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Zinc and nitrogen uptake by wheat plants with zinc fertilization via soil and foliar application

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ABSTRACT

The present investigation was conducted during *Rabi* season of 2019. The experiment was conducted in pots in net house with 12 treatments; first 6 treatments consisted of soil application alone at 6 levels (0,10, 20, 30, 40, 50 kg Zn ha^{-1} soil application) and last 6 levels with soil application + foliar sprays (FS) @ 0.5% (0+FS, 10+FS, 20+FS, 30+FS, 40+FS, 50+FS kg Zn ha^{-1}). Nitrogen and zinc content in grain and straw and its total uptake were estimated. Standard methods of observation, analysis of soil and plant samples, and appropriate statistical methods for the analysis of data were used. Different treatments had a significant effect on nitrogen and zinc content in grain and straw, and total uptake. The nitrogen and zinc content in grain and straw were recorded maximum with zinc application of 30 kg ha^{-1} + 0.5% FS. Total uptake of N and Zn were recorded maximum with 30 kg Zn ha^{-1}. Holistically, the application of zinc @ 30 kg ha^{-1} + 0.5% FS is recommended to improve nitrogen and zinc content in grains, and increase the total uptake of these nutrients by the plant.

Keywords: Zinc, nitrogen, wheat, micronutrient fortification

INTRODUCTION

Wheat is one of the major grains worldwide, which provides nearly 20% calorie and protein per capita worldwide and as a staple food, it is second only to rise in consumption (Long, 2019). Therefore, improving the daily Zn intake through wheat-derived processed foods is an important way to solve Zn deficiency. Generally, the regions with severe zinc-deficient soils are also the regions where zinc deficiency in human beings is very common. Therefore, there is a great need to improve cereal crops with adequate zinc nutrition. As a plant nutrient the role of zinc in crop production, including wheat cultivation, has been well established (Kanwar and Randhawa, 1974; Takkar *et al*., 1971).

India occupies 329 million hectares of land and area wise it ranks seventh in the world with 17% population and 2.5% world area. Omnibus signs are that by 2050 India will become the most populous nation in the world (FAO, 2020). These become a great challenge to fulfill the increasing food quality and production demand. Efficient fertilizer management is a very important factor to enhance the yield potential. Wheat is one of the important sources of the daily diet in developing countries, but its Zn content is relatively low. The Zn content of wheat grains needs to reach 45.0 mg kg^{-1} to meet the Zn needs of the human body (Liu, 2017). However, statistics show that the average Zn content in wheat grains worldwide is only 28.48 mg kg^{-1}, which is lower than the internationally recommended amount. The grain Zn content of wheat in different countries since the 1960s ranged from 8.00 to 88.20 mg kg^{-1} with an average value of 31.84 mg kg^{-1} (Wang *et al*., 2012; Oury *et al*., 2006; Czerniejewski *et al*., 1964). Soil fertility is an important factor, which decides the growth of a plant. It is determined by the presence or absence of nutrients i.e. macro and micronutrients. The availability of micronutrients is very dependent on the soil environment. The factors that affect the availability of micronutrients are organic matter, soil pH, lime content, sand, silt and clay contents revealed from different research experiments. The reason behind the depletion of soil fertility in India is mainly the intensive cropping system, imbalanced use of fertilizers, application of macronutrients alone, and ignorance of micronutrients and organic manures. Zinc is an essential element for the normal growth and development of plants. It plays a vital role in enzyme activation and is also involved in the biosynthesis of some enzymes and growth hormones (Marschner, 1995). Zinc deficiency is a very important nutrient problem in Indian soils. Total Zn concentration is sufficient in many agricultural areas, but available Zn concentration is deficient because of different soil and climatic conditions. Soil pH, lime content, organic matter amount, clay type, and the amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil (Adiloglu, 2006). In soil, Zn deficiency is very common in cereal-based cropping systems (Cakmak, 2002). Zinc deficiency is a prevalent micronutrient deficiency in wheat, leading to a severe reduction in wheat production and the nutritional quality of grains (Cakmak *et al*., 1996).

