

The Effect of Potassium and Zinc Application on Resistant to Lodging of Two Wheat Cultivars

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ABSTRACT

Wheat is one of the main resources of human food. Lodging is one of the most important factors that occurs in various regions and reduces wheat growth and yield. Therefore to study the effect of potassium and zinc application on resistant to lodging of two wheat cultivars, an experiment in a split-plot arrangement based on randomized complete block design (RCBD) in three replications was conducted in Dezful Agricultural Research Station at 2013-2014. The main plot was the use of the micronutrient zinc at three levels (0, 30, and 60 kg.ha⁻¹ of zinc sulfate), and the sub plot was potassium application at four levels (0, 100, 200, and 400 kg.ha⁻¹ of potassium sulfate). The results showed that zinc and potassium application increased their absorption by 90.34% and 34.96%, respectively, compared to the control. Moreover, the fiber content was 5.89% more compared to the control. Application of these elements had no significant effects on cellulose content, although its content was 3.47% higher than the control. The lignin content also rose by 60.51% compared to the control, and zinc at 30 kg.ha⁻¹ and potassium at 400 kg.ha⁻¹ reduced lodging percentage.

Keywords: Cellulose, Dezful, Fiber, Lignin, Planting, Stem

INTRODUCTION

With respect to production and area under cultivation, wheat is the fourth most important agricultural product in the world (FAO, 2004). Lodging in wheat (*Triticum aestivum* L.) is mainly observed in the final stages of its growth and development, and is increased by wind and storm at panicle emergence (Berry *et al.*, 2013). The intensity of lodging damage varies depending on the growth stage, and up to 40% of the yield may be lost because of lodging (Kelbert *et al.*, 2004). Researchers have stated that potassium deficiency in wheat reduces the growth of cambium in the stems and restricts formation of phloem and xylem tissues. Therefore, potassium deficiency weakens plant structural tissues and makes it vulnerable to lodging caused by factors such as wind and storm accompanied by rain (Malakouti, 2007).

Wheat is one of the sensitive plants to zinc deficiency. This element forms part of the structure of enzymes and is indirectly involved in lignin formation by activating energy generating and metabolic enzymes (Marschner, 1995). Peroxidase is one of the enzymes in

the activation of which zinc is involved. This enzyme plays a key role in cooperating with the enzyme catalase in photorespiration and in the glycolysis pathway in chloroplasts. Both zinc and copper are present in this enzyme (the copper-zinc peroxidase). Although the role played by zinc in peroxidase is not clear yet, the activity of this enzyme under conditions of zinc deficiency is much less than normal (Walker *et al.*, 1981). Peroxidases are abundant in stem and root cell walls. There is considerable evidence suggesting peroxidases present in cell walls play a role in the formation of lignin (Marschner, 1995).

Weaker fibers are formed in wheat when potassium level is low. Moreover, potassium is indirectly used in the structure of fibers and has an indirect influence on fiber length and strength (Cassman *et al.*, 1990). There are many unresolved issues concerning lodging. As for nutrition, the most important questions are the way macro- and micronutrients are provided, and the effects they have on lodging. Moreover, considering the frequent occurrence of wind and storms at panicle emergence, suitable strategies against lodging and cultivars resistant to lodging must be evaluated. This research tried to minimize the harmful effects of lodging on yield through potassium and zinc application.

MATERIALS AND METHODS

The main plot consisted of zinc micronutrient at three levels (0, 30, and 60 kg.ha⁻¹), and the subplot were potassium sulfate at four levels of 0, 100, 200, and 400 kg.ha⁻¹. Before planting, soil samples were taken from the depths of 0-30 centimeters, and soil physical and chemical characteristics were determined. Each plot consisted of 12 rows in four 60 cm ridges each 2 m long. Nitrogen fertilizer was applied at the customary rate in the region, and zinc and potassium were applied before planting. The treatments were as follows:

