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Integrated nutrient management (INM) in wheat (*Triticum aestivum* L.)

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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 Integrated Nutrient Management (INM) in wheat (*Triticum aestivum* L.).The soil's pH of 7.61, electrical conductivity (EC) of 0.23 dSm^{-1}, organic carbon content of 0.40%, and levels of available nutrients, such as potassium (K), phosphorus (P), and nitrogen (N), at 19.14, 216.30, and 149.30 kg ha^{-1}, respectively, were all within normal ranges. The Rabi season of 2023–2024 is when the experiment was set up. The experiment, which had three replications and a Randomized Block Design (RBD) layout, comprised fourteen treatment combinations.

Keywords: Wheat, nutrients, *Triticum aestivum* L.

Introduction
As a major cereal crop grown both domestically and internationally, wheat (*Triticum aestivum* L.) is a member of the Poaceae family. Rabi season is when wheat is primarily planted. It can be grown in temperate zones, cold regions of the north, and even tropical and subtropical zones, up to an altitude of 60 0C. Wheat is resistant to snow and extreme cold.

The 215.29 million hectares were planted with wheat, producing 730.84 million tons and having a productivity of 3390 kg ha^{-1} globally (Anonymous, 2019) [1]. 29.55 million hectares, or 13.43 percent of the world's total area, were cultivated for wheat in India last year; the country produced 101.20 million tons, up 1.3% from the year before, and the productivity was 3424 kg/ha^{-1} (Anonymous, 2019) [1]. Wheat is grown on 9.78 million hectares per year in Uttar Pradesh, yielding 31.99 million tons of production and 3269 kg of productivity per hectare. There is plenty of room to breed wheat varieties for higher yield and quality because U.P.'s wheat productivity is lower than that of Punjab (50.3 q ha^{-1}) and Haryana (44.1 q ha^{-1}) (Anonymous, 2019) [1].

It has been grown in the Indo-Gangetic plains solely using high analysis chemical fertilizers for the past few years, which has resulted in a widespread nutrient shortage. Farmyard manure (FYM) has been added to soil for centuries. This practice has improved soil structure, increased crop yield, soil fertility, soil organic matter, and facilitated microbiological activity for sustainable agriculture (Blair *et al*., 2006 and Kundu *et al*., 2007) [2, 3]. When compared to using only organic or inorganic fertilizer, the combination of both organic and inorganic fertilizers delayed days to 50% for heading, plant height, leaf area index yield, and yield components of wheat (Manna *et al*., 2005) [4]. The rapid depletion of micronutrients in the soil in India has been accelerated by intensive cropping with nutrient-exhaustive high yielding varieties and the use of high analysis fertilizer to increase food grain production (Singh, 2009) [5]. Of all the micronutrients, zinc deficiency is the most prevalent and is most frequently associated with calcareous and low organic matter soils. Thus, it is challenging to achieve sustainable productivity in cereal crops without applying zinc (Vasuki, 2010) [6].

In addition to recording noticeably higher root-shoot dry matter than inorganic fertilizer application, integrated use of organic and inorganic fertilizers also accelerated the process.

Materials and Methods

In the rural Kanpur district of Mandhana, 10 km from Kanpur in Uttar Pradesh, a field experiment was carried out during the rabi season of 2022–2023 on loamy sand to evaluate Integrated Nutrient Management (INM) in wheat (*Triticum aestivum* L.). The soil's pH of 7.61, electrical conductivity (EC) of 0.23 dSm^{-1}, organic carbon content of 0.40%, and levels of available nutrients, such as potassium (K), phosphorus (P), and nitrogen (N), at 19.14, 216.30, and 149.30 kg ha^{-1}, respectively, were all within normal ranges. The Rabi season of 2023–2024 is when the experiment was set up. The experiment, which had three replications and a Randomized Block Design (RBD) layout, comprised fourteen treatment combinations. T_1 100% T_1RDN(150 kg ha^{-1} Nitrogen), $T_2$75% RDN, $T_3$75% RDN + $ZnSO_4$ @ 25 kg ha^{-1}, T_4 75% RDN + Sulphur @ 40 kg ha^{-1}, $T_5$75% RDN + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}, T_6 75% RDN+25% N through FYM, T_7 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg ha^{-1}, $T_8$75% RDN+25% N through FYM + Sulphur @ 40 kg ha^{-1}, T_9 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg + Sulphur @ 40 kg ha^{-1}, T_{10} 75% RDN+25% N through (poultry manure), T_{11}75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1}, T_{12} 75% RDN+25% N through (poultry manure) + Sulphur @ 40 kg ha^{-1}, T_{13} 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}, T_{14}Control data were gathered on five plants chosen from each plot.

