ZINC AS A SUBSOIL NUTRIENT FOR CEREALS

A thesis submitted

by

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for the degree of

Doctor of Philosophy

in the

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of

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August, 1996

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ABSTRACT

In southern Australia, where subsoils are predominantly alkaline and pH increases with depth, the available zinc status of soils is low and cereals may suffer from zinc deficiency. This deficiency has traditionally been treated by application of zinc fertilizer to the cultivated layer from which the downward movement of zinc is unlikely. Evidence has accumulated over the past decade that a lack of zinc in the medium external to the root impairs the function of roots and that zinc may be required in subsoil as well as topsoil to correct the problem.

Field experiments were established at two sites at Minnipa in South Australia to measure the effects of deep placement to 0.4 m of zinc, nitrogen and phosphorus on wheat (*Tritium aestivum* L. cv. Machete) and barley (*Hordeum vulgare* L. cv. Stirling).

In view of the wide (0.45 m) spacing between the tynes of the deep ripper used for fertilizer placement, some clear effects were observed. Zinc concentrations in youngest emerged blades (YEBs) were generally highest where zinc was applied with nitrogen-phosphorus (NP) fertilizer. Grain yields were not highly correlated with zinc concentration in YEBs. Zinc concentration in grain was highest where a mixture in water of zinc sulphate, monoammonium phosphate and ammonium nitrate was applied to the subsoil. Subsoil placement of zinc and NP fertilizer significantly increased wheat grain yields and zinc concentrations in grain above placement in topsoil at one site in the second year. The apparent benefits of subsoil placement of zinc with NP fertilizers are worthy of further investigation in areas where alkaline subsoils occur.

In southern Australia, there exists a body of anecdotal evidence that wheat grown after field peas (*Pisum sativum* L.) is more productive than when grown after pasture legumes (principally *Medicago* spp.) The possibility that the different abilities of various species to mobilise zinc may be of benefit to following crops has only recently been considered. A deep pot experiment was conducted to compare the abilities of several antecedent species to cope with zinc deficient soil and to modify the available

zinc status of the soil to benefit wheat grown in the following year. Six species, *Lupinus pilosus* (cv. 20957), *Pisum sativum* L. (cv. Early Dun.), *Medicago truncatula* Gaertn. (cv. Parabinga), *Triticum durum* L. (cv. Durati), *Hordeum leporinum* Link and *Brassica juncea* Czern and Coss (cv. Pusa Bold) were grown in pots containing zinc-deficient Laffer sand fertilized with basal nutrients other than zinc. The same species, apart from *B. juncea,* were also grown in pots to which 0.25 mg Zn kg^{-1} soil was also added.

Of the five species, *L. pilosus* was the most zinc efficient and *H. leporinum* the least. *B. juncea* produced more dry matter in soil of low zinc status than other species and displayed no symptoms of zinc deficiency. The large seeded grain legumes produced significantly more dry matter to anthesis in zinc-deficient soil than *M. truncatula* or members of the *Poaceae*. *T. durum* (cv. Durati) was grown in the same pots and harvested three weeks after sowing when plants were almost completely necrotic. Durati shoots produced significantly more dry weight at harvest in soil of low zinc status following *P. sativum* than other species apart from *L. pilosus*. The data suggest that the reported better performance of cereals after *P. sativum* compared with *Medicago* based pastures is a real effect and may be due in part to an enhanced availability of zinc. In *T. aestivum* L. (cv. Excalibur) grown in the same soil for 20 weeks, zinc uptake following grain legumes in zinc deficient soil was significantly higher than after the *Poaceae* or *B. juncea*. Uptakes of several nutrients were significantly depressed in Excalibur grown after *H. leporinum* compared with other species. Durati appears to have a higher critical concentration for zinc than Excalibur.

The zinc efficiencies, root growth and production characterisitics of the wheat cultivars Gatcher (zinc-inefficient) and Excalibur (zinc-efficient) in infertile, alkaline subsoil typical of that which occurs on Eyre Peninsula were compared in a pot experiment. The principal hypothesis tested was that the zinc-efficiency of Excalibur, when compared with that of Gatcher, is due primarily to the ability of Excalibur to produce a greater surface area of roots. Zinc-efficient Excalibur wheat demonstrated a clear advantage in terms of grain yield compared with the inefficient cultivar Gatcher

when grown in a calcareous alkaline subsoil of low zinc status when other basal nutrients were added. Zinc uptake in Excalibur tops was the equivalent to that in Gatcher although Excalibur produced a total root length about half that of Gatcher. Excalibur also displayed a greater degree of internal efficiency for diverting zinc to grain formation.

Zinc efficiency offers a cost-effective approach to growing cereals on soils of low zinc status. However, more efficient grain production with respect to zinc supply does not necessarily imply higher zinc concentration in grain. The relationship between zinc placement in soil and grain concentration of zinc and other parameters in Excalibur were examined. Plants were grown in pots with three layers of sand each 20 cm deep. Basal nutrients were added to the whole soil but zinc was added at 0.5 mg Zn kg^{-1} soil in various combinations of layers. There were no differences in grain yield but the highest concentrations of zinc in grain occurred in pots containing added zinc in all three layers. Where only one layer was treated with zinc, concentrations of zinc in grain were highest where zinc was added to the bottom layer. In the zinc-efficient wheat cultivar Excalibur, high zinc concentrations in grain were dependent on a supply of adequate zinc throughout the root zone. Increasing the depth of placement to any degree above the standard 0.05 m used in the field in southern Australia is likely to have a beneficial effect on zinc concentration in grain.

The literature reveals a paucity of field studies of subsoil infertility, particularly with specific reference to zinc. The thesis describes investigations into field and pot studies of various aspects of subsoil infertility, including the possible roles of zinc efficiency in cereals and crop rotations in addressing this problem. The data indicate several promising avenues for further investigation.