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Impact of fertility levels and tillage techniques on wheat growth and yield in a rice-wheat cropping system

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Abstract
A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Impact of Fertility Levels and Tillage Techniques on Wheat Growth and Yield in a Rice-Wheat Cropping System. The soil was normal in pH of 7.65, electrical conductivity (EC) of 0.27 dSm-1, organic carbon content of 0.41%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 217.0, 19.5, and 149.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 20 treatment combinations, was laid out in Split Plot Design (SPD) with three replications.

Keywords: Fertilizer, tillage, growth regulator

Introduction
Being a significant prehistoric crop, wheat (*Triticum aestivum* L.) forms the foundation of our country's food security system. The expression "Dal roti chawal" acknowledged its importance in our way of life. Its straw is one of the main feedstuffs for many cattle. As a result, wheat is the food grain with the highest protein content; pulses come in first. It's used for things like bread, cakes, cookies, noodles, petri dishes, and chapattis. According to Anonymous (2018-19) [2], wheat grains contain the following nutrients: 60–68% starch, 8–15% protein, 1.5–2.0% fat, 2.0–2.5% cellulose, and 1.5–2.0% minerals. Because it provides more than 50% of the calories needed by those who primarily rely on it, the wheat crop significantly contributes to the nation's food security. Consequently, wheat serves as a significant global source of energy for animal feed and human diets. Approximately 224 million hectares of wheat are grown worldwide, and an average of 775.8 million metric tonnes are produced each year. The United States of America, China, India, and the European Union are the top four global producers of wheat.

India is the world's second-largest producer of wheat, thanks to its varied and rich agro-ecological conditions, which guarantee food and nutritional security to most of the country's population through production and consistent supply, especially in recent years. According to the Directorate of Economics and Statistics, wheat is grown on 33.64 million hectares in India, producing 107.59 million tons and 3206.30 kg ha^{-1} of productivity in 2019–20. Six main zones have been identified for the nation's wheat-growing region. The North-Western Plain Zone (NEPZ) is the region with the largest wheat cultivation area. All states in India except Kerala cultivate wheat. India's leading wheat-growing state is Uttar Pradesh. After Madhya Pradesh (area 6.39 million hectares and production 17.17 million tonnes) and Punjab (area 3.5 million hectares and production 17.14 million tonnes), respectively, Uttar Pradesh grows wheat on 9.85 million hectares with a production of 35.50 million tonnes.

The FAO (2013) projects that by 2050, there will be an approximate 900 million-ton global demand for wheat. By 2050, wheat production in India is expected to reach 109.24 million tonnes, while the country will require at least 140 million tonnes. 216.18 million hectares worldwide are planted to wheat, yielding 763.6 million metric tonnes at an average of 3530 kg ha^{-1} (Anonymous, 2020) [1]. With an average productivity of 3530 kg ha^{-1}, it covers 29.32 million ha in India and produces 103.6 million metric tonnes, or one third of the country's total food grain production (USDA report, 2020). By 2050, there will be 9.7 billion people on Earth, up from the current 7.7 billion. India has 1.3 billion people, making it the second most populous country in the world after China (1.41 billion), but by 2050, it is predicted to overtake China and reach a peak of 1.7 billion people (The UN World Population Prospects: The 2019 Revision). Wheat will therefore probably always be essential to maintaining food security throughout the world. With 9.65 million hectares (36.6%), 26.87 million tonnes (39.3%), and a productivity of 2785 kg ha^{-1}, Uttar Pradesh is the largest wheat-growing state in India (Anonymous, 2019) [2].

Approximately 90% of the world's rice is produced in Asia on 142 million hectares of land, yielding 622 million tons of rice (Rahman *et al*., 2018) [7]. About 43% of all food grains produced in India are produced from rice, making it one of the main contributors to food grain production (Uddin *et al*., 2012) [3].

Conventional tillage generally seeks to break up lumps and level the ground while also reversing and agitating a deep layer of soil, incorporating and eliminating plant debris, and exposing soil pests to sunlight for control. During both the winter and summer production seasons, conventional tillage entails a number of mechanical operations, such as deep plowing, deep disking, ripping, shallow tyne workings, and fine seedbed preparation following the harvesting of various grain crops. After that, there is a fallow season to allow the crops to absorb moisture before the next crop is planted. After heavy rains, this method leaves the soil surface bare, vulnerable to erosion by wind and water, and highly compacted. This necessitates re-loosening the soil in order to help control weed growth and encourage moisture absorption from subsequent rainfalls.