Zinc content can be enhanced by the fortification during breeding and by adding nutrients during food processing (Hao *et al*., 2015). Biofortification can quickly increase grain Zn content in wheat because of agronomic measures, such as the application of Zn fertilizer (Liu *et al*., 2017); therefore, field fertilization was gradually accepted and liked by farmers. The main application methods of Zn fertilizer include soil application, foliar application, and seed treatment (Wang *et al*., 2019). Therefore, the suitable Zn fortification, appropriate processing, and food type of wheat are important to meet people's Zn requirement through wheat.

Given the importance of zinc fertilization, the present investigation was planned to study the effect of zinc fertilization via soil application and foliar application on N and Zn uptake by the wheat crop.

METHOD AND MATERIALS

The pot experiment was conducted in pots in net house during 2019 with wheat in alluvial soil. The experiment had 12 treatments with first 6 treatments of soil application alone at 6 levels (0, 10, 20, 30, 40, 50 kg/ha + soil application)and last 6 treatments as soil+ foliar sprays@ 0.5% (0, 10, 20, 30, 40, 50 kg/ha+ soil +0.5% FS) were made separately for all the above treatments.

All the treatments were applied to wheat in *Rabi*. Soil moisture was maintained the field capacity by regular weighing the pots. Irrigation was given throughout the experiment period to keep the soil moist. At maturity, clean plants were harvested by cutting at above the soil surface by using stainless-steel scissors and grain samples were separated from the wheat plant. The dried grain and straw samples were then finely ground in a grinder for laboratory analysis. Total N was determined by the semi-micro Kjeldahl method (Jackson, 1973) and zinc content was determined by analyzing the diacid digest of plant samples with an atomic absorption spectrophotometer (Jackson, 1973).

RESULTS AND DISCUSSION

Zinc application significantly affects nitrogen and zinc content in grain and straw and the total uptake of N and Zn.

Nitrogen content in grain and straw (%)

Zinc levels proved significant improvement in nitrogen content in grain and straw (Fig.1); maximum nitrogen content (1.71%) in grain and straw (0.64%) was observed with treatment 30 kg + 0.5% FS. Minimum nitrogen content in both was reported in control-0 kg soil Zn ha^{-1} as 1.54% and 0.49%. However, treatments receiving the foliar application of zinc with basal dose proved superiority over treatments receiving zinc as basal dose.

Zinc content in grain and straw (ppm)

Zinc content in grain was influenced significantly by zinc levels (Fig. 2). Among the zinc treatments, maximum zinc content in grain and straw are 43.47ppm and 34.37ppm with treatment 30 kg + 0.5% FS, which was significantly higher

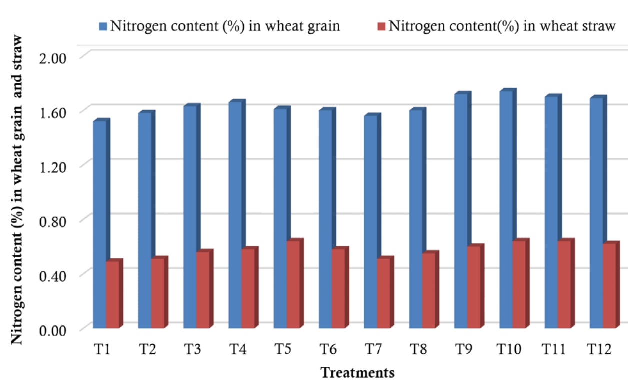

Fig. 1. Effect of zinc levels on total nitrogen content (%) in wheat grain and straw

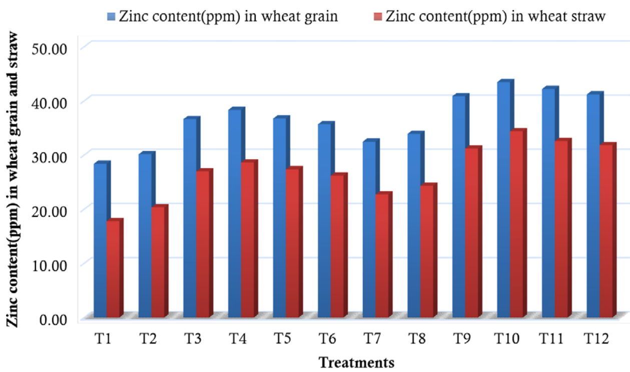

Fig. 2. Effect of zinc levels on total zinc content (ppm) in wheat grain and straw

than treatment 30 kg soil Zn ha^{-1} applied as a basal dose. Lowest Zn content was observed with 0 kg soil Zn ha^{-1} treatment (28.38 ppm and 17.18 ppm).