- T_1 : Soil potassium content + soil zinc content
- T_2 : Soil potassium content + 30 kg.h⁻¹ zinc sulfate
- T_3 : Soil potassium content + 60 kg.h⁻¹ zinc sulfate
- T_4 : 100 kg.h⁻¹ potassium sulfate + soil zinc content
- T_5 : 100 kg.h⁻¹ potassium sulfate + 30 kg.h⁻¹ zinc sulfate
- T_6 : 100 kg.h⁻¹ potassium sulfate + 60 kg.h⁻¹ zinc sulfate
- T_7 : 200 kg.h⁻¹ potassium sulfate + soil zinc content
- T_8 : 200 kg.h⁻¹ potassium sulfate + 30 kg.h⁻¹ zinc sulfate
- T_9 : 200 kg.h⁻¹ potassium sulfate + 60 kg.h⁻¹ zinc sulfate
- T_{10} : 400 kg.h⁻¹ potassium sulfate + soil zinc content
- T_{11} : 400 kg.h⁻¹ potassium sulfate + 30 kg.h⁻¹ zinc sulfate
- T_{12} : 400 kg.h⁻¹ potassium sulfate + 60 kg.h⁻¹ zinc sulfate

During the growing season, cultural practices such as irrigation were performed and mechanical and chemical (using 2, 4-D) weed control was carried out. Laboratory measurements including stem cellulose, lignin, potassium, and zinc contents were made at wheat maturity. The ADF method was used to measure stem lignin and cellulose contents with a Fiber Tech™ machine (model Foss 2010) (AOAC, 2009). Results were analyzed using SPSS, and mean comparisons was performed employing Duncan's multiple range test. Diagrams were drawn using Excel.

RESULTS

Table 1 shows soil characteristics at the experimental site. Zinc and potassium sufficient levels were determined to be 1 and 375 mg.kg⁻¹ of the soil of wheat grown farms in the region, respectively. Although about 200 mg.kg⁻¹ of soil has been adopted as the sufficient potassium level for cereals grown in loamy soils, the sufficient level determined for the region was 168 mg.kg⁻¹ of soil (Hosseini, 1997). The soil at the experimental site was clay loam and calcareous to some extent. Analysis of variance the experimental data indicated that the effects of the potassium treatment on lignin content and the effects of the zinc treatment on percentage of lodging were significant at 5% level of probability. Furthermore, the mutual effects of zinc and potassium application on zinc and fiber contents were also significant at 1% probability level (Table 2).

Table 1. Analysis of soil characteristics in the experimental site

N	P(Av.)	K(Av.)	Zn	Clay	Silt	Sand
(%)	(mgkg ⁻¹)	(mgkg ⁻¹)	(mgkg ⁻¹)	(%)	(%)	(%)
0.074	10.38	168	80	31	50	29

Table 2. Analysis of variance for different measured characteristics

Sources of variation	Df	Mean square					Lodging percentage
		Zn	K	Fiber	Cellulose	Lignin	
K treatment	3	32.705**	880.454**	20.324**	5.43**	499.45*	4863.417**
Zn treatment	2	0.477**	44.276*	1.306**	290.004**	290.004**	51.5*
Zn*K treatment	6	0.292*	19.959**	0.174*	40.673**	35.413**	101.833**
Experimental error	24	0.108	2.962	0.303	6.306	5.199	30
Total	36	92.16	41124.513	51638.919	466.608	7870.024	12879

The symbols ** and * represent significant at the 1% and 5% levels of probability, respectively.

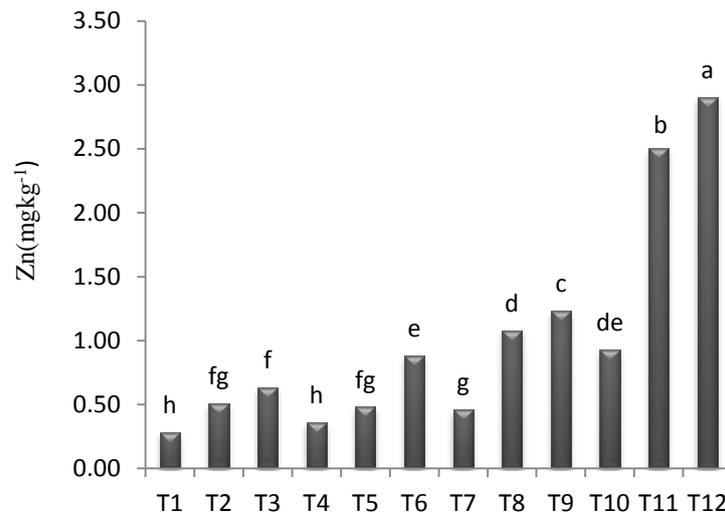


Figure 1. Interaction effects of various rates of zinc and potassium fertilizers on zinc absorption in wheat

The effects of zinc and potassium fertilizers on zinc absorption were significant (Figure 1). The maximum zinc absorption by wheat plants, which was 90.34% more than the control, belonged to T₁₂ (Figure 1).

