Critical level for zinc deficiency of field-grown wheat

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Summary. Zinc (Zn) deficiency is widespread in crops and pastures throughout the cereal belts of Western Australia, South Australia and western Victoria. Field experiments were conducted in South Australia to calibrate a plant test for diagnosing zinc deficiency in wheat under field conditions. The combined results of 12 experiments conducted over five seasons indicated a diagnostic critical level of 18 mg Zn/kg (DW basis) in YEBs (youngest fully emerged blades) of wheat at mid-tillering. For interpretation of commercial plant tests, the following criteria (mg Zn/kg in YEBs of wheat at midtillering) are proposed: deficient<I6; 16<marginal<24; adequate>24.

Introduction

Zinc deficiency is widespread in crops and pastures throughout the cereal belts of Western Australia, South Australia and western Victoria (1,2,7,11). Modern management practices appear to have increased the extent and severity of zinc deficiency. Severe zinc deficiency in Western Australia has been associated with a change from using single superphosphate on crops to high analysis fertilizer products (which contain much lower quantities of zinc) (4). Also, some herbicides can induce zinc deficiency, or exacerbate an existing deficiency, in treated crops (9,13). A series of field experiments was conducted in the Mallee and Eyre Peninsula regions of South Australia to calibrate a plant test for diagnosing zinc deficiency in major crops and pastures under field conditions. Prior to this programme, criteria for diagnosing zinc deficiency had largely been developed under artificial growing conditions in glasshouses. Results are presented here for a critical level diagnostic of zinc deficiency in young wheat plants, *Triticum aestivum,* grown under field conditions.

Methods

Field experiments were conducted on soil types typical of major production areas for cereal cropping in the Mallee and Eyre Peninsula regions of South Australia in the years from 1986 to 1992. Soil types varied between sites from heavy, grey, gilgai-forming, calcareous clay to non-wetting, siliceous sand. All plots were 8 rows wide and either 20 or 40m long, depending on the individual experiment. All treatments were replicated 4 or 6 times. Four varieties of wheat were used during the programme (Machete, Spear, Aroona and Schomburgk), although each experiment was sown to only one variety in any one year.

The majority of experiments were designed with six to eleven rates of soil-applied zinc, the highest rate being 20 kg/ha of zinc and the lowest (apart from nil controls) 0.1 kg/ha. Zinc was sprayed onto the soil surface as a solution of zinc sulphate and incorporated with a rotary-hoe. Plots were then sown with a crop species common for that area and are being re-sown each year in a typical rotation. These experiments are also being used to monitor the residual properties of soil-applied zinc. High rates of basal fertilizers were always used to ensure zinc was the only nutrient limiting production. Weeds were controlled with pre- and post-emergence herbicides where necessary. Seventy to one hundred whole plants were removed at random from each plot when plants were at a growth stage (Zadok's decimal coding system (15)) between 14 and 15.5. This growth stage was chosen because it is sufficiently early in the development of the crop that farmers would have the opportunity to apply a corrective foliar spray to the crop should a tissue test recommend it but late enough that seed sources of zinc should be exhausted and the crop's growth determined by the supply of zinc from the soil alone. If plants had become soiled during sampling, then all shoots were washed in deionised water. Folded blades, youngest fully emerged blades (YEBs) and the blade next oldest after the YEB were removed from plants and analyzed for zinc concentration with atomic absorption spectrometry (only results for YEBs, on a dry weight basis, are presented here). Plants were oven-dried and dry weights of shoots subsequently recorded.

Results from experiments which compared the effectiveness of soil sprays of zinc sulphate with zinc-enriched high analysis fertilizers were also included in the derivation of a critical level for zinc deficiency in major cereal and pasture species. These experiments were maintained for only one season but had the same sized plots and management strategies as the "permanent" series of experiments.