Reduced tillage is defined as full-width tillage, which leaves 15–30% of residue cover after planting and disturbs the entire soil surface. In the inland Pacific Northwest, additional conservation tillage techniques include sweep tillage systems, chisel, discs, under cutter fallow, and delayed minimum tillage. According to Schillinger *et al*. (2010) [4] and Sandoval (2021) [5], the under cutter method of fallow management uses wide V blade sweeps that slice beneath the soil surface and simultaneously deliver nitrogen during primary spring tillage followed by one or two non-inversion rod weeding operations during the summer to control weeds. Under cutter V-sweep, minimum tillage and delayed minimum tillage are both used as primary tillage techniques. After primary tillage, herbicides can be used to control weeds; however, secondary tillage techniques like rod weeding are more frequently employed. The main spring tillage with under cutter V-sweep in delayed minimum tillage is postponed until at least mid-May, in contrast to minimum tillage (Schillinger 2010) [4]. The use of growth regulators, also known as growth retardants, to lessen crop lodging in wheat has gained popularity worldwide. There have been reports, though, that lowering plant height in an effort to increase lodging resistance may also lower the canopy's capacity for photosynthetic energy, which would lower yield (Atikullah 2014) [6].

While organic plant growth promoters (PGPS), such as soil fertility and crop productivity, also aid in faster plant growth promotion and prevent grain disease, natural plant growth promoters (Phytohormones) are involved in pushing and stimulating root and shoot growth. Improved chemistry allows plant growth promoters to act on multiple sites within treated plants, rather than just the leaf surface. They are absorbed by the leaves as well as other plant parts.

Chemicals known as growth retardants can change a plant's structural makeup or essential functions by adjusting the hormone balance. This can help boost productivity, enhance quality, or make harvesting easier by reducing lodging, particularly in cereal crops (Zhang *et al*., 2017) [9]. Plant growth regulators (PGRs) and related compounds have the potential to reduce lodging by decreasing plant height. By decreasing stem elongation, synthetic PGRs like prohexadione-calcium, ethephon, trinexepac-ethyl, and chlormequat chloride (CCC) can reduce the risk of lodging. (Rajala and others, 2017) [10].

Materials and Methods

A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Impact of Fertility Levels and Tillage Techniques on Wheat Growth and Yield in a Rice-Wheat Cropping System. The soil was normal in pH of 7.65, electrical conductivity (EC) of 0.27 dSm-1, organic carbon content of 0.41%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 217.0, 19.5, and 149.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 20 treatment combinations, was laid out in Split Plot Design (SPD) with three replications. Methods of Tillage (Main Plot) T1: Conventional tillage, which involves two ploughings followed by sowing, T2: Reduced tillage, which involves a single plowing followed by sowing Levels of Fertility (Sub Plot 10) F1Absolute Control, F2RDF (150.60.40 NPK kg/ha), F375% RDF (112.5; 15 30 NPK kg/ha + 10 t FYM/ha), F4 125% RDF (187.5; 75; 50 NPK kg/ha), F5RDF (150; 60; 40 NPK kg/ha) + Two spray of chloromequate chloride (Lihocine 0.2% at first node (45 Days) and flag leaf stage (80 DAS), F6 RDF (150; 60; 40 NPK kg/ha) + Two Spray of tebunconzole (Folicur 430 SC @ 0.1%) at first node and flag leaf stage (80 DAS), F7 75% RDF (112.5:45:30 NPK kg/ha + 10 t FYM/ha + Two Spray of Chloromequate chloride (Lihocine 0.2% at first node (45 DAS) and flag leaf stage (80DAS), F875% RDF (112.5:45:30 NPK kg/ha + 10 t FYM/ha + Two Spray to tebunconzole (Folicur 430 SC @ 0.1% at first node and flag leaf stage, F9125% RDF (187.5:75:50 NPK kg/ha + Two Spray of Chloromequate chloride (Lihocine 0.2% at first node (45 DAS) and flag leaf stage (80 DAS), F10125% RDF (187.5:75:50 NPK kg/ha + Two Spray of tebunconzole Folicur 430 SC @ 0.1% (Folicur 430 SC @ 0.1% at first node and flag Leaf (80DAS) data were gathered on five plants chosen from each plot.