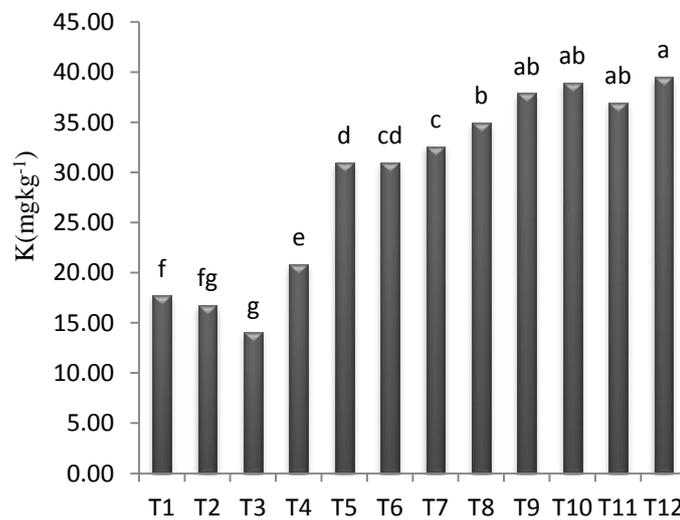


Figure 2. Interaction effects of various rates of zinc and potassium fertilizers on potassium absorption in wheat

Applying potassium and zinc sulfate at T₁₂ amounts raised potassium absorption by 54.40% more than the control compared treatment (Figure 2).

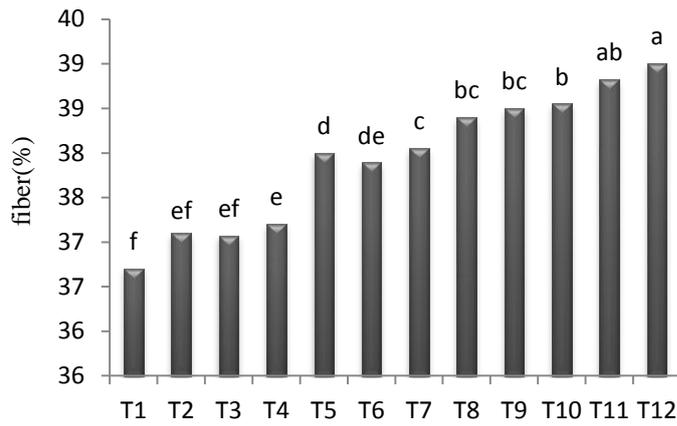


Figure 3. Interaction effects of various rates of zinc and potassium fertilizers on Fiber percentage in wheat

Interaction effects resulting from applying various rates of potassium and zinc fertilizers indicated that the maximum fiber percentage (which was 5.89% more than the control) belonged to T₁₂ treatment (Figure 3).

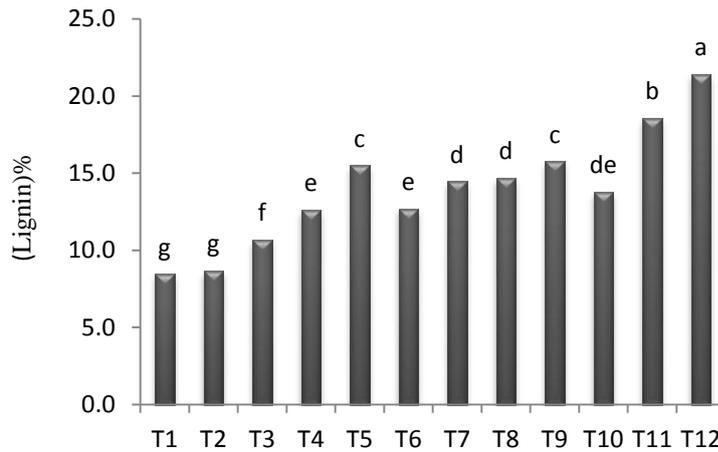


Figure 4. Interaction effects of various rates of zinc and potassium fertilizers on Lignin percentage in wheat

Applying potassium and zinc sulfate at T₁₂ amounts raised potassium absorption by 60.51% more than the control treatment (Figure 4).

