Effect of Zinc Fertilization and Irrigation on Grain Yield, Zinc Concentration and Quality of Cereal Species

A. Bagci[1], I. Erdal[2], I. Gultekin[1], A. Yilmaz[1], H. Ekiz[1], B. Sade[3], M.B. Torun[4] and I. Cakmak[5]

[1] Bahri Dagdas International Agricultural Research Institute, P.O.Box 125, Konya, TURKEY (abagci@selcuk.edu.tr)
[2] SDÜ Faculty of Agriculture Department of Soil Science, Isparta, TURKEY
[3] Selcuk University Faculty of Agriculture Department of Field Crops, Konya, TURKEY
[4] Çukurova University of Agriculture Department of Soil Science, Adana, TURKEY
[5] Sabanci University, Faculty of Engineering and Natural Sciences, Istanbul, TURKEY

INTRODUCTION

Zinc deficiency is a global constraint in soils occurring in many countries (Graham and Welch 1996) including Turkey where important losses in grain yield and quality were noted on calcareous soils, especially in Central Anatolia (Cakmak et al. 1999). Soil and plant samples collected in different parts of Central Anatolia showed that nearly 90% of soil samples had lower Zn concentrations than the accepted soil critical level of 0.5 mg kg^{-1}. The high soil pH, $CaCO_3$, low organic matter and low precipitation have been discussed as the main soil factors involved in widespread occurrence of Zn deficiency in the region. Zinc deficiency-related problems in crop production become more severe when plants exposed to drought stress. In this study, field experiments were conducted to study the effect of different Zn applications and irrigations on grain yield, phytate and protein concentration of different cereals under rain-fed and irrigated conditions.

METHODS

The experiments were conducted under field conditions in Konya, Central Anatolia. The effects of irrigation and Zn fertilization (0 and 14 kg Zn ha^{-1} as $ZnSO_4.7H_2O$) on grain yield, Zn concentration and grain quality (SDS sedimentation, protein and phytate concentration) were studied in two bread wheat (*Triticum aestivum*), two durum wheat (*Triticum durum*), two barley (*Hordeum vulgare*) and two triticale (*xTtriticosecale* Wittmark) cultivars which grown on a Zn-deficient field under rain-fed and irrigated conditions. The experiments were designed as a three-factor randomized complete block in split plots with four replications. The soils of the experimental site have a clay structure and low organic matter content (nearly 1 %). The soils were calcareous (42 % $CaCO_3$) with an alkaline reaction (pH = 8.3) and low DTPA-extractable Zn (0.15 mg Zn kg^{-1}).

RESULTS AND DISCUSSION

Zinc application under both rain-fed and irrigated conditions caused significant increases in grain yield. However, quality traits, namely the amount of SDS sedimentation and protein content, showed some decreases with Zn application, possibly due the dilution effects caused by marked increases in grain yield (Table 1).On average; both grain yield and Zn concentration of grains increased by nearly 60 % with Zn application under both water regimes. Under rainfed conditions, increase in grain yield by Zn was greater than the irrigated conditions with exception of barley (Table 1). Application of Zn enhanced grain Zn concentration; but simultaneously reduced grain P concentration. As expected, decreases in grain P were associated with decreases in grain phytate. Previously, it has been shown that Zn deficiency increases root uptake and root-to shoot transport of P in plants (Cakmak and Marschner, 1986). Possibly, due to this effect, Zn application into Zn deficient soil in Central Anatolia reduced root P uptake and grain deposition of P, and thus grain phytate

concentrations. Consequently, phtate/Zn ratios showed dramatic decreases (as average from 140 to 35) by Zn applications. The results of this study also demonstrated the existence of a large genotypic variation in Zn efficiency among the cereal species. Based on increases in grain yield in this study, the susceptibility of cereals to Zn deficiency under rain-fed condition increased in the following order: durum wheat > barley > bread wheat > triticale.

Table 1. Effect of soil Zn application on grain yield, grain Zn and protein concentrations and sedimentation of wheat genotypes grown on Zn-deficient calcareous soils under rain-fed and irrigated conditions in Central Anatolia.

	Rainfed			Irrigated			Difference (%)
	-Zn	+Zn	Difference (%)	-Zn	+Zn	Difference (%)	
Grain yield (kg ha^{-1})	2570	3990	55.1	3380	4950	46.6	50.3
Bread Wheat	2510	4210	67.9	3630	4990	37.7	52.8
Durum Wheat	1430	2560	79.2	2240	3900	74.5	76.8
Triticale	3230	4280	32.5	4190	5310	26.8	29.6
Barley	3130	4920	57.2	3460	5610	62.1	59.6
Protein content (%)	12.6	12.1	-3.6	12.7	11.5	-9.8	-6.7
Bread Wheat	12.4	11.9	-3.6	12.4	11.7	-5.8	-4.7
Durum Wheat	12.8	12.4	-2.5	13.0	11.5	-11.0	-6.7
Triticale	11.3	11.8	4.2	11.4	10.7	-5.5	-4.8
Barley	13.9	12.4	-10.8	14.1	11.9	-15.6	-13.2
SDS-Sedimentation (ml)	28.0	27.5	-1.5	27.5	25.1	-8.6	-5.0
Bread Wheat	40.7	37.5	-7.8	41.7	36.9	-11.5	-9.7
Durum Wheat	24.7	23.9	-3.2	23.6	21.6	-8.5	-5.9
Triticale	18.6	21.3	14.5	17.0	16.8	-1.6	6.5
Barley	0	0	0	0	0	0	0
Grain-Zn concentrations (mg kg^{-1})	9.3	14.0	50.3	8.6	14.5	68.2	58.9
Bread Wheat	8.8	12.3	39.0	7.3	12.1	65.8	52.4
Durum Wheat	9.6	14.6	52.9	9.6	14.2	48.1	50.5
Triticale	9.3	14.8	59.5	8.2	15.8	93.7	76.6
Barley	9.6	14.4	49.4	9.4	15.8	68.2	58.8

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