

Effects of Zn fertilizer on cadmium accumulation in durum wheat

Guangyao (Sam) Wang¹, Michael Ottman², and Rufus L. Chaney³

¹ School of Plant Sciences / Maricopa Ag Center, University of Arizona

² School of Plant Sciences, University of Arizona

³ Environmental Management and Byproduct Utilization Laboratory, USDA-ARS

Abstract

Proposed reduction in maximum allowable cadmium (Cd) level in wheat grain from 0.2 to 0.15 ppm by European Union (EU) could affect Arizona wheat growers substantially. The possible breeding programs and management practices needs to be developed to keep the industry competitive for this major market. In this study, we used two durum wheat cultivars (Ocotillo representing higher Cd genotypes and Havasu representing lower Cd genotypes) to study the potential of Zn fertilizer (as ZnSO₄ and ground tire rubber) to reduce Cd uptake in durum wheat at Yuma Ag Center. While cadmium level in the two varieties were different significantly, applying ZnSO₄ or ground rubber did not affect grain cadmium level, grain yield, or protein content significantly.

Introduction

Proposed reduction in maximum allowable cadmium (Cd) level in wheat grain from 0.2 to 0.15 ppm by European Union (EU) could affect Arizona wheat growers substantially. Due to the fact that most durum wheat in Arizona is exported to the EU and a significant portion of the grain contains more than 0.1 ppm Cd, the possible breeding programs and management practices needs to be developed to keep the industry competitive for this major market.

While the AZ wheat breeding program is making significant progress in lowering Cd in durum wheat, growers will still have the problem of producing durum wheat with Cd lower than 0.15 ppm consistently in some growing regions. This is due to the fact that Cd level in wheat is also affected by soil properties and management (Chaney, 2010). Therefore, it's important to look for agronomic practices specific to the soils of AZ that could reduce Cd uptake by wheat.

Cd is a heavy metal present naturally in all soils and added annually in phosphate fertilizers; normally it is strongly bound in alkaline soils and therefore has low availability for uptake by plants. However, when cadmium is dissolved from the soil, it becomes available for absorption by plants; high soil chloride promotes solubility and wheat uptake of soil Cd. Toxicity of Cd to plants is not relevant because much lower wheat Cd is required for sale than required to be phytotoxic. Low plant available Zn in soil promotes Cd uptake and also promotes toxicity of Cd to animals which ingest plant products. The risk from plant Cd is exacerbated by inadequate available supplies of zinc (Zn), calcium and iron in the diet of humans and animals.

A number of studies showed that the soil Cd and Zn concentrations as well as Cd:Zn ratio are key factors in Cd uptake by plants. Cd is actually absorbed by the root Zn transporter, so low supply of plant available Zn promotes Cd accumulation by plants. Applying Zn fertilizer inhibits Cd uptake and translocation by wheat, especially in soils with low plant available Zn. Applying a rate of 5.5 lbs/A Zn in Australia was found to reduce Cd concentration significantly in wheat produced on soil prone to Zn deficiency (Oliver et al., 1994). When the equivalent of 30 lbs/A Zn fertilizer was applied in a greenhouse experiment, Zn concentration in wheat shoot increased from 25.7 to 55.6 ppm, and Cd concentration was reduced from 0.90 to 0.09 ppm (Khoshogofar et al., 2004).

WestBred conducted research in Yuma for one year to evaluate the ability of Zn fertilizer to reduce Cd uptake in the grain of durum in an unpublished study. Cd level in the grain was reduced about 10-15% from a topdress application of zinc fertilizer at tillering at rates ranging from 2-8 times the normal agronomic rate (Kim Shantz, personal communication). Unpublished studies by Khoshogofarmanesh and Chaney showed that foliar Zn had less effect on Cd uptake and transfer to grain than did soil application of Zn to deficient soils. Although these studies

provided important information, it may be possible to reduce Cd uptake in durum grain more than the 10-15% in the WestBred study by applying Zn to the soil before planting (rather than foliar spray at tillering) to allow the fertilizer to equilibrate in the soil and incorporating the fertilizer into the soil (rather than topdressing) which allows more of the root length to be exposed to soil with higher plant available Zn.

To reduce the input cost, an alternative Zn fertilizer such as ground rubber could be used. Tire rubber is a waste with about 1.5% purified Zn, about as low in Cd as the best Zn fertilizer such as ZnSO₄ products. The rubber is a problematic waste in big cities, so use of ground rubber as a Zn fertilizer could help with rubber disposal and supply a clean source of Zn at low cost to growers. At the same time, ground rubber could provide organic matter as complex and slowly biodegraded organic materials, supply wheat with iron and sulfur, and increase soil infiltration.

Therefore, we used two durum wheat cultivars (Ocotillo representing higher Cd genotypes and Havasu representing lower Cd genotypes) to study the potential of Zn fertilizer (as ZnSO₄ and ground tire rubber) to reduce Cd uptake in durum wheat at Yuma Ag Center because soil in Yuma has highest Cd content among the major wheat-producing areas in AZ.