Results and Discussion

Yield attributes

Number of spikes m^{-2}

The maximum number of spikes (304.24 m-2) among the integrated nutrient management sources were recorded under 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} (T_{13}). This treatment was found to be significantly superior over the control (T_{14}) treatments and to be on par with the remaining treatments.

Length of spike (cm)

Spike length is a significant factor in determining grain yield because it is directly correlated with the number of spike lets and grains spike-1. Another criterion for evaluating the grain yield in cereal crops could be spike length. The examination of the data as it is shown in Table 1. With 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} (T_{13}) treatments, the maximum length of spike (10.20 and 10.30 cm) was recorded. This treatment was found to be statistically at par with T_1, T_5, T_7, T_8, T_9, T_{11}, and T_{12}, but significantly higher than the other treatments.

Number of grains $spike^{-1}$

The information on the quantity of grains per spike is shown in Table 1. showed that different levels of integrated nutrient management had a significant impact on the number of grains per spike. The application of 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} (T_{13}) treatment resulted in the highest number of grains (42.30), which was statistically comparable with T_1, T_3, T_4, T_5, T_6, T_7, T_9, T_{10}, T_{11}, and T_{12}, but significantly higher than T_2 and T_{14} treatments.

Test weight (1000-grains weight)

The information in Table 1 showed that the sources of integrated nutrient management had no discernible impact on wheat test weight. With the application of 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} (T_{13}), the maximum test weight (35.20g) was recorded, and the minimum under the control (T_{14}) treatment.

Yield

Grain yield (q ha^{-1})

The information presented in Table 2 demonstrated that integrated nutrient management practices had a significant impact on grain yield. The maximum grain yield (45.30 q ha^{-1}) was achieved by the treatment 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} (T_{13}). This treatment outperformed the others by 26%, 17.88%, 20.97%, 10.81%, 14.1%, 11.25%, 13.68%, and 43.70%, respectively Kanaujia (2016) [7]. where the treatments T_1, T_7, T_9, T_{11}, and T_{12} were statistically equivalent.

Straw yield (q ha^{-1})

The information presented in Table 2 made it abundantly evident that integrated nutrient management techniques significantly impacted the yield of straw. In comparison to the second year, the value of the straw yield was significantly lower in the first year. The integrated nutrient management system that produced the highest straw yield (62.05 q ha^{-1}) was 75% RDN+25% N through poultry manure + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} Verma *et al*. (2017) [8]. This yield was comparable to T_1, T_7, T_9, T_{11}, and T_{12}, but significantly higher than T_2, T_3, T_4, T_5, T_6, T_8, and T_{10}.

Biological yield (q ha^{-1})

Table 2 provides a clear summary of the data. The combination of 75% RDN+25% N through poultry manure + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} produced the maximum biological yield (107.35 q ha^{-1}) Singh. (2010) [9]. This combination was statistically comparable *et al*. to T_1, T_5, T_6, T_7, T_8, T_9, T_{11}, and T_{12}, but significantly better than T_2, T_3, T_4, and T_{10}. The control plots had the lowest biological yield of all the treatments (66.05 q ha^{-1}).

Harvest index (%)

The information shown in Table 2 showed that sources of Integrated Nutrient Management had no discernible impact on the harvest index. With the application of 75% RDN+25% N through poultry manure + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}, the maximum harvest index (42.20) and minimum (38.61) under control (T_{14}) treatment were determined Singh *et al*. (20219) [10].

