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Effects of nitrogen fertilization on heavy metal content of corn grains

Efectos de la fertilización nitrogenada en el contenido de metales pesados de granos de maíz

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Abstract. Nitrogen fertilization has played a significant role in increasing crop yield, and solving problems of hunger and malnutrition worldwide. However, excessive nitrogen inputs do not significantly increase crop yields but may lead to many serious environmental problems. The effects of nitrogen fertilization rate were studied on heavy metal content of corn grains. Our results show that nitrogen fertilization management is beneficial for reducing production costs, protecting the environment, and improving the quality of farm products.

Key words: heavy metals, nitrogen fertilization, corn grain, food safety, ICP-MS.

Resumen. La fertilización nitrogenada ha tenido un rol significativo en incrementar los rendimientos de los cultivos, y resolver problemas de hambre y malnutrición en todo el mundo. Sin embargo, la fertilización nitrogenada excesiva no incrementa los rendimientos de los cultivos significativamente sino que puede conducir a severos problemas ambientales. Los efectos de la tasa de fertilización nitrogenada se estudiaron en el contenido de metales pesados en granos de maíz. Nuestros resultados muestran que el manejo de la fertilización nitrogenada es benéfico para reducir los costos de producción, proteger el ambiente, y mejorar la calidad de productos agrícolas.

Palabras clave: metales pesados, fertilización con nitrógeno, granos de maíz, seguridad alimenticia, ICP-MS.

INTRODUCTION

Several heavy metals, especially Pb and Cd, are toxic to humans if their intake exceeds a critical value. As a result of the environment, there are heavy metals in foods, such as beverages and food drinks (Onianwa et al., 1999), edible oil (Mendil et al., 2008) and crop grains and cereals (Cuadrado et al., 2000). It is very important to (1) control the content of heavy metals and (2) find methods to control it in foods. Since 1994, China set the tolerance limits of cadmium and lead in foods (Chinese National Standard Agency, 1994a; Chinese National Standard Agency, 1994b). The EU legislation also set threshold limits for concentrations of heavy metals in foods (EC, 2002). Thus, governments have begun to pay an increased attention to food safety, regarding limits in heavy metal food concentrations. Concentrations of heavy metals in food have been shown to be closely related to heavy metal concentrations in soil (Krauss et al., 2002). Crop species, tillage systems (Lavado et al., 2001) and field management (i.e.: quality of irrigation water) (Rattan et al., 2005) can also affect food heavy metal concentrations. However, effects of nitrogen fertilization on concentrations of heavy metals in corn grain have not yet been reported.

Nitrogen fertilization is necessary for growth and development of plants. However, applications of nitrogen fertilizer have largely exceeded plant needs in China (Ju et al., 2006; Hu et al., 2006). Excessive and inappropriate nitrogen fertilizer applications can result in severe environmental and ecological problems (Hans, 2006; Ju et al., 2006; Clemens et al., 2008).

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Since 2008, there has been much attention on food safety (Cordell et al., 2009; Editorial of Soil & Tillage Research, 2009; Ni et al., 2009; Khan et al., 2009). Yield increases and crop quality are two important challenges for modern agriculture.

We investigated the effects of nitrogen fertilization on the concentration of heavy metals in corn grain. Thereafter, the relationship between nitrogen fertilizer input *versus* heavy metal level is discussed.

MATERIALS AND METHODS

Corn seeds. The corn cultivar Denghai 3719 was used, whose seeds were produced and presented by Shandong Denghai Seeds Co., Ltd.

Fertilizers. They were (1) urea (total N≥46.4%, produced by PetroChina Ningxia Petrochemical Company, Beijing xilu No. 1338, Yinchuan city of Ningxia province, P.R China); (2) superphosphate (total P_2O_5 ≥ 16%, produced by Yunnan Honglin Chemicals Co., Ltd, Kaiyuan city of Yunnan Province, R. P. China); (3) KCl (total K_2O ≥ 60% produced by Ural Potassium fertilizer joint-stock company (Berezniki city of Perm state, Russia); (4) $ZnSO_4$ ($ZnSO_4$ ≥ 95% produced by Shandong Zouping Zhenzhong Chemicals Co., Ltd., Zouping city, Shandong province of P.R. China).

Experimental procedures

Field management

Field experiments were carried out at the Shangzhuang experimental station, China Agricultural University, Beijing, from 25 April to 20 September 2007. Individual plants were planted at a rate of 100 000/hm^2. Every treatment was repeated four times.

Physico-chemical soil properties can be found elsewhere (Hu et al., 2006).

Fertilization scheme

P fertilizer, K fertilizer and Zn fertilizer were applied as basal fertilizer. One third of N fertilizer was applied as basal fertilizer before planting, and 2/3 of N fertilizer was applied as topdressing fertilizer on 12th June.

Table 1. Fertilization scheme of N fertilizer (kg/ha).
Tabla 1. Esquema de fertilización con N (kg/ha).

Fertilizer	CK	CON	OPT	OPT+30%	OPT-30%
N	0	450	160	208	112
P	90	90	90	90	90
K	80	80	80	80	80
Zn	15	15	15	15	15

The concentration of mineral nitrogen (Nmin) in basal soil before basal fertilizer application was 62 kg/ha. CK Treatment: No N fertilizer was used during the whole growth period of corn, which is the zero control; CON treatment: fertilizing according to local farmer practices; OPT treatment: fertilizing to obtain the best ratio of yield to input; OPT+30% treatment: nitrogen fertilizer input was 30% more than OPT treatment; OPT-30% treatment: nitrogen fertilizer input was 30% less than optimized treatment.