Materials and Methods

The experiment was conducted at Yuma Ag Center. ZnSO₄ fertilizer and ground rubber were studied separately in the same field. For each of ZnSO₄ fertilizer and ground rubber, the experiment was a split-plot design. The main plot was the fertilizer treatment and split-plot was the cultivar treatment. One month before wheat planting, four rates of ZnSO₄ fertilizer (0, 10, 20 and 30 lbs/A Zn) and four rates of ground rubber (0, 1, 2, and 3 Tons/A) was applied into the soil and field irrigated to promote equilibration of soil microbial growth and Zn fertilizer. The 1, 2 and 3 Tons/A of ground rubber corresponds to 30, 60 and 90 lbs/A of Zn, respectively (higher rates of Zn will be applied in the ground rubber because this source is slowly released/solubilized

in the soil as the rubber is biodegraded). Durum wheat cultivars with higher grain Cd (cv. Ocotillo) and lower grain Cd (cv. Havasu) was planted in the second week of January, 2011.

Prior to fertilizer application, soil samples were taken to measure baseline soil Zn and Cd level. Soil was examined for total and DTPA-extractable Cd and Zn. During the wheat growing season, foliar samples were taken at jointing and flag leaf to establish Zn and Cd uptake patterns in Arizona. Wheat grain was harvested at maturity and grain yield and quality (Cd and Zn) were analyzed. Because low levels of Cd are expected to be reached in the Zn fertilized wheat, inductively coupled plasma mass spectrometry (ICP-MS) was used to reliably measure the Cd levels in the grain; other nutrients in grain and foliar elements will be measured by ICP-atomic emission spectrometry.

Results

There were no significant interactions between variety and fertilizer treatment on all measurements, therefore the effects of variety and fertilizer are presented separately. Applying ground rubber or ZnSO₄ did not affect grain yield or protein content significantly (Table 1). The differences between Ocotillo and Havasu in grain yield and protein content were not significant, either, indicating the two varieties had similar production in the experiment.

Applying ZnSO₄ and ground rubber did not affect Zn level in the grain significantly (Table 2). Ground rubber affected Cd level in the grain, with 2 ton/a treatment having highest Cd level and 1 ton/a treatment having the lowest Cd level among the treatment. Neither ground rubber nor ZnSO₄ affected Fe level in durum grain. The reason for the response is not clear and further studies are needed to confirm the trend.

There were significant differences in grain Zn, Cd, and Fe between the two varieties. Ocotillo had higher Zn, Cd, and Fe compared to Havasu. The Cd level in Ocotillo were well above 0.2 ppm in both ground rubber and ZnSO₄ experiment, indicating this variety may not be a good choice if the grain is exported to EU. This experiment also confirmed that breeding can lead to promising varieties with less Cd uptake.

References

- Chaney, R.L. 2010. Cadmium and Zinc. In *Trace Elements in Soils* (Edited by P. Hooda). P410-439.
- Khoshgoftar, A.H., H. Shariatmadari, N. Karimian, M. Kalbasi, S.E.A.T.M. van der Zee, and D.R. Parker. 2004. Salinity and zinc application effects on phytoavailability of cadmium and zinc. *Soil Sci. Soc. Am. J.* 68:1885-1889.
- Oliver, D.P., R. Hannam, K.G. Tiller, N.S. Wilhelm, R.H. Merry, and G.D. Cozens. 1994. The Effects of zinc fertilization on cadmium concentration in wheat grain. *J. Environ. Qual.* 23: 705-711

Table 1. Grain yield and protein of two durum wheat varieties affected by ground rubber and ZnSO₄.

Experiment	Factor	Level	Grain yield (lb/a)	Grain protein (%)	
Ground rubber	Ground rubber rate	0 ton/acre	8449 a	15.41 a	
		1 ton/acre	7593 a	14.75 a	
		2 ton/acre	9094 a	14.82 a	
		3 ton/acre	8666 a	14.99 a	

	Variety	Ocotillo	8851 a	15.03 a	
		Havasu	7997 a	14.95 a	

ZnSO ₄	ZnSO ₄	0 lb Zn/acre	9135 a	15.23 a	
		10 lb Zn/acre	8247 a	14.94 a	
		20 lb Zn/acre	9563 a	14.93 a	
		30 lb Zn/acre	9879 a	14.68 a	

	Variety	Ocotillo	9351 a	15.07 a	
Havasu		9061 a	14.82 a		

Table 2. Grain Cd, Fe, and Zn of two durum wheat varieties affected by ground rubber and ZnSO₄.

Experiment	Factor	Level	Zn (ppm)	Cd (ppm)	Fe (ppm)	
Ground rubber	Ground rubber rate	0 ton/acre	44.2 a	0.177 a	28.6 a	
		1 ton/acre	41.5 a	0.147 b	27.6 a	
		2 ton/acre	40.0 a	0.178 a	28.0 a	
		3 ton/acre	39.0 a	0.176 ab	27.6 a	
	Variety	Ocotillo	41.5 a	0.237 a	28.6 a	
		Havasu	37.6 b	0.102 b	27.8 b	
	ZnSO ₄	ZnSO ₄	0 lb Zn/acre	42.1 a	0.188 a	31.0 a
			10 lb Zn/acre	44.5 a	0.201 a	28.8 a
20 lb Zn/acre			43.7 a	0.180 a	28.5 a	
30 lb Zn/acre			38.3 a	0.187 a	27.8 a	
Variety		Ocotillo	45.2 a	0.280 a	30.9 a	
		Havasu	39.2 b	0.098 b	27.1 b	