IMPACT OF AGRONOMIC PRACTICES ON CADMIUM UPTAKE BY PEANUTS

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Abstract

Expansion of the peanut industry onto acidic, sandy soils with irrigation potential is being hampered by the propensity of the peanut crop to accumulate high concentrations of the heavy metal Cd. We report the results of field trials near Bundaberg examining the impact of liming, fertiliser Zn application and irrigation frequency on the Cd concentration of a number of peanut cultivars grown on soils with high phytoavailable Cd levels. Choice of cultivar proved to be the most significant factor affecting kernel Cd concentration at each location in these studies, although none of the cultivars could produce kernel with Cd concentrations that met market requirements. Neither liming or Zn application had a major impact on kernel Cd, although the lack of a lime effect may have been due to an inability to ameliorate a sufficient proportion of the plant root zone. The effect of irrigation scheduling on kernel Cd concentration requires further study, as good in-crop rainfall minimised differences between treatments. Data suggest that site selection, through effects of soil type and fertiliser history, remains the most effective practice to minimise Cd in peanut kernels.

Keywords: Peanuts, cadmium, lime, zinc, irrigation

The peanut industry is currently expanding onto acidic, sandy soils where there is the potential for high yields and quality under irrigated production. However, where these soils have had a history of P fertiliser application there is considerable risk of accumulating the heavy metal cadmium (1) at levels greater than the Maximum Permitted Concentration (MPC, 0.05 mg Cd/kg). This is particularly evident in areas where sugarcane, improved pastures or horticultural production have been part of the local land use.

Research in other species (3, 4) has shown that manipulation of soil pH and soil Zn status may be useful agronomic strategies to minimise Cd uptake, but no information exists on the impact of these management strategies in peanuts. In addition, commercial experience suggests that appropriate irrigation scheduling may also affect kernel Cd levels by reducing root activity in deeper, unamended layers of the soil profile. This paper reports the results of field trials examining the effect of these variables on Cd content of a number of peanut cultivars.

Materials and methods

Field trials were established under supplementary irrigation at three sites in the vicinity of Bundaberg, in southeast Queensland, during the period 1994-1997. Soil classification and selected chemical characteristics of each site are detailed in Bell et al. (1), with a brief summary showing pH, Cd and Zn concentrations in the top 60 cm of the profile provided in Table 1.

The first experiment was established on a red podsolic at Kolan prior to the 1994/95 growing season. Five rates of limestone (0, 4, 8, 12 and 16 t/ha) were applied during October 1994 in a randomised complete block design with three replicates. The lime was incorporated into the top 10-15 cm of the profile using offset discs and the Virginia peanut cv. NC7 was sown one month later. Soils were sampled to a depth of 30 cm at flowering (approx. 2 months after lime incorporation) to determine the effects of lime treatment on pH prior to pod development. Pod yields were determined at maturity and kernels (with testa) were analysed for Cd concentrations.

The experimental area was re-sown with NC7 peanuts in the 1995/96 season, with a second soil sampling undertaken prior to podding and crop yields and kernel Cd concentrations determined at maturity.

The second experiment was established on an earthy sand at Calavos prior to the 1995/96 growing season. Five rates of Zn (0, 5, 10, 20 and 40 kg Zn/ha) as ZnSO4.5H20 were broadcast onto plots and incorporated to a depth of 25-30 cm using a reversible plough on 20 November 1995. Virginia peanuts cv. Florunner and Southern Runner were sown on 8 December in a split plot design with three replications, while soil samples were collected to a depth of 60 cm shortly after crop establishment. Plant samples were collected during early podding and analysed for Zn and Cd concentrations, while pod yields and kernel Cd concentrations were determined at maturity.

The experimental area was re-sown to peanuts (cv. Red Spanish) in January 1997. Soil samples were taken to a depth of 40 cm just prior to flowering, while pod yields and kernel Cd and Zn concentrations were determined at maturity.

The third experiment was established on a yellow podsolic soil at Clayton. A number of commercially available Virginia cultivars and experimental lines were sown in late February 1997 and grown as bulk crops until flowering. At this stage, two different irrigation schedules were established by placing tensiometers at 20 cm depth in the crop row to indicate pore water pressures. Target pore water pressures of -2 kPa and -5 kPa were used to determine time of irrigation in 'wet' and 'dry' treatments, with the objective of forcing the crop to rely to varying extents on subsoil moisture reserves. Pod yields were determined at maturity and kernels (with testa) were analysed for Cd concentration.

Results

Lime application

The application of lime at the Kolan site produced significant shifts in soil pH, although these effects were confined to the top 20 cm of the profile - even 15 months after application (Table 2). Lime application had no effect on either yield of peanuts or on the kernel Cd concentration. Crops in both years exceeded the MPC for Cd by a considerable margin, with the lower yield in 1995/96 primarily due inadequate irrigation capacity in a very dry year.

