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Effect of Sowing Dates and Zinc Fertilization on Soil Nutrients Availability after Harvest of Different Varieties of Wheat (*Triticum Aestivum L.*)

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Abstract

A field experiment was conducted during rabi season 2023-24 and 2024-25 at the Instructional Farm, College of Agriculture, Jodhpur. To study the effect of sowing dates and zinc fertilization on soil nutrients availability after harvest of different varieties of wheat. The experiment was laid out in split plot design with 3 replications and comprised of 24 treatments. Results revealed that Zinc fertilization markedly enhanced soil nutrient status, with the treatment 25 kg $ZnSO_4.7H_2O$/ha basal application + one 0.5% foliar spray at grain filling recording the highest available N, P, and Zn during both years and pooled analysis. On pooled basis, this treatment improved nitrogen, phosphorus, and zinc by 5.95%, 7.98%, and 51% over the control, making it the most effective.

Keywords: Sowing Dates, Zinc, Soil Properties, Wheat

Introduction

Wheat (*Triticum aestivum L.*) is one of the world's most important cereal crops, widely grown across diverse climatic and geographic regions, and serves as the second most cultivated staple food globally. In India, it occupies 30.47 million hectares with a production of 106.84 million tonnes, contributing significantly to national food and nutritional security (DAC & FW, 2021-22). Wheat grains are rich in carbohydrates, protein, essential vitamins, minerals, and gluten, making them highly valuable for both traditional foods and processed products. The performance of wheat varieties varies with genetic potential and environmental conditions, highlighting the importance of selecting climate-resilient cultivars (Hussain et al., 2012). Sowing time plays a crucial role in [17], as delayed sowing exposes the crop to terminal heat stress, reducing grain filling duration and productivity. Early sowing generally produces bolder grains, while late sowing leads to shrivelled grains and lower test weight [1, 8].

Zinc fertilization can mitigate some of these adverse effects by enhancing photosynthesis, chlorophyll content, and antioxidant activity. Zinc is essential for plant metabolism, enzyme activity, gene expression, and stress tolerance, yet its deficiency is widespread due to continuous cultivation and soil-related constraints. More than half of the world's wheat is grown on zinc-deficient soils, affecting both crop productivity and human health, as zinc deficiency contributes to growth retardation and weakened immunity. Agronomic biofortification through soil and foliar zinc application has proven effective in improving grain yield and grain zinc concentration, especially in northern India. Understanding interactions among variety, sowing time, and zinc nutrition is therefore critical for optimizing wheat productivity and enhancing nutritional quality [3, 15].

Materials and Methods

A field experiment was conducted during rabi season 2023-24 and 2024-25 at the Instructional Farm, College of Agriculture, Jodhpur. The experiment consisted of twenty-four treatment combinations comprising two sowing dates (5th and 25th November), three varieties (GW 11, DBW 187 and DBW 372) and four levels of zinc fertilization (Control, 25 kg $ZnSO_4.7H_2O$/ha basal application, two foliar applications of 0.5% spray of $ZnSO_4.7H_2O$ at flowering and grain filling stage and 25 kg $ZnSO_4.7H_2O$/ha basal application + one foliar application of 0.5% spray of $ZnSO_4.7H_2O$ at grain filling stage). Combinations of these treatments were evaluated under a split-plot design (SPD), with sowing dates and varieties allotted to the main plots and zinc fertilization treatments assigned to the sub-plots, each replicated three times. Zinc was applied as per treatments and mixed well in soil prior to sowing of the crop. The soil of the experimental field was loamy sand in texture, slightly alkaline in soil reaction (pH 7.7 and 7.6), non-saline in conductivity (EC 0.12 and 0.11 dS/m), low in organic carbon (0.13 and 0.14 %) and available nitrogen (174.1 and 177.5 kg/ha), whereas medium in phosphorus (14.9 and 16.3 kg/ha) and high in available potash (287.4 and 289.6 kg/ha) during 2023 and 2024, respectively. Recommended dose of fertilizer i.e., 90 N, 40 P_2O_5 and 20 K_2O kg/ha were applied through commercial fertilizers viz., Urea, DAP and MoP. After harvest of the crop, soil samples were collected from the random spots from each plot and then it was pooled to make a composite sample for soil testing, which was of about 500 g. Samples were oven dried at 65^{o}C till the constant weight was achieved. Soil organic carbon, pH, EC, bulk density, available nitrogen, phosphorus and potassium were analyzed from the soil samples. Following methodologies and procedures were adopted for determination of soil-

