Management factors that affect cadmium uptake by wheat grain

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Summary. The Cd concentrations in grain from two harvests of Interstate Wheat Variety trials varied greatly between varieties and between sites. The highest grain concentrations were found in some of the newer varieties compared with some more commonly grown varieties. Further higher grain Cd concentrations were found in wheat grown in sites with low pH and lighter textured soils. Crop rotation had highly significant (P<0.00 I) effects on grain Cd concentrations. The highest grain concentration at both sites in this study (Tarlee and Kapunda) was in wheat grown after lupins.

Introduction

Cadmium (Cd) concentrations in cereals have recently become a concern in Australia. Although the Cd concentrations in Australian cereals do not pose a health risk they are of concern from a marketing viewpoint because the maximum permissible concentration of Cd in grain, (0.05 mg/kg), which is set by the National Health and Medical Research Council, is relatively low and may be exceeded under some circumstances (5). The main source of Cd in Australian agricultural soils is phosphatic fertilisers. The amount of Cd in phosphatic fertilisers depends mainly on the concentration of Cd in the parent phosphate rock (1 I).

Although the use of low Cd-fertiliser will minimise further additions of Cd to the soil it will not solve the problem of uptake of residual Cd if it is available to plants. Consequently the only course of action available to farmers to minimise uptake of residual Cd is to manipulate farm management practices. However, there is little published information and experience relating to the influence of farm management practices on Cd uptake by cereals. This work investigated Cd concentrations in Australian wheat varieties from nationwide trials, and also the effect of crop rotations on Cd concentrations in wheat, *(Triticum aestivum),* grain.

Methods

Effects of crop rotations on grain Cd concentrations

Two field experiments established at sites 80 km to the north and north-east of Adelaide, South Australia, were the basis of this study. Grain from a rotation x stubble management x nitrogen experiment at Tarlee and a rotation x tillage x fertiliser rate experiment at Kapunda were analysed for Cd concentration. The former experiment was established by the South Australian Department of Agriculture and the latter was established by CSIRO Division of Soils. Grain from two replicates of two harvests (1986 and 1987) of the Tarlee experiment and from three replicates of the 1990 harvest of the Kapunda experiment were analysed. Further details of both experiments are given elsewhere (8,10).

Varietal differences in Cd accumulation

Grain from the B series of the Interstate Wheat Variety (IWV) trials was obtained from the Bread Research Institute, Sydney NSW. Two harvests (1988 and 1989) consisting of approximately 15 varieties from approximately 14 sites were analysed.

Cd analysis

The digestion procedure was adapted from a method developed by the Victorian State Chemistry Laboratory (9). Duplicate analyses were made on one third of the samples from the Tarlee and Kapunda experiments and on all samples from the IWV trials. To check the reproducibility of the analytical procedure two samples of wheat flour (National Bureau of Standards No. 1567a) were included in every third batch. The expected Cd concentration for this sample was 0.026 ? 0.002 mg/kg and the mean value obtained from ten separate batches was 0.024 ? 0.002 mg/kg. Further details are given in (7).

Soil sampling and analysis

Eight and ten cores of soil were collected at Tarlee (0-10 cm) and Kapunda (0-5 cm), respectively, across each plot, bulked and air-dried at 40?C. The soils were then sieved to pass a 2 mm mesh screen and mixed well before being sub-sampled. pH measurements (1:5, 0.0IM CaCl2) were made on all replicates of the Tarlee soils but only on the "high" fertiliser treatment of the Kapunda soils. Soil from all replicates from both Tarlee and Kapunda were extracted with EDTA (3) and the extractions were analysed on a flame atomic absorption spectrophotometer for Cd. A bulked soil sample collected across each IWV trial site was used for pH measurements and EDTA extractions.

Results and discussion

Effects of crop rotations on grain Cd concentrations

The mean Cd concentrations (mg/kg) in grain from Tarlee were calculated across three stubble treatments and two or three nitrogen rates in 1986 and 1987, respectively. The mean grain concentrations for 1986 and 1987 for four of the eight crop rotations are shown in Fig. 1. Crop rotation had highly significant (P<0.001) effects on grain Cd concentration in both harvests from Tarlee and the 1990 harvest from Kapunda.

The highest mean Cd concentration in grain in both harvests from Tarlee (Fig. I) and in 1990 from Kapunda (Fig. 2) were found in wheat grown after lupins, *(Lupinus angustifolius).* The next highest mean concentrations in grain in both harvests from Tarlee were in wheat grown after peas, *(Pisum sativum),* beans *(Vicia faba)* and sown pasture (almost 100% legume) (data not shown). The lowest mean Cd concentrations in grain from Tarlee and Kapunda were in wheat grown after barley.

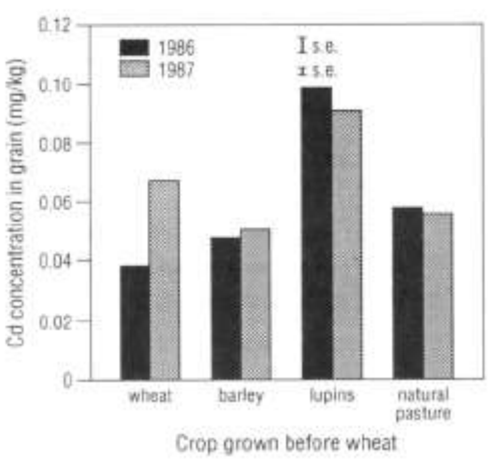

Figure 1. Mean Cd concentration (mg/kg) in relation to crop rotation for two harvests (1986 and 1987) from Tarlee. The means are calculated across three stubble treatments and two or three nitrogen treatments in 1986 and 1987, respectively.

