



Effect of iron and zinc on yield and uptake of oat in alluvial soil of western Uttar Pradesh

Jogendra Kumar

Department of Agricultural Chemistry, RMP (PG) College, Gurukul Narsan, Haridwar, Uttarakhand, India

Abstract

A pot experiment was carried out to investigate the effects of iron and zinc on oat yield and uptake. Four treatments of iron ($F_0 = 0$, $F_1 = 3$, $F_2 = 6$, and $F_3 = 9$ mg kg⁻¹) and zinc ($Zn_0 = 0$, $Zn_1 = 3$, $Zn_2 = 6$, and $Zn_3 = 9$ mg kg⁻¹) were used. The maximum grain and straw yields were recorded under Fe_2 treatment of iron. However, the highest dose (Fe_3) of iron significantly decreased the grain and straw yield of oat as compared to Fe_0 , Fe_1 and Fe_2 treatments. The grain and straw yields of oats increased with increasing levels of Zn up to the Zn_2 treatment. The application of Fe significantly increased the Fe uptake by oat grain and straw was recorded up to Fe_2 treatment of Fe. The maximum Fe uptake was observed at Zn_2 treatment of Zn. The increasing levels of Fe application significantly decreases the uptake of Zn by grain and straw of oat showing an antagonistic effect of Fe on Zn utilization by grain and straw. The maximum yield of oat grain and straw was recorded under $Fe_2 + Zn_2$ treatment. The application of Zn in different levels increased the Zn uptake by both grain and straw of oat significantly.

Keywords: Iron, zinc, yield, uptake, oat

Introduction

Plant nutrient management is mainly governed by the level of nutrients in the soil. Plants need micronutrients (mineral elements) in small quantities to perform a range of physiological functions (White *et al.* 2012) [17]. By virtue of their functions in the building and repair of protoplasm and regulation of metabolic processes, micronutrients play an important role in the maintenance of the physical organisation and activities in living cells. These are generally deficient in saline, sodic, highly leached, sandy, and highly calcareous soils, and an application of these micronutrient cations on such soils has favoured the growth and yield of crops. In addition to these, several factors, including weathering of minerals, liming, degree of leaching, mineralization of organic matter, and moisture content, are said to control the status of micronutrient cations of soils. The relative abundance of different chemical forms of these micronutrient cations varies from soil to soil, depending upon these factors.

Among various important micronutrients, iron (Fe) and zinc (Zn) are important for plant growth. It is the main component of various heme and nonheme Fe enzymes and carriers, such as cytochromes and ferredoxins. Cytochromes are respiratory electron carriers, whereas ferredoxins are involved in nitrogen fixation, photosynthesis, and electron transfer (Frossard *et al.* 2000; Fageria and Stone, 2012) [4, 3]. Iron in plants has an essential role in the development and formation of chlorophyll, maintains chloroplast structure and also improves the photosystems. Iron also helps in the formation and activation of enzymes (Weisany *et al.* 2013) [16]. It supports the process of oxidation. The process of oxidation releases energy from sugars and starches, as a result of nitrate convert to ammonia in plants. It is also involved in the metabolism of nucleic acid (Havlin *et al.* 2014) [5]. In alkaline soils, it is likely to occur in short supply, which may be inadequate to meet the requirements of cultivated crops. Several factors, including mineralization of organic matter, redox potential, degree of leaching, calcareousness, and moisture level, are said to control the

iron status of soils. Determination of most deficiencies has been based primarily on visual symptoms, field experiments, pot experiments, and plant analysis.

Similarly, Zn plays an important role in the activation of enzymes and also used in auxin metabolism, which are involved in different process including growth and development (Baligar and Fageria, 2005) [3]. Zn plays a key role in the formation of protein and amino acids. It maintains the cellular and physiological function of plants. Zinc improves grains as it is involved in pollen synthesis, their fertility and seed set processes. Zn application increases plant resistance as Zn deficient plants are susceptible to diseases. Zinc fertilization significantly enhances yield, yield components and quality related parameters of crops (Chattha *et al.* 2017) [2].

In recent years, the continued use of higher amounts of fertilizers, intensive cropping and the use of high-yielding varieties has tended to the deficiencies of micro nutrients in soil and a number of crops have been found to respond favourably to the application of iron and zinc. The use of chemical fertilizers, which are commonly used at present for supplying major plant nutrients, is likely to encourage or depress the availability of other nutrients as well.