Zinc application

Application of Zn fertiliser had no significant effects on accumulation of biomass or yield in either year, but Zn concentration in plant tops and in kernels generally increased with increasing Zn rate. Cultivars differed significantly in the concentrations of both Zn and Cd in whole plant biomass at early podding and in kernels at maturity. Florunner was able to accumulate Zn at higher concentrations in plant biomass (98 mg/kg) than either Red Spanish (54 mg/kg) or Southern Runner (59 mg/kg), while both Red Spanish and Florunner accumulated more Cd in plant biomass (1.16 and 1.03 mg/kg, respectively) than Southern Runner (0.67 mg/kg).

Cultivars differed significantly in kernel Cd concentration, although all exceeded the MPC by a considerable margin. Red Spanish (0.52 mg Cd/kg) accumulated the most Cd, followed by Florunner (0.38 mg Cd/kg) and Southern Runner (0.29 mg Cd/kg). Differences between cultivars far exceeded any effects of Zn fertiliser applications. Application of 40 kg Zn/ha caused reductions in kernel Cd concentration of between 13% (Red Spanish) and 30% (Florunner), although this effect was only statistically significant in cv. Florunner (Fig. 1). It was interesting to note that while Florunner was the only cultivar to show a significant response to applied Zn in terms of reduced Cd concentration in kernels, it was also the only cultivar able to accumulate high concentrations of Zn in shoot tissue.

Irrigation frequency

The late sowing date, combined with excellent seasonal conditions in terms of rainfall distribution, resulted in only minimal differences in soil water status between the differential irrigation regimes in this study. Soil pore water pressures in the 'dry' treatment only reached the target deficit of -5 kPa during a period of approx. two weeks in early pod fill, after which rain fell frequently enough to minimise differentials for the remainder of the season.

Despite only slight differences in soil water status, there were indications that irrigation frequency may affect kernel Cd concentrations in some cultivars (Fig. 2). This was particularly evident in the important commercial cvs. Streeton, Southern Runner and NC7. Once again, cultivar differences in kernel Cd concentration appeared to be more important than effects of management.