Yield attributes and yield

Ear length (cm)

Conventional tillage produced the longest ears (11.55 cm), which is comparable to reduce tillage (10.54 cm). Reduced tillage yielded the shortest ears (10.54 cm).

The highest recorded ear length among the fertility levels was 12.87 cm for 125% RDF + tebunconzole, 12.52 cm for 125% RDF + chloromethylene chloride, and 12.02 cm for 75% RDF + 10 t FYM/ha + tebunconzole. In the control treatment, the lowest ear length was 9.07 cm, which was comparable to RDF (9.72 cm) and 75% RDF + 10 t FYM/ha (10.12 cm). Ear length did not exhibit a significant interaction between fertility levels and tillage practice.

Number of grain ear^{-1}

There was a noticeable variance in the amount of grain per ear in the tillage technique. Conventional tillage yielded the highest number of grains per ear (42.27), comparable to that of reduced tillage (40.80).

The highest amount of grain per ear was observed at fertility levels of 125% RDF + tebunconzole (44.43), 125% RDF +

chloromethylene chloride (44.83), and 75% RDF + 10 t FYM/ha + tebunconzole (43.33), in that order. In the control treatment, the minimum number of grains per ear was 37,08, which was comparable to RDF (39.23) and 75% RDF + 10 t FYM/ha (40.18). Ear length did not exhibit a significant interaction between fertility levels and tillage practice Sharma *et al*. (2015) [13].

Grain weight ear^{-1}

Conventional tillage yielded the highest grain weight per ear (1.59 g), comparable to that of reduced tillage (1.41 g).

The highest recorded grain weight per ear across all fertility levels was 1.82 g for 125% RDF + tebunconzole, 1.80 g for 125% RDF + chloromethylene chloride, and 1.69 g for 75% RDF + 10 t FYM/ha + tebunconzole, respectively Rajanna *et al*. (2018) [11]. In the control treatment, the minimum grain weight per ear was measured at 1.09 g, which was comparable to RDF (1.27 g) and 75% RDF + 10 t FYM/ha (1.33 g) Rajput *et al*. (2008) [12].

1000 grain weight (g)

The variance analysis is included in Appendix VI, and Table 1 reports the data related to grain weight of 1000. There seemed to be a difference in the tillage method for grain weights of 1000. With conventional tillage, the maximum weight of 1000 grains was recorded at 37.51 g, which is comparable to reduce tillage at 34.50 g.

The maximum weight of 1000 grains was observed in 125% RDF + tebunconzole (42.03 g), 125% RDF + chloromethylene chloride (40.36 g), and 75% RDF + 10 t FYM/ha + tebunconzole (39.15 g) among the fertility levels, in that order. The control treatment's minimum weight of 1000 grains (29.35 g) was comparable to that of RDF (32.42 g) and 75% RDF + 10 t FYM/ha (33.22 g). Regarding the 1000 grain weight, there was no discernible interaction between the tillage method and fertility levels.

Grain yield (q ha^{-1})

Conventional tillage yielded the highest grain yield (50.86 q), which is comparable to reduce tillage (49.30 q).

The highest grain yield was observed at fertility levels of 125% RDF + tebunconzole (54.32 q), 125% RDF + chloromethylene chloride (53.51 q), and 75% RDF + 10 t FYM/ha + tebunconzole (52.62 q), in that order. The control treatment produced the lowest grain yield (44.69 q), which was comparable to RDF (47.00) and 75% RDF + 10 t FYM/ha (47.82 q). Grain yield was significantly impacted by the interaction of tillage technique and fertility levels.

Straw yield (q ha^{-1})

The study found that conventional tillage yielded a maximum straw yield of 66.51 q, which was similar to reduction tillage's yield of 65.55 q.

The highest recorded straw yield across all fertility levels was found in 125% RDF + tebunconzole (70.47 q), which was followed by 125% RDF + chloromethylene chloride (69.51 q) and 75% RDF + 10 t FYM/ha + tebunconzole (68.42 q). The control treatment yielded the least amount of straw (61.48 q), which was comparable to RDF (62.82 q) and 75% RDF + 10 t FYM/ha (63.47 q). The yield of straw was significantly impacted by the interaction between fertility levels and tillage practices.

Biological yield (q ha^{-1})

Conventional tillage () yielded the highest biological yield and is comparable to reduce tillage.