The growth of a plant depends on many factors, among which nutrient supply, rate of absorption, distribution of nutrients to functional sites and the degree of mobility within the plants are important. Mutual antagonistic interaction between the micronutrients as well as with certain macronutrient either in soils or at the absorption sites or within the plant are well documented (Tiwari *et al.* 1976; Takkar *et al.* 1976) [14, 13]. The application of macro and micronutrients is recommended to ameliorate their deficiencies. Nutrient interactions in soils and plants are to be expected unless available nutrient contents are monitored through regular soil and plant analysis programs. Keeping in mind the facts stated above, the current study was conducted to investigate the effect of iron and zinc on oat crop yield and uptake in alluvial soil of western Uttar Pradesh.

Materials and Methods

The effect of iron (Fe) and zinc (Zn) on oat yield and uptake was studied in a pot experiment using four levels of Fe ($F_0 = 0$, $F_1 = 3$, $F_2 = 6$, and $F_3 = 9$ mg kg⁻¹) and Zn ($Zn_0 = 0$, $Zn_1 = 3$, $Zn_2 = 6$, and $Zn_3 = 9$ mg kg⁻¹). The experiment was conducted in a factorial randomised block design with three replications. The soil for this experiment was collected from the surface (0-15 cm) of a field of C.C.R. (P.G.) College farm, Muzaffarnagar. The collected soil was crushed with a wooden hammer and sieved through a 2 mm sieve before use. The required earthen pots of similar size and shape were selected, cleaned, and lined with polythene sheets. After mixing the soil thoroughly, 10 kg of soil was filled in each pot. Iron and zinc were applied through iron chelate and zinc sulphate, respectively. The basal doses of nitrogen and potassium (60 mg kg⁻¹ N and 30 mg kg⁻¹ K₂O) were applied through urea and potassium sulphate at the time of sowing. At an appropriate moisture level, the soil of each pot was pulverised and seeded with 10 seeds of oat on November 20. The plants were thinned to five when they attained a height of 5–10 cm. The plants in pots were

irrigated with deionized water as and when required. The plants were grown up to maturity. At harvest, the yield of grain and straw was recorded separately.

The pH, electrical conductivity (EC), organic carbon (OC) content, and calcium carbonate (CaCO₃) content of the soil were determined using standard procedures given by Jackson (1967) [7]. Available Fe and Zn were determined using the method described by Lindsay and Norvell (1978) [8]. Calcium carbonate was determined by Piper's (1950) [10] rapid titration method. Organic carbon was determined by the Walkley and Black (1934) [15] chromic acid digestion rapid titration method.

The straw and grain samples were analysed for Zn and Fe. The samples were wet digested with a nitric and perchloric acid mixture as outlined by Johnson and Ulrich (1959) [7]. The Zn and Fe in acid extract were determined by adopting standard methods. The uptake of nutrients by plants was calculated by multiplying their content values with the corresponding dry matter yield. The physico-chemical properties of the soil used for the experiment are given in table 1.

Table 1: Physico-chemical properties of the soil.

pH	EC (dSm ⁻¹)	CaCO ₃ (%)	Organic carbon (%)	Available Zn (kg ha ⁻¹)	Available Fe (mg kg ⁻¹)	Sand (%)	Silt (%)	Clay (%)	Soil texture
7.6	0.08	0.25	0.50	0.68	3.2	60.0	19.7	19.9	Sandy loam

Results and Discussion

Yield

The grain and straw yield of the oat crop increased significantly with the Fe application up to Fe₂ level over control (table 2). Both the levels of Fe₁ and Fe₂ of Fe proved significantly superior over control in respect of oat yield. The maximum grain and straw yields (7.32 and 11.70 g pot⁻¹) were recorded under Fe₂ treatment of Fe. The percent increase in grain and straw yield due to Fe₁ and Fe₂ over control was 1.1 and 3.1 and 5.0 and 2.1, respectively. The highest dose (Fe₃) of Fe significantly decreased the grain and straw yield of oat as compared to Fe₀, Fe₁, and Fe₂

treatments. These results are similar to the findings of Shukla (1987) [12].