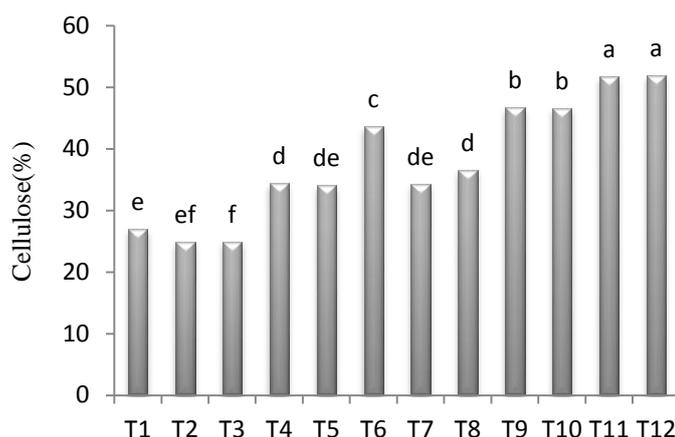


Figure 5. Interaction effects of various rates of zinc and potassium fertilizers on Cellulose percentage in wheat

Interaction potassium and zinc sulfate at T₁₂ treatment raised potassium absorption by 48.02% more than the control (Figure 5).

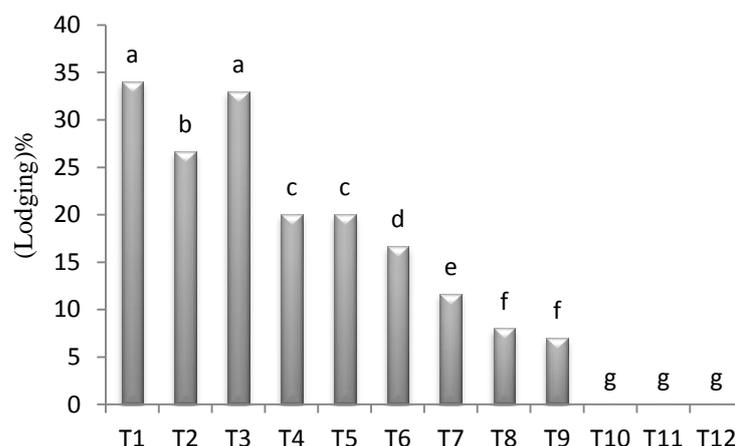


Figure 6. Interaction effects of various rates of potassium and zinc fertilizer on lodging percentage in wheat

Comparison of the interaction effects related to applying potassium and zinc fertilizers at various rates indicated that lodging in T₁₀, T₁₁ and T₁₂ (with potassium fertilizer at 400 kg.h⁻¹) reached to zero percentage. Results showed that there were no significant differences between treatments T₁ and T₃, T₄ and T₅, T₈ and T₉, T₁₀ and T₁₁ and T₁₂. T₂ treatment showed a decrease of 27.53% (in lodging) compared to the control and T₃ a 19.21% rise (in lodging) compared to T₂ (Figure 6).

DISCUSSION

Liebhart and Manson (1976) reported that potassium reduced lodging in corn, but the physiological reasons for this reduction have not been clarified yet. Furthermore, in 1965, they showed that potassium deficiency increased root weakness, reduced stem parenchymal consolidation, and caused stem lodging in corn. In a study on potassium fertilizer application in rice, it was found that potassium deficiency reduced stem growth, strength, and diameter

leading to increased lodging. It was also observed that potassium application could decrease lodging resulting from high rates of nitrogen application (Bhiah *et al.*, 2010).