The highest biological yield was observed at 125% RDF + tebunconzole (), 125% RDF + chloromethylene chloride, and 75% RDF + 10 t FYM/ha + tebunconzole fertility levels, in that order. The minimum biological yield was observed in the control treatment () which was at par with RDF () and 75% RDF + 10 t FYM/ha (Sharma *et al* 2008) [14]. The interaction between fertility levels and tillage practice had a significant impact on biological yield.

Harvest index

The highest harvest index was observed with conventional tillage (43.22) which is at par with reduce tillage (42.73).

The highest harvest index among the fertility levels was found in 125% RDF + tebunconzole (43.47), which was followed by 125% RDF + chloromethylene chloride and 75% RDF + 10 t FYM/ha + tebunconzole, in that order. The control treatment (42.19) showed the minimum harvest index, which was comparable to the RDF (42.46) and 75% RDF + 10 t FYM/ha treatments. Fertility levels and tillage practices had a significant interaction effect on the harvest index.

Table 1: Effect of tillage practices and fertility levels on ear length (cm), number of grain ear^{-1}, grain weight ear^{-1} and 1000 grain weight (g)

Treatment	Ear length (cm)	Number of grain ear^{-1}	Grain weight ear^{-1}	1000 grain weight (g)
Tillage Practices				
Conventional tillage	11.55	42.27	1.59	37.51
Reduce tillage	10.54	40.80	1.41	34.50
SE(m)	0.085	0.129	0.008	0.086
C.D.	0.557	0.848	0.053	0.566
F1 (Control)	9.07	37.08	1.09	29.35
F2- RDF (150.60.40 NPK kg/ha)	9.72	39.23	1.27	32.42
F3-75% RDF + 10 t FYM/ ha	10.12	40.18	1.33	33.22
F4-125% RDF	10..52	40.83	1.41	34.48
F5- RDF + chloromequate chloride	10.87	41.18	1.47	35.65
F6- RDF + tebunconzole	11.17	41.58	1.52	36.64
F7- 75% RDF + 10 t FYM/ ha + Chloromequate chloride	11.52	42.63	1.61	37.80
F8-75% RDF + 10 t FYM/ ha + tebunconzole	12.02	43.33	1.69	39.15
F9-125% RDF + chloromequate chloride	12.52	44.83	1.80	40.36
F10-125% RDF + tebunconzole	12.87	44.42	1.82	41.03
SE(m)	0.111	0.399	0.017	0.323
C.D.	0.319	1.149	0.050	0.929

Table 2: Effect of tillage practices and fertility levels on grain yield, straw yield, biological yield and harvest index of wheat

Treatment	Grain yield	Straw yield	Biological yield	Harvest index
Tillage Practices				
Conventional tillage	50.86	66.51	117.382	43.22
Reduce tillage	49.30	65.55	114.869	42.73
SE(m)	0.081	0.088	0.078	0.074
C.D.	0.528	0.573	0.572	0.478
F1 (Control)	44.69	61.48	106.05	42.19
F2- RDF (150.60.40 NPK kg/ha)	47.0	62.82	109.68	42.46
F3-75% RDF + 10 t FYM/ ha	47.82	63.47	111.34	42.85
F4-125% RDF	48.89	64.62	113.44	42.97
F5- RDF + chloromequate chloride	49.68	65.55	115.73	43.06
F6- RDF + tebunconzole	50.73	66.73	117.47	43.18
F7- 75% RDF + 10 t FYM/ ha + Chloromequate chloride	51.52	67.25	119.25	43.23
F8-75% RDF + 10 t FYM/ ha + tebunconzole	52.62	68.42	120.96	43.35
F9-125% RDF + chloromequate chloride	53.51	69.51	122.99	43.39
F10-125% RDF + tebunconzole	54.32	70.47	124.66	43.47
SE(m)	0.179	0.168	0.173	0.164
C.D.	0.513	0.482	0.511	0.481

Conclusion

With the aforementioned conclusions in mind, farmers may be advised to use conventional tillage, which entails two ploughings followed by sowings, in conjunction with 125% RDF (187.5:75:50 NPK kg/ha + Two Sprays of Tebunconzole Folicur 430 SC @ 0.1%) (Folicur 430 SC @ 0.1% at first node and flag leaf (80 DAS)) to achieve efficient tillage, increased yield, and profitability in the wheat, rice, and wheat undercropping system.

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