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Zinc Fertilization Effect on Nutrient Uptake, Yield and Soil Fertility after Harvest of Wheat

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ABSTRACT: Effect of zinc fertilization on soil fertility, yield and nutrient uptake after harvest of wheat (*Triticum aestivum* L.) was estimated at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat in *rabi* season (2018-19). Ten different treatments such as RDF, RDF + 10 kg $ZnSO_4$/ha (Soil application), RDF + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering and milking stage), RDF + Seed priming (1% Zn solution),RDF + Seed priming (2% Zn solution), RDF + 10 kg $ZnSO_4$/ha (Soil application) + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages), RDF + 10 kg $ZnSO_4$/ha (Soil application) + Seed priming (1% Zn solution), RDF + 10 kg $ZnSO_4$/ha (Soil application) + Seed priming (2% Zn solution), RDF + 10 kg $ZnSO_4$/ha (Soil application) + Foliar Spray of $ZnSO_4$@ 0.5% (at flowering and milking stages) + Seed priming (1% Zn solution) and RDF + 10 kg $ZnSO_4$/ha (Soil application) + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering and milking stages) + Seed priming (2% Zn solution) were evaluated in randomized block design with four replications. Results inferred that wheat variety GW 451 showed significant positive effect on soil fertility, yield, nutrient uptake and nutrient content when fertilized with RDF + 10 kg $ZnSO_4$/ha (Soil application) + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering and milking stages) + Seed priming (2% Zn solution).

Keywords: Nutrient uptake, Soil fertility, Wheat, Yield, Zinc.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second-largest cereal crop in the world following rice, also it is the major important staple food concerning more than thousands of million human beings in the world (Mutum *et al.*, 2021). India is the second-largest producer of wheat in the world by means of significant growth in wheat output during the past forty years as Dr. N. E. Borlaug developed the Mexican Dwarf Wheat (*Triticum aestivum* L.), also known as common bread wheat, at CIMMYT which is now commonly cultivated in India (Yadav *et al.*, 2010). In terms of area and production, India comes to second place after China among the nations that cultivate wheat (Peng *et al.*, 2009). In 2020-21, wheat production in India reached 108.75 million tonnes, with an average national productivity of 3424 kg/ha (ICAR-IIWBR, 2021). However, Gujarat's productivity was comparatively lower due to inadequate irrigation facilities, imbalanced fertilizer use, and lack of awareness about modern agricultural techniques, such as selecting appropriate genotypes, optimal sowing time, seed rate, spacing, weed control, fertilization, and protection measures.

As even a minor deficit can significantly lower production, micronutrients are crucial for plant nutrition (Fageria, 2001). Many aspects must be considered for adequate micronutrient nutrition of plants. The capacity of the soil to supply these nutrients, the pace at which nutrients are absorbed to functional locations, the mobility of nutrients within plants, and interactions between some macronutrients and micronutrients are among these aspects Grivetti and Ogle (2000). Different fertilizers could be applied in specific directions to boost the wheat crop's yield and protein content (Long *et al.*, 2000). Green revolution era has witnessed the progressive appearance of the micronutrient deficiency. In order of incidences of deficiency, Zn deficiency is most widespread (48%), followed by B (33%) Fe (13%), Mo (7%) and Mn (4%) (Rattan *et al.*, 2009). Superiority of $ZnSO_4$ in a large number of field experiments has been observed (Ratan, 2011).

According to Dangarwala *et al.*(1994), 24% of the soils in Gujarat state and almost 58% of the soils in North Gujarat are Zn deficient, which is over half of all soils in India. Lack of zinc reduces agricultural productivity and quantity (Chauhan *et al.*, 2014). Insufficient zinc content in grain and straw is recognized as the fifth risk factor contributing to nutrition deficiencies in developing countries for both humans and animals (Rathore *et al.*, 2015). This issue has recently received a lot of attention. One third of the world's population currently experiences insufficient zinc consumption, and a million hectares of cropland are currently damaged by zinc deficiency (Bharde and Patel 2003). In the developing world, cereal crops are crucial for meeting daily caloric needs, yet they naturally contain very little zinc in their grains, especially when produced on Zn-deficient soils (Cakmak, 2008).

