3F2: Zero tillage + residue addition + 100% RDF+ Microbial consortia, T3F3: Zero tillage + residue addition + 100% RDF + 25% starter dose of N, T3F4: Zero tillage + residue addition + 75% RDF + FYM @ 5t ha^{-1}, T3F5: Zero tillage + residue addition + 75% RDF + Microbial consortia, T4F1: Conventional tillage + residue addition + 100% RDF, T4F2: Conventional tillage + residue addition + 100% RDF + Microbial consortia, T4F3: Conventional tillage + residue addition + 100% RDF + 25% starter dose of N, T4F4: Conventional tillage + residue addition + 75% RDF + FYM @ 5t ha^{-1}, T4F5: Conventional tillage + residue addition + 75% RDF + Microbial consortia. Chopped blackgram residues from the previous crop were incorporated @ 5 t ha^{-1} in the plots with residue incorporation in both zero tillage and conventional tillage. The treatments with microbial consortia contain different strains of decomposers which aid in decomposition of crop residues applied in the plots. For 1 ha area 25 liter of microbial consortia along with 500 liters of water (50 ml/liter or 750 ml microbial consortia/15-liter tank) was sprayed as per the described treatments.

Results and discussion

Table 1: Effect of tillage practices and nutrient doses on soil available N (kg ha^{-1}) at the harvesting of rice

	F_1	F_2	F_3	F_4	F_5	Mean A
ZT	243.60	244.00	244.75	242.60	242.79	243.55
CT	239.24	241.60	242.18	237.20	238.53	239.75
ZT+RA	250.11	250.50	251.06	249.34	249.56	250.11
CT+RA	247.51	248.22	249.00	246.20	247.03	247.59
Mean B	245.12	246.08	246.75	243.83	244.48	
Factors	C.D. (5%)					
Factor(A)	2.511					
Factor(B)	N/A					
Factor(A X B)	N/A					

(F1: 100% RDF; F2: 100% RDF + Microbial consortia (decomposers); F3: 100% RDF + 25% starter dose of N; F4: 75% RDF + FYM @ 5t/ha; F5: 75% RDF + Microbial consortia(decomposers)

The average data of two years from Table 1 indicated the impact of tillage practices and nutrient doses on soil available nitrogen (N). Tillage practices had a significant impact on nitrogen availability. The ZT+RA (zero tillage + residue addition) treatment exhibited the highest level of available nitrogen, measuring 250.11 kg ha^{-1}. This treatment differed significantly from other tillage practices. However, the lowest concentration of available nitrogen was observed under CT treatment. The difference is likely due to the conventional puddling of soil, which increased mineralization up to 60 days after transplanting. The initial spike in mineralization under CT might have led to higher N losses. Any excess mineralized N after fulfilling the crop's initial nitrogen demands, could have been lost through denitrification, nitrate leaching, ammonia volatilization or surface runoff. Studies have been reported that denitrification losses of 50% or more of applied N are common in flooded rice soils. The Frequent fluctuations in moisture content due to flooding and drainage create ideal conditions for denitrification. These findings align with previous studies by McGarry *et al.* (1987) [10]; Palma *et al.* (1998) [11]; Alam *et al.* (2020) [9].

Nutrient doses and their interaction effect with tillage practices and nutrient doses did not significantly influence soil available nitrogen levels over the study period.

Table 2: Effect of tillage practices and nutrient doses on soil BD (Bulk Density, g cm^{-3}) at the harvesting of rice

	F1	F2	F3	F4	F5	Mean A
ZT	1.47	1.45	1.47	1.44	1.46	1.46
CT	1.52	1.50	1.51	1.48	1.50	1.50
ZT+RA	1.45	1.42	1.44	1.41	1.43	1.43
CT+RA	1.49	1.47	1.48	1.47	1.48	1.48
Mean B	1.48	1.46	1.48	1.45	1.47	
Factors	C.D. (5%)					
Factor(A)	0.018					
Factor(B)	0.020					
Factor(A X B)	N/A					

(F1: 100% RDF; F2: 100% RDF + Microbial consortia (decomposers); F3: 100% RDF + 25% starter dose of N; F4: 75% RDF + FYM @ 5t/ha; F5: 75% RDF + Microbial consortia (decomposers)