Table

Soil Parameters	Method of Analysis	References
Bulk density (Mg/m^3)	Method No. 421 b, USDA Handbook No. 60	Richards, 1954
Available N (kg/ha)	Alkaline $KMnO_4$ method	Subbiah and Asija, 1956
Available P_2O_5 (kg/ha)	0.5 N sodium bicarbonate extractable P_2O_5	Olsen *et al.* 1954
Available K_2O (kg/ha)	Flame photometric method	Jackson, 1973

Available Zn (mg/kg)	DTPA extractable Zn using AAS	Lindsay and Norvell, 1978
EC (dS/m) (1:2 soil water suspension at 25 ℃)	Method No. 4 USDA Handbook No. 60	Richards, 1954
Soil pH (1:2 soil water suspension)	Method No. 421 b, USDA Handbook No. 60	Richards, 1954

Data were analyzed statistically for analysis of variance (ANOVA). Treatments were compared by computing the 'F-test'. The significant differences between treatments were compared by critical difference at 5% level of probability [10].

Results and Discussion

The results (Tables 1 and 2) showed that sowing dates, wheat varieties, and zinc fertilization had no significant effect on soil pH, bulk density, EC, and available potassium after harvest. Likewise, sowing dates and varieties did not influence available nitrogen and phosphorus, but zinc fertilization significantly improved both nutrients. The treatment 25 kg $ZnSO_4.7H_2O$/ha basal + one foliar spray (0.5%) at grain filling recorded the highest nitrogen and phosphorus, with increases of 5.95% and 7.98% over the control in pooled data.

For available zinc, sowing dates showed no effect, but varieties differed significantly, with DBW 372 recording the highest zinc content. Zinc fertilization had a strong impact, and the combined treatment (basal + foliar spray) recorded the maximum zinc level, giving a 51% increase over control, and remained at par with the basal treatment alone. Overall, the combined zinc application was the most effective in improving soil nutrient status after wheat harvest during 2023-24 and 2024-25 as well as in pooled analysis. It might be due to effect of zinc on microbial nitrogen fixation in soil which was also indicated by [2] and [6]. The application of zinc fertilization significantly increased the available zinc in the soil. As expected, a linear increase in available zinc content in soil was observed with 25 kg $ZnSO_4.7H_2O$/ha basal application + one foliar application of 0.5% spray at the grain filling stage after harvest of the crop. The experimental soil being low in available zinc might have resulted in increased available zinc with the increasing level of zinc application. There could be a 'Priming effect' which possibly caused solubilization of native zinc with increase in the rate of zinc application. The result was in conformity to those of reported by [2, 4, 6].

Zinc application did not produce any significant change in the basic physico-chemical properties of the soil. The soil pH remained unaffected across treatments, indicating that the mild acidity of zinc sulphate was insufficient to alter pH under field conditions, which is consistent with earlier reports noting that micronutrient application rarely modifies soil reaction in the short term [16]. A slight and temporary increase in EC immediately after zinc application was observed due to the soluble nature of $ZnSO_4.7H_2O$; however, this rise diminished with subsequent irrigations. Similarly, bulk density showed no significant variation and remained primarily governed by inherent soil texture and organic matter content, aligning with previous studies showing minimal influence of zinc fertilization on soil physical properties. Any minor decrease in BD under zinc-treated plots may be attributed to improved root biomass and organic residue accumulation rather than a direct effect of zinc itself [12, 14].

Table 1: Effect of Sowing Dates, Varieties and Zinc Fertilization on Soil pH, Bulk Density and Electrical Conductivity (EC) of Soil after Crop Harvest

Treatments	**Soil pH**			**Bulk density (mg m^{-3})**			**EC (dS/m)**		
	2023-24	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**
Sowing Dates									
D_1: 5th November	7.6	7.69	7.64	1.538	1.551	1.545	0.11	0.113	0.112
D_2: 25th November	7.6	7.67	7.63	1.537	1.55	1.544	0.111	0.11	0.111
SEm±	0.01	0.01	0.01	0.005	0.003	0.003	0.001	0.001	0.001