The structural elements of growth, hormones and chlorophyll both depend on zinc as it participates in a variety of enzymatic processes (Rout and Das 2009). Zinc is essential for the healthy growth and reproduction of plants, animals and people (Singh *et al.*, 2016). When zinc supplies are insufficient in plants, crop yields are reduced and crop quality is usually compromised in plants (Kumari and Prasad 2014). Zinc plays a crucial role in significant biochemical pathways, serving as a structural component or regulatory co-factor for various enzymes and proteins involved in protein metabolism, auxin metabolism (growth regulation), membrane integrity, and pathogen resistance (Singh, 2017). Soil zinc deficiency adversely affects crop quality and yield, leading to potential yield losses of up to 30% in cereal crops (Noulas *et al*., 2018). Lack of zinc results in stunted wheat growth with whitish-brown patches, progressing to necrosis in severe cases, along with reduced tillering, spikelet sterility, chlorotic midribs, loss of turgidity, and emergence of brown streaks and blotches on lower leaves (Suganya *et al*., 2020). Zinc can be used as fertilizer to significantly increase crop quality and yield. Zinc sulphate is the zinc (Zn) source that is most frequently used in crop production (Shivay *et al.*, 2008).

MATERIALS AND METHODS

In the rabi season of the academic year 2018-19, the experiment took place at the Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat. The experimental field had loamy sand soil with a pH of 7.56, low organic carbon (0.21%), available N (164.9 kg/ha), medium available P_2O_5 (41.05 kg/ha), and high available K (264.61 kg/ha). Wheat variety GW 451 was seeded at a rate of 120 kg/ha with an inter-row spacing of 22.5 cm after treating the seed with Fipronil 5 SC at 6 ml/kg seed. The seeds were sown manually, 4 to 4.5 cm deep, and evenly spaced in a previously prepared furrow. Various zinc fertilization regimes were applied, and several wheat growth and yield-related characteristics were measured, including plant population, plant height, number of effective tillers per meter of row length, length of ear head, number of grains/ear head, 1000 grain weight, grain yield, and straw yield.

As a common treatment, each plot received a distinct broadcast of the quantity required of well-decomposed FYM. It was incorporated into the soil in the right places prior to seeding. The furrows were manually treated with the full dose of P_2O_5 and the half dose of N in the form of DAP and urea, respectively, before planting the crop in accordance with the procedures. The remaining half dose of Nitrogen was applied as urea to each plot after the first and fourth irrigations in two equal portions (25% at CRI, 25% at flag leaf stage) according to the treatments. The crop was raised using the recommended treatments and procedures for the region, with zinc being applied as zinc sulphate (21% Zn) for base application. The observations of yield attributes and quality indicators were statistically analyzed using Fisher's (1950) analysis of variation method. A randomized complete block design was used for this.

RESULTS AND DISCUSSION

A. Effect on yield

Treatments T_{10}, T_9, T_8, T_7, T_6, and T_2 showed significantly higher grain yield (4795 kg) compared to other treatments, according to Table 1. The application of RDF combined with 10 kg $ZnSO_4$/ha + foliar spray of $ZnSO_4$ @ 0.5% (at flowering and milking stages) + Seed priming (2% Zn solution) in T_{10} likely contributed to the increased grain production. The ample supply of Zn nutrition and balanced N, P, and K improved various physiological processes, such as photosynthesis, respiration, and nitrogen metabolism, resulting in enhanced growth and yield-related parameters and overall grain yield improvement. The findings of Nawab *et al.* (2011); Kulhare *et al.* (2014); Mauriya *et al.* (2015); Arif *et al.* (2017); Firdous *et al* (2018); Jat *et al.* (2018) are entirely consistent with these findings.

The application of RDF combined with 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% (during flowering and milking phases) + Seed priming (2% Zn solution) (T10) resulted in significantly higher straw yield (6093 kg) compared to other treatments. The increased straw yield can be attributed to the ample supply of Zn nutrition and balanced NPK, which enhanced photosynthesis, respiration, nitrogen metabolism-protein synthesis, and other biochemical and physiological processes. This improvement in growth and yield-related parameters is consistent with previous studies of Kulhare *et al.* (2014); Mauriya *et al.* (2015); Arif *et al.* (2017); Firdous *et al.* (2018); Jat *et al.* (2018).