The yield was increased with increasing doses of Zn up to Zn₂ level, thereafter, a significant reduction in grain and straw yield was noticed at Zn₃ treatment over Zn₂ treatment of zinc. However, the yield obtained due to Zn₃ treatment was significantly higher than those of Zn₀ treatment. The percent increase in grain and straw yield over Zn₀ treatment were 10.2 and 7.6, 15.2 and 14.0, 11.0 and 11.4 at the treatment of Zn₁, Zn₂, and Zn₃ of Zn, respectively. Shukla (1987) [12] also reported the similar results.

Table 2: Effect of Fe and Zn levels on yield (g pot⁻¹) and uptake (mg kg⁻¹) of oat crop.

Treatment	Yield		Uptake			
	Grain	Straw	zinc		Iron	
			Grain	straw	Grain	Straw
Fe levels						
Fe ₀	6.97	11.45	219.97	224.4	266.02	383.40
Fe ₁	7.05	11.65	218.27	220.12	273.92	292.62
Fe ₂	7.32	11.70	214.17	218.05	278.90	409.45
Fe ₃	6.37	10.90	210.65	214.85	273.80	389.57
SE±	0.06	0.11	0.041	0.054	0.05	0.032
CD (P=0.05)	0.12	0.22	0.083	0.132	0.13	0.077
Zn levels						
Zn ₀	6.35	10.50	215.20	216.45	270.02	243.00
Zn ₁	7.00	11.30	216.85	219.42	272.50	417.07
Zn ₂	7.32	12.20	216.45	219.75	276.87	422.42
Zn ₃	7.05	11.70	215.80	219.95	270.25	422.42
SE±	0.06	0.11	0.041	0.05	0.05	0.032
CD (P=0.05)	0.12	0.22	0.83	0.132	0.13	0.077

Uptake

The application of Fe significantly increased the Fe uptake by oat grain and straw was recorded up to Fe₂ treatment of Fe (table 2). Different rates of Zn *viz.* Zn₁ and Zn₂ application enhanced the uptake of Fe, which was increased

from 270.02 (Zn₀) to 276.87 (Zn₂) in grain and from 243.00 to 422.42 in straw. The increasing levels of Zn up to Zn₂ improved the Fe uptake by oat grain and straw and the maximum Fe uptake was observed at Zn₂ treatment of Zn. Similar results also reported by Prasad and Singh (1985) [11]

and Mukhi and Shukla (1987) [9]. However, Shukla (1987) [12] reported that the uptake of Fe increased up to 5 mg kg⁻¹ of applied Zn and decreased thereafter.

The increasing levels of Fe application significantly decreases the uptake of Zn by grain and straw of oat showing antagonistic effect of Fe on Zn utilization by grain and straw (table 2). The application of Zn in different levels increased the Zn uptake by both grain and straw of oat significantly. Similar values were also reported by Shukla (1987) [12].

Interaction effect

The interaction of Fe and Zn had a significant effect on the grain and straw yield of oat (table 3). The grain and straw

yields of oats were increased when these two elements were applied in combination. The maximum yield of oat grain and straw was recorded under Fe₂ + Zn₂ treatment. The higher level of Fe (Fe₃) showed an antagonistic effect on the grain and straw yield of oat.

The interaction effect of Fe and Zn was significant on Zn content in oat grain (table 4). The Zn content in oat grain was decreased with the increasing of Fe applied. All the treatment of Fe showed an antagonistic effect on the utilization of Zn by oat grain under all the levels of Zn. The maximum value of Zn content in oat grain was noticed with the Fe₀ + Zn₃ treatment combination. However, the minimum value of Zn content in oat grain was recorded under the Fe₃ + Zn₀ treatment combination.

Table 3: Interaction effect of Fe and Zn on oat grain and straw (g pot⁻¹) yield.

Fe levels (mg kg ⁻¹)	Grain				Straw			
	Zn ₀	Zn ₁	Zn ₂	Zn ₃	Zn ₀	Zn ₁	Zn ₂	Zn ₃
Fe ₀	6.1	7.1	7.4	7.4	10.3	11.2	12.3	12.0
Fe ₁	6.5	7.0	7.6	7.1	10.8	11.6	12.4	11.8
Fe ₂	6.7	7.4	7.7	7.5	10.3	11.7	12.6	12.2
Fe ₃	6.1	6.6	6.6	7.2	10.6	10.7	11.5	10.8
SE±	0.7				0.11			
CD (P=0.05)	0.13				0.23			

Table 4: Interaction effect of Fe and Zn on Zn content in grain of oat (mg pot⁻¹).