C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Varieties									
V_1: GW 11	7.59	7.67	7.63	1.537	1.549	1.543	0.112	0.11	0.111
V_2: DBW 187	7.61	7.69	7.65	1.54	1.553	1.547	0.11	0.114	0.112
V_3: DBW 372	7.59	7.69	7.64	1.536	1.55	1.543	0.111	0.111	0.111
SEm±	0.01	0.01	0.01	0.004	0.004	0.003	0.001	0.005	0.002
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc Fertilization ($ZnSO_4.7H_2O$)									
Z_0: Control	7.6	7.69	7.64	1.541	1.552	1.547	0.114	0.11	0.112
Z_1: 25 kg/ha BA	7.57	7.67	7.62	1.535	1.552	1.544	0.11	0.114	0.11
Z_2: 2 FS*	7.61	7.68	7.64	1.536	1.552	1.544	0.113	0.112	0.112
Z_3: 25 kg/ha BA+1 FS**	7.61	7.69	7.65	1.538	1.546	1.542	0.111	0.111	0.111
SEm±	0.01	0.01	0.01	0.005	0.004	0.003	0.001	0.001	0.005
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

BA: Basal application, 2FS*: two foliar sprays of 0.5% at flowering and grain filling stage, 1FS**: One foliar spray of 0.5% at grain filling stage

Table 2: Effect of Sowing Dates, Varieties and Zinc Fertilization on Soil Ph, Bulk Density and Electrical Conductivity (EC) of Soil after Crop Harvest

Treatments	Available nutrient content in soil (kg/ha)									Available Zn (mg/kg)		
	Nitrogen			Phosphorus			Potassium					
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Sowing Dates												
D_1: 5th November	165.47	166.32	165.89	20.45	21.7	21.07	318.41	321.26	319.83	0.503	0.505	0.504
D_2: 25th November	165.83	167.66	166.74	20.8	21.88	21.34	321.57	322.48	322.03	0.496	0.502	0.499
SEm±	1.3	0.7	0.74	0.18	0.22	0.14	1.33	1.21	0.9	0.002	0.003	0.002
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Varieties												
V_1: GW 11	164.52	166.55	165.54	20.38	21.6	20.99	319.17	320.37	319.77	0.493	0.5	0.497
V_2: DBW 187	166.19	167.2	166.7	20.63	21.9	21.27	320.05	322.43	321.24	0.501	0.503	0.502
V_3: DBW 372	166.23	167.21	166.72	20.87	21.86	21.36	320.76	322.81	321.78	0.504	0.507	0.506
SEm±	0.6	0.53	0.4	0.22	0.21	0.15	1.5	1.27	0.98	0.003	0.002	0.002
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.008	0.006	0.005

Zinc Fertilization ($ZnSO_4.7H_2O$)												
Z_0: Control	161.11	162.61	161.86	19.83	20.77	20.3	319.32	322.46	320.89	0.399	0.402	0.4
Z_1: 25 kg/ha BA	163.18	164.26	163.72	20.42	21.77	21.09	320.05	321.42	320.74	0.595	0.601	0.598
Z_2: 2 FS*	167.39	169.02	168.2	20.9	22.12	21.51	320.22	321.8	321.01	0.402	0.405	0.403
Z_3: 25 kg/ha BA+1 FS**	170.91	172.07	171.49	21.36	22.49	21.92	320.37	321.8	321.08	0.603	0.606	0.604
SEm±	0.69	0.61	0.46	0.25	0.24	0.17	1.73	1.47	1.13	0.003	0.002	0.002
C.D. (P=0.05)	1.98	1.74	1.29	0.72	0.69	0.49	NS	NS	NS	0.009	0.006	0.005

BA: Basal application, 2FS*: two foliar sprays of 0.5% at flowering and grain filling stage, 1FS**: One foliar spray of 0.5% at grain filling stage

Conclusion

On the basis of a two-year investigation, it may be concluded that sowing dates and wheat varieties did not alter the soil's basic chemical properties, zinc fertilization played a decisive role in enhancing soil nutrient status. The application of 25 kg $ZnSO_4.7H_2O$/ha basal + one 0.5% foliar spray at grain filling stage consistently recorded the highest levels of available nitrogen, phosphorus, and zinc, showing substantial improvements over the control. This combined zinc application proved to be the most effective strategy for maintaining and enhancing soil fertility after wheat harvest across both years and pooled analysis.

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