The data presented in Table 2 revealed a significant impact of tillage practices and nutrient doses on BD (bulk density). The average highest bulk density value was recorded in CT (1.50 g cm^{-3}) which significantly differed from other tillage practices except for CT+RA. However, the lowest bulk density value was observed in ZT+RA treatment (1.43 g cm^{-3}). This might be due to the fact that puddling in conventional tillage practices involved saturating and compacting the soil through flooding and mechanical manipulation. This practice generally resulted in an increase in soil bulk density. The compaction caused by puddling could lead to a reduction in pore space and increased soil bulk density. Zero tillage or non puddling, involved minimal soil disturbance and aimed to preserve soil structure and organic matter content. The results were in accordance with Gangwar *et al*. (2006) [12] and Gathala *et al.* (2011) [13], who observed that soil bulk density decreased at the time of puddling but with the settling of soil particles it increased till the maturity of the crop, resulting in higher soil bulk density after the harvest of the rice crop is more in conventional tillage than in reduced tillage. The presence of crop residue on the soil surface in zero tilled plots could promote better soil aggregation and increase pore space, leading to a further decrease in bulk density (Surekha *et al*., 2004) [14].

Regarding nutrient doses F1 and F3 nutrient doses recorded the highest mean value of bulk density (1.48 g cm^{-3}), which showed statistical parity with the F2 and nutrient F5 nutrient dose, while F4 (1.45 g cm^{-3}) showed the lowest mean value of bulk density. The decrease in bulk density under F4 amended plots could be attributed to an increase in humic substances, resulting in better aggregation, increased root growth and the formation of biopores in the soil due to the presence of FYM in combination with inorganic fertilizers. Similar findings were also recorded by Bhagat and Verma (1991) [15] and Shirani *et al*. (2002) [16].

The interaction effect of tillage practices with nutrient doses did not exert a significant influence on bulk density.

Table 3: Effect of tillage practices and nutrient doses on soil porosity (%) at the harvesting of rice

	F1	F2	F3	F4	F5	Mean A
ZT	44.72	45.48	44.77	45.86	45.10	45.19
CT	42.83	43.39	42.88	43.76	43.02	43.18
ZT+RA	45.49	46.43	45.67	46.80	46.05	46.09
CT+RA	43.78	44.53	43.96	44.72	44.15	44.23
Mean B	44.20	44.96	44.32	45.29	44.58	
Factors	C.D. (5%)					
Factor(A)	0.637					
Factor(B)	0.712					
Factor(A X B)	N/A					

The data presented in Table 3 demonstrated the influence of tillage practices and nutrient doses on soil porosity (%). The mean data of two years represented a significant impact on soil porosity due to tillage practices and nutrient doses at rice harvesting.

ZT + RI, among all the tillage practices exhibited the highest porosity (46.09%), significantly differed from other tillage practices. However, the lowest porosity percentage was found in CT (43.18%). The lower porosity percentage in conventionally tilled puddled plots compared to zero tilled plots could be attributed to the effects of puddling on soil structure. Puddling involved saturating the soil with water and then mechanically churning it to prepare for planting. This process compacted the soil, reducing the size and number of pores within it. In contrast, zero tillage involved minimal soil disturbance, typically resulted in better soil structure and higher porosity. The lack of mechanical disturbance allowed for the preservation of soil aggregates and pore spaces, which can contribute to higher porosity percentages in zero tilled plots compared to puddled plots. Similar results were also reported by He *et al.* (2009) [19]; Gao *et al.* (2019) [18]; Kumar *et al*. (2022) [20].

Regarding nutrient doses, the highest value of porosity percentage was recorded under F4 nutrient dose (45.29%), which showed statistical parity with F2 and F5 nutrient doses. However, the lowest was recorded under F1 nutrient dose. This could be attributed to the addition of FYM in the F4 nutrient dose, which promotes total soil porosity. The microbial decomposition products of organic manures, such as polysaccharides and bacterial gums, are known to act binding agents for soil particles. These binding agents could decrease soil bulk density by improving soil aggregation, thereby increasing porosity. This finding is in line with previous studies by Bhatia and Shukla (1982) [17]; Bhagat and Verma (1991) [15] and Shirani *et al.* (2002) [16].

Moreover, the interaction between nutrient doses and tillage practices doses did not significantly influence porosity percentage.

Conclusion

From the study it was concluded that zero tillage + residue addition was the most effective among all tillage treatments in improving nitrogen status and physical properties of soil (bulk density and percentage porosity). However, among fertilizer doses F3 nutrient dose exceeds in available nitrogen than other doses, while F4 nutrient dose and F1& F3 nutrient dose exceed in porosity percentage and bulk density, respectively.

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