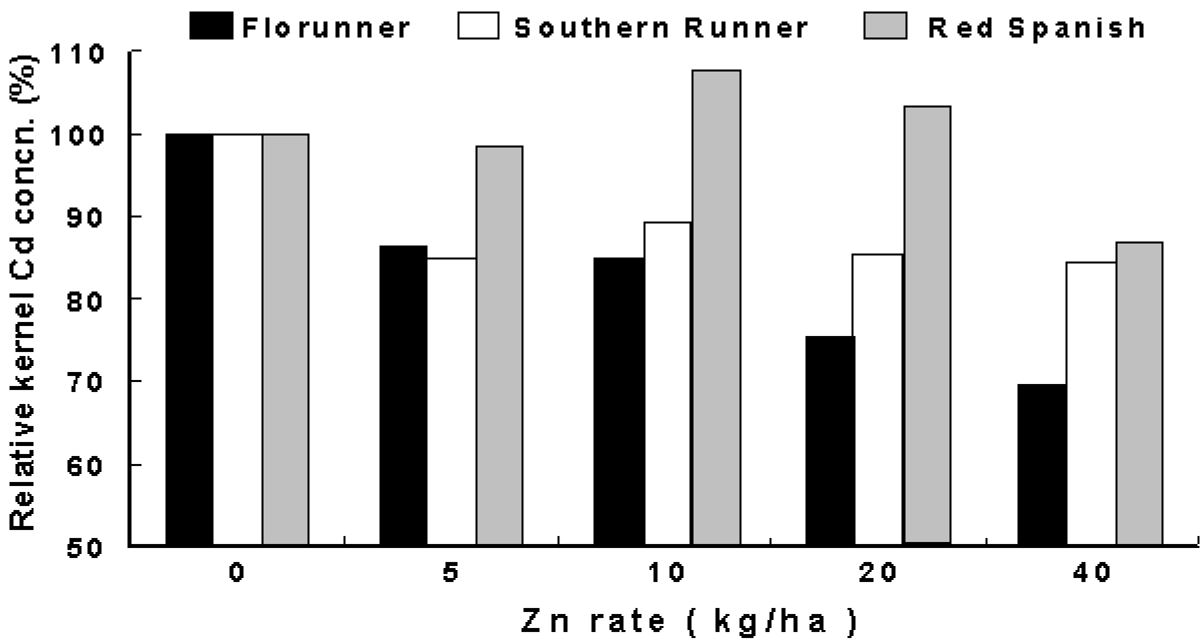

Figure 1

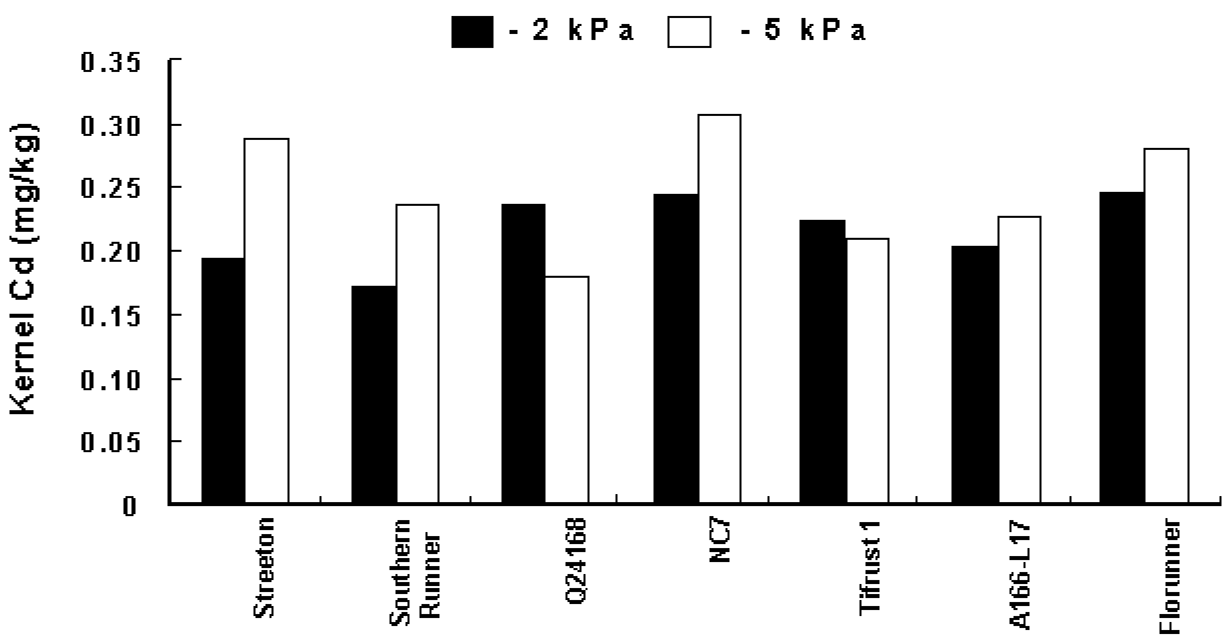

Figure 2

Discussion

The soils on which these studies were undertaken were typical of the lighter textured soils in coastal regions targeted by the industry as potential areas of expansion. The EDTA - Cd concentrations in these soils were similar to those in other long term cropping areas on acidic soils (1), while soil pH and DTPA Zn levels were also within the normal range.

None of the traditional Cd management options investigated in this study have had a major impact on kernel Cd concentration in peanuts, despite the fact that Cd concentrations have fallen significantly in some instances. Choice of cultivar produced much greater effects on kernel Cd than rates of Zn fertiliser at Calavos, and cultivar differences at Clayton were similarly significant. However, no cultivar at any site produced marketable kernel that met the MPC for Cd.

Despite evidence from pot studies suggesting that increasing pH due to lime application would reduce Cd uptake in peanut (1), there was a complete lack of effect of lime applications on Cd uptake in the field at Kolan (Table 2). This type of result has also been recorded in other crop species reviewed by McLaughlin et al. (2). Our data show that most of the ameliorating effects of lime on soil pH occurred in the top 20 cm of the soil profile and we have shown (Table 1) that significant amounts of Cd were present to at least 60 cm depth. The inability of the water-winch irrigation systems used at both Kolan and Calavos to maintain adequate soil water status in the top 20 cm ensured significant root activity in the lower, more acidic soil layers. It is therefore not surprising that the lime treatments did not affect kernel Cd concentrations.

The lack of any marked effect of soil Zn status on Cd uptake in the peanut cultivars at Calavos was also not surprising in the light of published evidence in other crop species. Realistic rates of Zn application (up to 50 kg Zn/ha) have produced only small changes in Cd concentration of other species like potatoes or wheat (eg. 0.02 - 0.04 mg Cd/kg : 2, 4), but such changes can have an important effect on the marketability of produce when the Cd concentration does not exceed the MPC by a large amount. Our results from Calavos show that even in the most responsive cv. Florunner, where 40 kg Zn/ha reduced kernel Cd by 0.14 mg Cd/kg, kernel Cd concentrations were still more than 6 times the MPC and no lower than could be achieved by using the cv. Southern Runner alone.

Finally, the preliminary finding that irrigation scheduling may influence kernel Cd has considerable significance for irrigated production areas. Manipulation of soil moisture to minimise root activity in deeper layers of the soil profile, which cannot be easily amended with lime and other inputs, is feasible in such cropping systems - especially with trickle irrigation. This aspect of our research will receive considerable attention in future seasons.

Conclusions

Choice of cultivar proved to be the most significant factor affecting kernel Cd concentration at each location in these studies, although none of the cultivars could minimise Cd concentrations to the extent that kernel from any of the experimental sites could meet market requirements. Neither of the traditionally recommended Cd management practices (liming or Zn application) had a major effect on kernel Cd, although the application of Zn fertiliser may be useful for relatively responsive cultivars like Florunner when Cd concentrations are approaching the MPC. These data suggest choice of soil type and site selection based on fertiliser history remain the most effective practices to minimise Cd in peanut kernel. Irrigation scheduling to minimise root activity in deeper, unamended soil layers requires further investigation.

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