Results and discussion

The combined results of 12 experiments conducted over a period of five consecutive seasons indicated a diagnostic critical level of 18 mg Zn/kg in YEBs (Fig. I). The definition of critical level used in this paper is that concentration of zinc in YEBs at which dry matter production at sampling is 90% of maximum. The curve used to define the critical level (see Fig. I) was fitted by hand. Hand-fitting the curve was chosen rather than any statistical procedure (e.g. Mitscherlich (16) or Smith-Dolby (14)) because this procedure has proved useful in determining plant test criteria (6,12). Furthermore, hand- fitting curves provides the opportunity for biological interpretation of the data. This allows for differing weight to be given to outlying data points. For example, outlying points with high zinc concentrations in YEBs but below the maximum growth plateau are given equal weight to all other points in a statistical procedure. This may substantially reduce the critical level because they will decrease the numerical value of the growth plateau. However, in a hand-fitting procedure, these outliers can be assigned diminished weight because they are more likely due to some identified (or unidentified) confounding factor in the experiment (e.g. changing soil type, disease patch) than an accurate indication of the crop's requirement of zinc for maximum growth. The hand-fitting approach is most appropriate to analysis of data from field experiments because the highly variable nature of the field environment makes it very difficult to eliminate or avoid all confounding factors across the whole experimental site.

YEBs were chosen as the most appropriate tissue to sample for a diagnostic test of zinc deficiency in wheat for three reasons. The first is that plant growth (estimated by dry weight of shoots) is sensitive to decreasing concentrations of zinc in YEBs (evidenced by the sharp decline in dry shoot weights below concentrations of 20 mg Zn/kg, see Fig. 1). The second is that it is an easily identified tissue in the young wheat plant: the YEB was defined as the youngest blade on the main stem with an exposed ligule. The third reason is a pragmatic one: YEBs have already been identified as an appropriate tissue to sample for many other nutrients (see Reuter 1986 (10)) and their choice is already established in many commercial tissue testing services. Critical levels were higher but more variable in folded blades, but lower in the leaf next oldest after the YEB. Critical levels also declined with increasing plant age after the growth stages reported here.

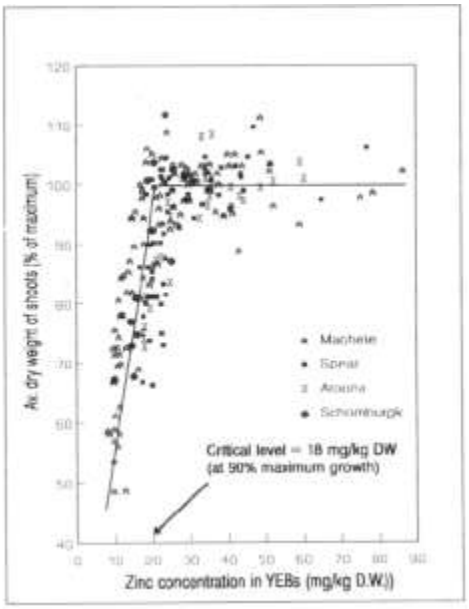

Figure 1. Hand-fitted critical level curve for zinc in youngest fully emerged blades of wheat at mid-tillering. Combined mean results from 12 field experiments conducted over 5 seasons.

The critical level of 18 mg Zn/kg in YEBs is different to the value of 10 mg Zn/kg being used in Western Australia (1). It is difficult to provide a reasonable explanation for this difference except that different varieties would have been used in the two states. There is some evidence from the results presented here (Fig. 1) that the critical level for Machete may have been different to Aroona and Spear. The critical level derived for Machete was approximately 16 mg Zn/kg. A curve fitted to data for Spear and Aroona resulted in a critical level of 22 mg Zn/kg. However, as the data for individual varieties are limited (replication only through different locations and seasons) it is difficult to ascribe much weight to the apparent critical level differences presented here. Although differences in critical levels between varieties has been reported for wheat and manganese (8), the absence of differences is more common (3,5).

Although these data have been used to define a critical level for zinc deficiency in young wheat plants, a critical range is probably more appropriate as a summary of the results for use by agronomists and agribusiness representatives when interpreting tissue tests from broad-acre wheat crops. In light of these results, tissue tests should be interpreted as deficient if the concentration of zinc in YEBs is below 16 mg Zn/kg, adequate if above 24 mg Znikg, and marginal if between 16 and 24. Interpretation using a critical range has an "in-built" safety margin which does not exist with a critical level approach where a crop could be diagnosed as deficient or adequate depending on a difference as low as 2 mg Zn/kg.

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