Detecting methods. Corn grain powder (0.5 g) was weighed, digested with 1.5 mL HNO_3 and 0.5 mL H_2O_2, diluted to 10 mL. The digestion procedure was as follows: 150°C for 15 min at 500 W power, 200°C for 20 min at 800 W power and 100°C for 10 min at 400 W power. Diluted solutions were subjected to analysis for Pb and Cd by ICP-MS (ELAN DRCII, PE company of USA).

Parameters of Apparatus. For parameters of Inductively Coupled Plasma (ICP) refer to Rui et al. (2007) and Chen et al. (2009): power, 1350 W; flow rate of cooling gas (Ar), 15.0 L/min; flow rate of supplemental gas (Ar), 1.80 L/min; flow rate of carried gas (Ar), 0.95 L/min. Parameters of Mass Spectrometry: vacuum of analysis room, 5.89×10^{-6} Tor r; impulse voltage, 950 V. Detection parameters: resolution (10% peak height); 0.8amu (Nor), 0.6 amu (H); retention period, 50ms; times of replication, 4; times of circulation, 10; mode of analysis, scanning of mass; period of analysis, 1.05 min; rate of sample, 1ml/min.

Stability study and standard curve. Extraction from the same sample was repeatedly injected into ICP-MS during 2 hours. RSD was less than 3% after 30 min, and less than 4% after 2 hours. This indicates that the instruments and the extracting solution were stable over a 2-hour period.

Concentrations of Cd and Pb were detected using this method. The correlation coefficients (r^2) for both standard curves was 0.9999.

Statistical analysis. Data were analyzed by one-way analysis of variance using SPSS 11.5 for Windows, and Excel (n=3).

RESULTS

Relationship between nitrogen fertilizer input *versus* Cd and Pb contents. Cadmium content in corn grain was positively related to the Napierian logarithm of nitrogen fertilizer input (Fig. 1). This indicates that nitrogen fertilizer input should be reduced to have a lower Cd content in corn grain.

Content of Pb in corn grain was negatively related to nitrogen fertilizer input (Fig. 2).

Fig. 1. Relationship between Cd concentration in corn grain and total Nmin in soil.
Fig. 1. Relación entre la concentración de Cd en granos de maíz y N mineral en el suelo.

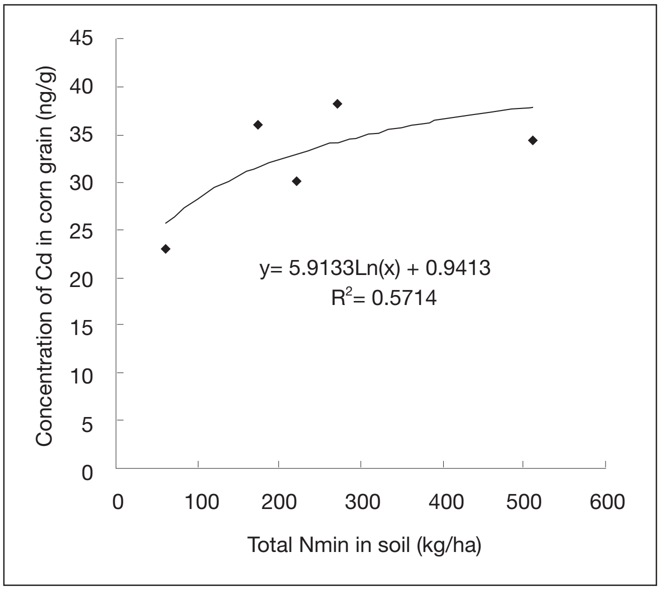
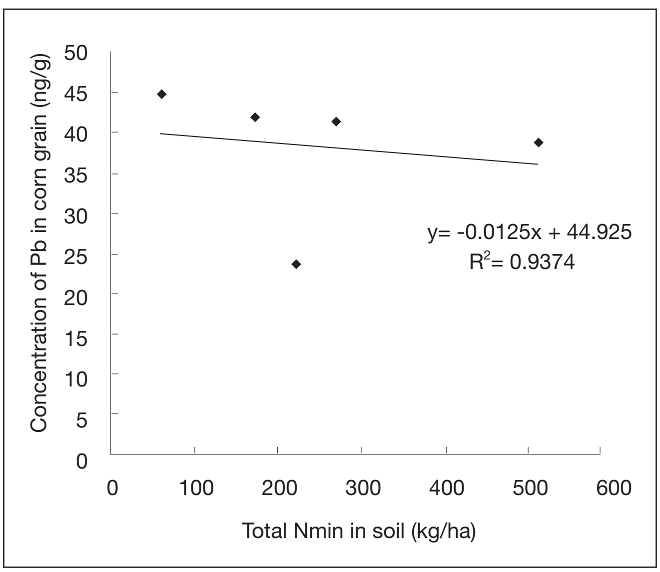


Fig. 2. Relationship between Pb concentration in corn grain and total Nmin in soil.
Fig. 2. Relación entre la concentración de Pb en granos de maíz y N mineral en el suelo.



DISCUSSION

Nitrogen fertilizer has played a significant role in increasing crop yield and solving problems of hunger and malnutrition. Ju et al. (2009) showed that excessive nitrogen inputs did not significantly increase crop yields but led to much larger N losses to the environment; this resulted in serious environmental problems (Ju et al., 2009). This implies that application rates of nitrogen fertilizer to crops, which are the same as the OPT treatment in this study, become increasingly important (Zhu, 2006). Content of Cd in corn grain was positively correlated to nitrogen fertilizer input (Fig. 1). Correlation between N fertilizer input and content of Pb in corn grain, however, was negative (Fig. 2). The OPT treatment showed a better heavy metal quality than any of other nitrogen fertilizer treatments in this study.

CONCLUSION

This study shows that managing N fertilization is beneficial for (1) reducing production costs, (2) protecting the environment, and (3) improving quality of farm products.

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