B. Effect on nutrients content

Zinc fertilization had a significant impact on the nitrogen (N) content in the grain. Treatment T10 showed the highest N content (2.04%) in the grain, while treatment T1 had the lowest N content (1.85%). However, the N content in the straw remained unaffected by the various treatments of zinc fertilization. Though highest (0.659%) and lowest (0.628%) N content was recorded with treatment T_{10} and T_1, respectively. This might be due to increase the activity of the enzymes leading to more assimilation of nitrogen by the wheat plant resulting in increased content of nitrogen Bather and Patel (2005); Chaudhary (2014); Dogra *et al.* (2014).

The phosphorus content in both grain and straw of wheat was not significantly affected by the different treatments. However, numerically higher phosphorus contents in grain (0.315%) and straw (0.350%) were obtained under the treatment RDF + 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution). Conversely, the lowest phosphorus content in grain (0.295%) and straw (0.331%) was observed under treatment T_1. This difference might be attributed to the potential antagonistic effect of zinc on phosphorus, as suggested by Dogra *et al.* (2014).

Table 1: Effect of zinc fertilization on yield and available nutrients in soil.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available Zn (mg/kg)
T_1: RDF (120:60:00 kg NPK/ha)	3558	4550	170.00	42.95	0.371
T_2: RDF + 10 kg $ZnSO_4$/ha (Soil application)	4164	4650	166.25	41.39	0.474
T_3: RDF + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages)	3653	4907	169.50	42.70	0.416
T_4: RDF + Seed priming (1% Zn solution)	3850	5031	168.00	42.17	0.418
T_5: RDF + Seed priming (2% Zn solution)	3953	5303	168.25	41.82	0.420
T_6: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages)	4319	5467	164.25	38.02	0.466
T_7: T_2 + Seed priming (1% Zn solution)	4409	5608	163.36	37.20	0.476
T_8: T_2 + Seed priming (2% Zn solution)	4485	5709	163.00	36.52	0.487
T_9: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (1% Zn solution)	4641	5897	165.25	36.21	0.490
T_{10}: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution)	4795	6093	163.25	35.49	0.495
S.Em±	250.97	309.92	3.76	2.03	0.02
CD (P = 0.05)	728.26	899.32	NS	NS	0.06
CV (%)	12.00	11.65	4.53	10.28	9.13

Treatment T_{10}, which involved RDF along with 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution), showed significantly higher Zn content in both grain (65.11 mg/kg) and straw (40.49 mg/kg) compared to other treatments. This increase in Zn content was also observed in treatments T_9, T_8, T_7, T_6, and T_5, where it was on par with T_{10}. Conversely, the lowest Zn content in grain (41.27 mg/kg) and straw (20.70 mg/kg) was recorded under the control treatment (T_1). The positive effect of zinc application on Zn content in wheat may be attributed to the low initial Zn status in the soil and the increased concentration of applied zinc in the solution, leading to enhanced zinc absorption by the plant. This result is in conformity with Zeidan *et al.* (2010); Pooniya and Shivay (2011); Abid *et al*. (2013); Dogra *et al.* (2014); Firdous *et al.* (2018).

C. Effect on nutrients uptake

Treatment T_{10} exhibited the significantly highest N uptake by grain (98.34 kg/ha) and straw (39.89 kg/ha), as shown in Table 2. This was observed when using RDF along with 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming 2% Zn solution. However, treatments T_6, T_7, T_8, and T_9 also showed comparable N uptake values. The increase in total N uptake by the grain could be attributed to the synergistic effect between nitrogen (N) and zinc (Zn) present in these treatments. Similar conclusion was drawn by Chaudhary (2014); Mauriya *et al*. (2015).

Treatment T_{10} (RDF + 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% + Seed priming 2% Zn solution) showed significantly the highest phosphorus (P) uptake by grain (14.92 kg/ha) and straw (21.45 kg/ha), on par with T7, T8, and T9 in grain, and on par with T_5, T_6, T_7, T_8 and T_9 in straw. The lowest P uptake by grain (10.50 kg/ha) and straw (15.06 kg/ha) was observed in the control treatment (T_1). The increase in total P uptake by grain could be attributed to the synergistic effect between P and Zn. Similar results for phosphorus uptake were reported by Chaudhary (2014); Mauriya *et al.* (2015).