Table 1: Number of Spikes m^{-2}, Spike Length (cm), No. of grains $spike^{-1}$, 1000-grains weight (g) of wheat crop as influenced by integrated nutrient management practices.

Treatments	No. of Spike m^{-2}	Spike Length (cm)	No. of grains $spike^{-1}$	1000-grain weight (g)
T_1: 100% RDN (Recommended Dose of Nitrogen)	290.48	9.90	42.00	35.00
T_2: 75% RDN	274.29	8.60	38.00	33.10
T_3: 75% RDN + $ZnSO_4$ @ 25 kg ha^{-1}	285.35	8.70	38.80	33.60
T_4: 75% RDN + Sulphur @ 40 kg ha^{-1}	277.68	8.60	38.60	33.40
T_5: 75% RDN + $ZnSO_4$@ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}	303.78	9.60	39.00	34.10
T_6: 75% RDN+25% N through FYM	296.74	9.00	38.90	33.70
T_7: 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg ha^{-1}	299.28	9.60	40.00	34.50
T_8: 75% RDN+25% N through FYM + Sulphur @ 40 kg ha^{-1}	297.07	9.40	39.80	34.00
T_9: 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg + Sulphur @ 40 kg ha^{-1}	302.54	10.40	42.00	35.10
T_{10}: 75% RDN+25% N through (poultry manure)	294.01	9.00	39.00	34.10
T_{11}: 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1}	292.26	9.90	41.00	34.80
T_{12}: 75% RDN+25% N through (poultry manure) + Sulphur @ 40 kg ha^{-1}	294.58	9.40	40.20	34.20
T_{13}: 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}	304.24	10.30	42.30	35.20
T_{14}: Control	221.09	7.90	36.50	31.60
S.Em±	12.24	0.39	1.34	1.42
CD at 5%	35.59	1.13	3.91	NS

Table-2: Grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index of wheat crop as influenced by various integrated nutrient management practices.

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1: 100% RDN (Recommended Dose of Nitrogen)	41.70	58.40	100.10	41.66
T_2: 75% RDN	33.50	51.53	76.03	40.10
T_3: 75% RDN + $ZnSO_4$ @ 25 kg ha^{-1}	37.20	53.98	91.18	40.80
T_4: 75% RDN + Sulphur @ 40 kg ha^{-1}	35.80	53.00	88.80	40.32
T_5: 75% RDN + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}	40.40	56.70	97.10	41.25
T_6: 75% RDN+25% N through FYM	38.90	55.39	94.29	41.00
T_7: 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg ha^{-1}	41.30	58.00	99.30	41.59
T_8: 75% RDN+25% N through FYM + Sulphur @ 40 kg ha^{-1}	40.20	56.45	96.65	41.32
T_9: 75% RDN+25% N through FYM + $ZnSO_4$ @ 25 kg + Sulphur @ 40 kg ha^{-1}	44.60	61.60	106.20	42.00
T_{10}: 75% RDN+25% N through (poultry manure)	39.10	55.80	94.90	41.20
T_{11}: 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1}	42.70	59.45	102.15	41.80
T_{12}: 75% RDN+25% N through (poultry manure) + Sulphur @ 40 kg ha^{-1}	40.50	57.55	98.05	41.67
T_{13}: 75% RDN+25% N through (poultry manure) + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}	45.30	62.05	107.35	42.20
T_{14}: Control	25.50	40.55	66.05	38.61
S.Em±	1.67	1.62	3.95	1.41
CD at 5%	4.87	4.70	11.49	NS

Conclusion

The following conclusions can be made in light of the experimental results mentioned above and the discussion in the pages that precede them.

When compared to other treatments, the application of 75% RDN+25% N through poultry manure + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} proved to be more effective for sustainable wheat production. In terms of integrated nutrient management strategies, in both experimental years, the application of 75% RDN+25% N through poultry manure + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 40 kg ha^{-1} resulted in the maximum nutrient availability and uptake by wheat crop grain and straw.

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