The higher Zn concentration in wheat grain than straw showed that Zn is easily mobilized to sink, i.e., grain. Similar findings have been reported by Prasad *et al.* (2012). Foliar Zn spray is an effective way for biofortification of wheat grains with Zn. A synergistic external foliar supply Zn source is more effective than Zn-only spray in increasing grain Zn concentration and bioavailability (Xia *et al*., 2018).

Application of Zn as $ZnSO_4$ to soil or foliar application is an effective way to increase grain Zn concentration with a remarkable yield increase. Applying Zn with macronutrient fertilizers or at higher rates will give optimum yield and higher grain Zn concentration. Similarly, applying Zn for ≈100% relative grain yield will greatly increase grain Zn concentration (Hussain *et al*., 2010). There was 83.5% increase in grain Zn concentration by foliar Zn application alone, while soil Zn application was less effective. Such marked increases in grain Zn by foliar Zn application would have important contributions to improving dietary intake of Zn by human beings. Almost in all experiments conducted in seven countries, the increments in grain Zn associated with only foliar Zn spray was more than 10 mg Zn kg^{-1} grain. In the case of soil + foliar Zn application, an increment of 20 mg per kg grain was found in half of the field tests. The targeted levels of Zn in wheat grain for better human nutrition can be achieved substantially by foliar Zn application.

Total uptake of Nitrogen and Zinc

Appraisal of data in Table 1 indicated that nitrogen uptake by grain was $ZnSO_4$ significantly improved by different zinc levels during both the years of experimentations. All zinc levels treatments were at par with each other and significant over control. Maximum uptake of nitrogen and zinc was obtained with the treatment received 30 kg Zn ha^{-1}as a basal dose + 0.5% FS as 0.931 and 3.232.

Table 1. Effect of zinc levels on total uptake of Nitrogen and Zinc

Treatments	Total uptake of N (mg kg^{-1})	Total uptake of Zn (mg kg^{-1})
T_1	0.530	1.416
T_2	0.608	1.624
T_3	0.731	2.378
T_4	0.783	2.581
T_5	0.752	2.268
T_6	0.764	2.129
T_7	0.577	1.769
T_8	0.656	1.943
T_9	0.836	2.942
T_{10}	0.931	3.232
T_{11}	0.863	2.999
T_{12}	0.833	2.862
SEM ±	0.028	0.135
C.D. (at 5%)	0.058	0.278

Uptake of Zn was increased in soil + foliar application in comparison to soil application alone. The highest uptake of Zn was registered with soil application + 0.5% FS which was higher over control (no Zn). Higher Zn concentration in soil + foliar-applied Zn might be due to foliar-applied Zn was more easily absorbed by the leaves of the plant and translocated to reproductive parts, hence accumulation was more as compared to soil application alone. Similar results were also reported by Mathpal *et al.* (2015), Shivay *et al.* (2015). More concentration of Zn and uptake of micronutrients in chelated-Zn applied plots were also reported by Ghasal *et al.* (2017).

Foliar Zn application alone or in combination with soil Zn application resulted in significant improvement in grain Zn concentrations as it increased from 27.4 mg kg^{-1} to 48.0 mg kg^{-1} by foliar Zn application. Similar observations have been reported by Zhang *et al*. (2012).

CONCLUSION

In the study, the application of zinc @ 30 kg ha^{-1} + 0.5% FS improved nitrogen and zinc content in grains, and increase the total uptake of these nutrients by the plant, in comparison to the conventional practice of only soil application. Therefore, the application of zinc @ 30 kg + 0.5% FS would be a better practice for increasing N and Zn content and their uptake in wheat in the alluvial soil of Uttar Pradesh.

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