The uptake of Zn by grain and straw was significantly affected and presented in Table 2. The highest Zn uptake by grain (315.34 g/ha) and straw (247.19 g/ha) was recorded under treatment T_{10}, except for treatments T_9, T_8, T_7, and T_6 in grain, and T_9, T_8, and T_7 in straw. The lowest Zn uptake by grain (146.73 g/ha) and straw (142.79 g/ha) was observed in T_1. The positive effect of zinc application on its uptake by grain and straw may be due to the increased concentration of applied zinc in the soil solution, leading to enhanced zinc absorption by the plant. Similar results were reported by Abid *et al*. (2013); Chandel *et al*. (2013); Kulhare *et al.* (2014); Mauriya *et al.* (2015); Pooniya and Shivay (2011); Rathod *et al.* (2012).

D. Effect on available nutrients status in soil

The data summarized in Table 1 indicates that different Zn fertilization treatments did not significantly influence the available N content in the soil after the harvest of the wheat crop. However, numerically higher available N in the soil after harvest (170.00 kg/ha) was recorded with treatment T_{10} (100% RDF), while the lowest (163.00 kg/ha) was observed with treatment T_8 (RDF + 10 kg ZnSO4/ha (Soil application) + Seed priming (2% Zn solution). The available P_2O_5 content in the soil after harvest showed no significant differences due to different treatments.

Regarding available Zn content in the soil after harvest, the data in Table 1 showed significant differences influenced by different treatments. The significantly higher available Zn content (0.495 mg/kg) in the soil after crop harvest was recorded with the application of RDF + 10 kg $ZnSO_4$/ha + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution) (T_{10}), and it was on par with T_2, T_6, T_7, T_8, and T_9 treatments. The lowest available Zn content (0.371 mg/kg) in the soil after crop harvest was recorded under the control treatment (T_1). The increased available Zn in the soil with zinc fertilization may be attributed to the additional application of zinc in the soil.

Table 2: Effect of zinc fertilization on nitrogen, phosphorus and zinc content and uptake by grain and straw of wheat.

Treatments	N content (%)		P content (%)		Zn content (mg/kg)		N uptake (kg/ha)		P uptake (kg/ha)		Zn uptake (g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: RDF (120:60:00 kg NPK/ha)	1.85	0.628	0.295	41.27	20.70	0.331	66.07	28.53	10.50	15.06	146.73	142.79
T_2: RDF + 10 kg $ZnSO_4$/ha (Soil application)	1.88	0.641	0.308	57.49	37.57	0.341	78.62	29.74	12.78	15.87	238.29	174.42
T_3: RDF + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages)	1.89	0.631	0.299	53.87	36.57	0.334	69.29	30.95	10.92	16.38	196.44	179.27
T_4: RDF + Seed priming (1% Zn solution)	1.91	0.635	0.303	55.76	37.17	0.336	73.69	31.89	11.66	16.90	214.43	187.21
T_5: RDF + Seed priming (2% Zn solution)	1.93	0.638	0.306	59.19	38.08	0.339	76.50	33.73	12.07	17.98	233.92	202.83
T_6: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages)	1.97	0.648	0.311	61.21	38.24	0.343	86.22	35.15	13.18	18.89	265.15	208.31
T_7: T_2 + Seed priming (1% Zn solution)	2.00	0.649	0.311	62.58	38.74	0.345	88.01	36.38	13.70	19.34	275.91	217.35
T_8: T_2 + Seed priming (2% Zn solution)	2.01	0.651	0.312	63.91	39.42	0.347	90.37	37.06	13.97	19.80	286.58	224.54
T_9: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (1% Zn solution)	2.02	0.655	0.314	63.90	39.72	0.348	94.00	38.48	14.49	20.52	296.66	234.47
T_{10}: T_2 + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution)	2.04	0.659	0.315	65.11	40.49	0.350	98.34	39.89	14.92	21.45	315.34	247.19
S.Em±	0.04	0.01	0.01	2.24	0.89	0.00	6.63	1.58	0.49	1.25	20.53	13.12
CD (P = 0.05)	0.12	NS	NS	6.51	2.60	NS	19.25	4.59	1.42	3.64	59.57	38.08
CV (%)	4.30	3.83	5.67	7.68	4.74	2.61	16.16	9.26	7.64	13.77	16.63	13.00

CONCLUSIONS

Based on the experimental results, it can be concluded that fertilizing wheat variety GW 451 with RDF + 10 kg $ZnSO_4$/ha (Soil application) + Foliar Spray of $ZnSO_4$ @ 0.5% (at flowering & milking stages) + Seed priming (2% Zn solution) had a positive impact on yield, nutrient content, nutrient uptake, and nutrient status in the soil.

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Conflict of Interest. None.

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