P levels (mg kg ⁻¹)	Zn levels (mg kg ⁻¹)			
	Zn ₀	Zn ₁	Zn ₂	Zn ₃
Fe ₀	40.0	44.0	49.0	52.0
Fe ₁	39.0	43.0	46.0	49.0
Fe ₂	38.0	41.0	43.0	46.0
Fe ₃	36	33.0	41.0	43.0
SE±	1.14			
CD (P=0.05)	2.25			

Conclusion

It may be concluded that the application of Fe is beneficial only up to Fe₂ (6 mg kg⁻¹) for yield and uptake of oat. The yield was increased with increasing doses of Zn up to Zn₂ level, thereafter, a significant reduction in grain and straw yield was noticed at Zn₃ treatment. The increasing levels of Fe application significantly decreases the uptake of Zn by grain and straw of oat showing antagonistic effect of Fe on Zn utilization by grain and straw. The application of Zn in different levels increased the Zn uptake by both grain and straw of oat significantly. The maximum yield of oat grain and straw was recorded under Fe₂ + Zn₂ treatment. The higher level of Fe (Fe₃) showed an antagonistic effect on the grain and straw yield of oat.

Acknowledgement

The author is thankful to Dr. Chaman Singh, Professor, Deptt. of Agricultural Chemistry, RSM (PG) College, Dhampur, Bijnore (UP) for providing the data for this article.

References

- Baligar VC, Fageria NK. Soil aluminium effects on growth and nutrition of cacao. *Soil Sci. Plant Nutri*,2005;51(S):709-713.
<https://doi.org/10.1111/j.1747-0765.2005.tb00097.x>
- Chattha MU, Hassan MU, Khan I, Chattha MB, Mahmood A, Nawaj M, *et al.* Biofortification of wheat cultivars of combat zinc deficiency. *Plant Sci*,2017;8:281.
- Fageria NK, Stone LF. Micronutrient deficiency problems in South America. In: Alloway, B.J., editor, *Micronutrient deficiencies in global crop production*. Springer, Dordrecht, Netherlands, 2012, 245-266. Doi: 10.1007/978-1-4020-6860-7-10
- Frossard E, Bucher M, Machler F, Mozafar A, Hurrel R. Potential for increasing the contents and bioavailability of Fe, Zn and Ca in plants for human nutrition. *J. Sci. Food and Agriculture*,2000;80(7):861-879.
- Havlin JL, Tisdale SL, Nelson WL, Beaton JD. *An Introduction to Nutrient Management* (8th Ed.) Pearson Upper Saddle River, New Jersey, USA, 2014, 505.
- Jackson ML. *Soil chemical analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, 1967.
- Johnson CM, Ulrich A. *Analytical methods for use in plant analysis*. Calif. Agric. Stat. Bull, 1959, 766.
- Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*,1978;42:421-428.
- Mukhi AK, Shukla UC. Iron and zinc relationship in rice grown in submerged soils. *J. Indian Soc. Soil Sci.*, 35:685-689.
- Piper CS. *Soil and plant analysis*. The University of Adelaide, Australia, 1950.
- Prasad BR, Singh B. Zinc- iron interaction in rice crop due to application of their EDTA complex. *J. Indian Soc. Soil Sci.*,1985;33:201-203.
- Shukla LM. Effect of zinc and iron application on micronutrients nutrition of rice. *J. Indian Soc. Soil Sci.*,1987;35:322-324.

13. Takkar PN, Bansal RL, Mann MS, Randhawa NS. Micronutrient status of soils and wheat crop of Punjab. *Fertilizers News*,1976:21(8):47-51.
14. Tiwari KN, Pathak AN, Upadhyay RL. Studies on Fe and Zn nutrition of rice at varying moisture regimes in a black clay soil of Uttar Pradesh. *J. Indian Soc. Soil Sci*,1976:24(3):303-307.
15. Walkley A, Black TA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*,1934:37:29-38.
16. Weisany W, Raei YY, Allahverdipoor KH. Role of some of mineral nutrients in biological nitrogen fixation. *Bull. Environ. Pharma. Life Sci.*,2013:2(4):77-84.
17. White PJ, Broadley MR, Gregory PJ. Managing the Nutrition of Plants and People. *Applied and Environmental Soil Science*, 2012. doi.org/10.1155/2012/104826.