THE EFFECTS OF FARM MANAGEMENT PRACTICES

ON

CADMIUM CONCENTRATION IN WHEAT GRAIN

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX **page**

SUMMARY

Cadmium is a heavy metal that is not known to have any essential biological function in plants or animals. There has recently been concern that Cd concentrations in some Australian food products may exceed the maximum permissible concentration (MPC) set by the Australian National Health and Medical Research Council (NHMRC) for the general category of 'unspecified foods', namely 0.05 mg kg^{-1} fresh weight. Thus, in Australia the concern about Cd in wheat grain has arisen from a marketing and trade viewpoint.

In Australia, the main source of Cd in agricultural soils is phosphate fertilizers. Although the use of phosphatic fertilizers containing low Cd concentrations will minimise the input of Cd into the agricultural system it will not solve the problem of Cd uptake by grain because of the accumulation of residual Cd in the plough layer (0-10 cm). Many factors control the availability of Cd in soil for plant uptake. Among the most widely documented are soil pH, clay content and form, organic matter content and Zn concentrations in the soil. This study has focussed on the effect of the following factors on Cd concentrations in wheat grain: Zn nutrition, crop rotations, tillage practices, and soil pH in field and glasshouse experiments. The effectiveness of soil extraction procedures to correlate Cd concentration in grain and extractable soil Cd was also investigated.

Grain and soil samples were collected from thirteen field experiments located across South Australia and four field experiments located in southern Queensland. The Zn concentration in the soils at all sites was determined to be inadequate for crop growth prior to the establishment of the experiments. Zinc was applied as zinc sulphate at rates ranging from 0-20 kg Zn ha^{-1} The grain was analysed for Cd concentration and the soil samples (0-10 cm) were analysed for pH and EDTA-extractable Cd and Zn concentrations. Grain from the South Australian experiments was also analysed for

other metals using inductively-coupled plasma (ICP) analysis. This study showed that applications of Zn (approximately 2.5 - 5.0 kg ha^{-1}) to soils that had inadequate Zn concentrations for crop growth decreased the Cd concentrations in grain by up to half at some sites. The Cd concentrations in grain from the Queensland experiments were near the detection limit which made it difficult to assess any trends in Cd concentrations with increasing rates of Zn application.

Grain and soil samples were obtained for 2 years (1986 and 1987) from a rotation x stubble x nitrogen experiment at Tarlee, S.A. and for 2 years (1989 and 1990) from a rotation x tillage x fertilizer experiment at Kapunda, S.A. In the Tarlee experiment, wheat is grown every year in two phases in each of eight rotations with cereals, legumes or pasture. The three stubble treatments are stubble burning, incorporation and surface retention. Nitrogen is applied as ammonium nitrate at 0 and 40 kg ha^{-1}. In the Kapunda experiment, wheat is grown annually in a continuous wheat rotation and every second year a wheat/volunteer pasture and a wheat/lupins rotation. The three tillage systems are direct drill, reduced till and conventional cultivation. The two fertilizer treatments are low (15 kg P and 40 kg N ha^{-1}) and high (30 kg P and 80 kg N ha^{-1}).

Grain from both experiments was analysed for Cd concentrations and soil was analysed for pH and EDTA-extractable Cd. Soil from the Tarlee experiment was also analysed for $Ca(NO_3)_2$ - extractable Cd. In both years of the Tarlee experiment and the 1990 harvest of the Kapunda experiment the highest Cd concentrations in grain were found in wheat grown after lupins and generally the lowest were in wheat grown after cereal. No explanation can be offered for the observation of higher Cd concentrations in wheat grain grown after lupins.

The Cd concentrations in grain increased significantly with increasing rates of nitrogen in both the 1986 and 1987 harvests of the Tarlee experiment. However, stubble treatment had no significant effect on the Cd concentration in grain in either year. Fertilizer treatments had no significant effects on Cd concentrations in grain from the Kapunda experiment.

Raising soil pH is the most commonly recommended practice to minimize Cd uptake by plants. In this study, the interaction between soil type, applied Cd and soil pH was investigated in a glasshouse experiment. The pH of four soils, which varied in physical and chemical characteristics, was adjusted with sulphur or lime to give a range of 4 - 6 (1:5, 0.01M $CaCl_2$). Cadmium was applied in a sand matrix to give a range from 0 - 2.7 mg Cd kg^{-1} soil. Cd concentrations in grain and plant material were determined on all replicates and soil pH, EDTA-, $CaCl_2$- and $Ca(NO_3)_2$-extractable Cd concentrations were measured on one-half of the replicates.

Raising soil pH decreased Cd concentrations in grain grown on three of the four soils used in the glasshouse experiment (a Typic Rhodoxeralf, a Natric Palexeralf and a Mollic Palexeralf). However on a Sodic Haploxerert, the Cd concentration in grain did not change significantly with increasing soil pH. The Cd concentrations in grain were found to decrease following the addition of S at the highest Cd treatment (2.7 mg Cd kg^{-1}) on the Sodic Haploxerert.

The effects of soil pH on Cd concentration in grain were also assessed in the field. Grain and soil samples were obtained from eight experiments in the Wagga Wagga, NSW and Rutherglen, Vic. regions. Sulphur and lime had been added to adjust soil pH to give a range from 4 - 6. Cadmium concentrations in grain, soil pH and EDTA-extractable Cd were measured on one-half of the replicates.

The responses of Cd concentrations in grain to raising soil pH in field experiments was extremely variable between sites and between seasons at individual sites. Consequently, the common recommendation of raising soil pH to decrease Cd concentrations in grain is not always valid and further studies are required to determine the factors that influence whether a decrease in Cd concentration of grain will occur following the application of lime under field conditions.

Three extraction procedures were studied to assess the correlation between Cd concentration in grain and extractable soil Cd with the view of using an extraction procedure for predicting Cd concentrations in wheat grain. The extractants were EDTA, $Ca(NO_3)_2$ and $CaCl_2$. These three extractants were chosen because they have been used by many other researchers but seldom compared, and they extract different fractions of soil Cd. Generally there was a poor relationship between EDTA-extractable Cd and Cd concentrations in grain. The only exception to this was the regression between Cd concentration in grain and EDTA-extractable Cd for each individual soil used in the glasshouse experiment when all Cd treatments were considered. The positive correlation was most likely due to the wide range of soil Cd concentrations covered.

There was a good relationship between $CaCl_2$- and $Ca(NO_3)_2$-extractable Cd and Cd concentrations in grain grown on two soils in the glasshouse experiment (Mollic Palexeralf and Natric Palexeralf). The correlation for both extractants was poor for plants grown on the Sodic Haploxerert, which was most likely due to the absence of any change in Cd concentration in grain with increasing pH of this soil. Of the three extractants studied, $CaCl_2$ and $Ca(NO_3)_2$ showed the best correlations with Cd concentrations in grain. However, more work is required with a wider range of soil types to ascertain the effectiveness of the extractants to predict Cd concentrations in grain.

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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