Applying zinc fertilizer at 10 kg⁻¹ to the surface of the soil, and especially spraying it at 5 kg⁻¹ on wheat plants, increased total dry matter content and stem diameter (Bukvic, 2003). In a study conducted on corn, it was found that applying fertilizers containing zinc under conditions of zinc deficiency increased zinc content the most in the stems, with leaves showing the second highest rise in zinc content, and the roots exhibiting the least increase in zinc content (Hangand *et al.*, 2007). In a research on four types of wheat stems in various cultivars, it was found that cellulose was more capable to resist lodging compared to lignin (Berry *et al.*, 2013). Results showed that cellulose was the important compound in resistance to lodging. Therefore, potassium deficiency weakens plant structural tissues and makes it susceptible to lodging by factors such as wind and storms accompanied by rain. In wheat, as in other cereals, potassium deficiency reduces stem strength resulting in lodging, which will lower yield (Navabi, 1998). Results of simultaneous application of 0.5% Zn, 0.5% K, and 0.5% N, had the greatest effect on number of panicles, number of tillers, and plant height. However, plant height, number of panicles, and number of tillers per unit area declined if only 0.5% K was applied (Defan *et al.*, 1999). These findings conform to those of previous research (Narang *et al.*, 1997) that showed potassium acted as a modifier when N and P contents were high and raised yield (Gul *et al.*, 2011). The undesirable effects of zinc deficiency appear in meristematic tissues (that is, in the main locations of cell division and elongation) (Broalley *et al.*, 2007). At such times, tissues are in great need of zinc, especially for protein synthesis (Chauhan *et al.*, 2006). Zinc is a structural constituent of many enzymes (Hacisalihoglu *et al.*, 2003). Application of zinc increases activities of the enzyme peroxidase leading to more lignin production because phenolic compounds required for lignin formation are released into cell apoplast. H₂O₂ is also needed in lignin formation, which is produced from the oxidation of NADH present in cytoplasmic membrane (and this oxidation is catalyzed by another peroxidase). This lignin formation damages cell walls and makes them woody. Phenolic compounds accumulate in cells and are released into the solution outside the cells (Marschner, 1995; Olsen, 1980). Herbaceous stems also vary in their resistance to breaking but available physiological data is insufficient to explain this variance. The relationship between lignin and lodging was studied many years ago. Welton (1928) stated that lignin played an important physiological role and could strengthen cell walls and make plants resistant to lodging. High lignin content prevents decomposition and removal of compounds, maintains sufficient water pressure in cells, and makes plants resistant to lodging. Vascular bundles of lignified sheaths and stem skeletonization are factors that support plants. Since parenchyma is the main constituent of stem tissues, cells in middle internodes may be lignified and the cell walls may thicken and form part of the node (Herman, 1984). Results of research conducted on barley (*Hordeum vulgare* L.) with the purpose of studying the reasons for stem brittleness, and of determining the degree of stem bending with increased cell wall thickness, indicated that the cellulose content of cell walls in stems resistant to breaking was 6-6.4% more compared to cell walls in brittle stems. There was a correlation between maximum bending and cellulose content but not between maximum bending and non-cellulose compounds. Brittle stems had less cellulose compared to stems resistant to breaking (Kokubo *et al.*, 1989).

A positive correlation was reported in barley between cellulose content of stem cell walls and the maximum resistance to stem bending. Moreover, there was a correlation between lodging and cell wall thickness and sclerenchyma thickness (Zuber *et al.*, 1999).

Zinc and potassium application improved wheat characteristics such as fiber percentage, lignin percentage, and cellulose content. Moreover, increased their contents in stems. Of course, the increase in zinc content was negligible but the rise in potassium content was considerable. It seems potassium application caused zinc accumulation in plant organs, while zinc application had less effect in increasing plant potassium content but, in the end, increased plant zinc content that was used in seeds. Simultaneous zinc and potassium application raised their absorption by 90.34 and 54.40%, respectively, compared to the control (Figures 1 and 2). Tandon (1992) referred to the role played by potassium in increasing zinc concentration in plants and to increases in potassium efficiency that are caused by zinc.

Applying various rates of potassium and zinc fertilizers showed that the maximum wheat fiber content belonged to T₁₂ with potassium at 400 kg.h⁻¹ and zinc at 60 kg.h⁻¹, and was 5.89% more than the control (Figure 6). Therefore, simultaneous application of potassium sulfate at 400 kg.h⁻¹ and zinc sulfate at 60 kg.h⁻¹ at planting time is important in improving qualitative characteristics of wheat plant organs, and leads to increase resistance to lodging. Of course, the result of all these processes will be wheat yield increase in areas where wheat is susceptible to lodging.

CONCLUSION

Results of this experiment showed that potassium and zinc application in soils in which the contents of these two elements are below the critical levels improves structural characteristics of wheat and increases stem strength, which will lead to increase plant resistance to lodging. Therefore, based on results of this experiment, it is necessary to apply potassium sulfate and zinc sulfate at 400 kg.h⁻¹ and 30 kg.h⁻¹, respectively, to achieve wheat resistance to lodging and to obtain suitable wheat yield.

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