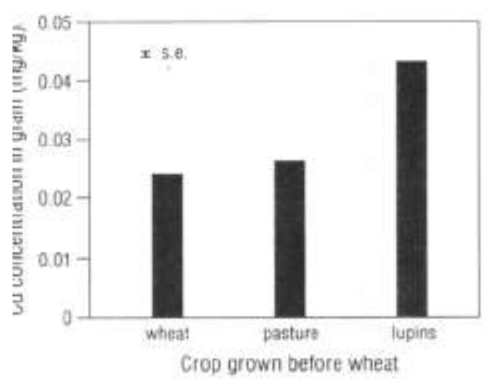

Figure 2. Mean Cd concentration in wheat grain (mg/kg) grown after the designated crop in the Kapunda experiment (1990). The means are calculated across two fertiliser treatments.

Since the rhizosphere of legumes is more acidic than the bulk soil (6,4). the increased Cd uptake by wheat grown after lupins may be partly due to rhizosphere acidification. We were unable to verify this since the soil used for pH analysis was a bulk sample collected across each plot. Consequently any subtle chemical changes occurring on the micro-scale that may have affected Cd availability could not be detected. Alternatively lupins have been found to produce exudates which may bind Cd in a form that is more readily available to the crop grown in the following year.

The increased grain Cd concentrations in wheat grown after lupins may have important implications for farm management practices, particularly since many farmers are being encouraged to include more grain legumes in their crop rotation sequence. In areas where high grain Cd concentrations are of concern, attention may need to be given to the wheat varieties grown and the order of crops within a rotation sequence.

Varietal and site differences in Cd accumulation

Varietal differences. Although grain was collected from 14 sites across Australia, data for only three sites are shown to give an indication of the range of Cd concentrations found (Fig. 3). The highest grain Cd concentrations (mg/kg) for wheat varieties at any site ranged from 0.045 - 0.070, and 0.053 - 0.096, in 1988 and 1989, respectively, and the lowest ranged from 0.002 - 0.006 and 0.002 - 0.008, in 1988 and 1989, respectively. Several of the newly-released varieties had significantly ($P<0.05$) higher grain Cd concentrations than many of the more commonly grown varieties at the majority of sites in both 1988 and 1989. In 1988 the highest concentrations at most sites were found in Reeves, C8MMMMMMC/45/3 and SUN118A. Similarly in 1989 an assessment of the 14 IWV sites, showed that "new" varieties such as 79W/78I and MMMMCWLAR 13/9 had significantly ($P<0.05$) higher grain Cd concentrations. Furthermore those varieties with the high Cd concentrations in both years were from specific plant breeding institutions and had common parentage. This suggests there may be a genetic component to Cd uptake by plants and breeders may inadvertently be selecting for increased Cd uptake by certain varieties during the selection procedure.

Site differences. Grain Cd concentrations for each variety differed significantly ($P<0.001$) between sites. Generally lower Cd concentrations (0.02) were found on the lighter textured soils with higher pH. The sites shown in Fig. 3 were chosen to reflect a range of soil properties and a range of grain Cd concentrations. Our studies, including unpublished data, confirmed the overall low concentrations of Cd in Australian wheat grain as shown by others for Queensland (1), South Australia (A.F. Richards *et al.,* unpublished data) and nationally (2). The Cd concentrations in grain from some sites were close to, and in some cases exceeded, the MPC (0.05 mg/kg). Apart from choice of variety, these higher values may be due to a combination of several factors:

- geochemistry controlling high concentrations of Cd in local rocks and soils;
- high application rates of phosphate fertilisers containing high Cd concentrations;
- soils of low pH and/or lighter texture.

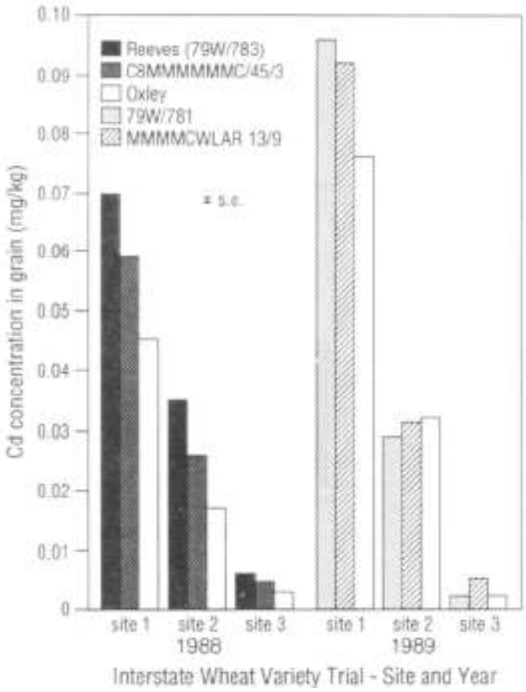

Figure 3. Grain Cd concentrations for five varieties sown at three sites in the Interstate Wheat Variety Trials. Two varieties were grown in 1988, two in 1989 and Oxley was grown in both years. Site details are:

Site 1 : fine loamy sand, pH_{Ca} 4.80

Site 2 : coarse loamy sand, pH_{Ca} 4.80

Site 3 : silty loam, pH_{Ca} 7.39

The potential impact of these factors will depend on the extent to which they overlap. Often high Cd concentrations in grain from one farming area or region can be diluted by blending the grain with that from different sources. Problems may only arise when grain from a restricted area is grown for specialty markets.

Acknowledgements

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