NUTRITIONAL STATUS OF WHEAT ON ACID AND LIMED SOILS IN SOUTHERN NSW

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Abstract

Widespread lime application in southern and central NSW began in the 1980's, and re-liming of these soils is now taking place.? The cumulative applications of lime raises concerns about depression of crop yield through induced mineral deficiencies. Three experiments were re-established in 1996 at Young, Henty and Ryan. Treatments included lime applications in 1982 or 1983 (nil, 2, 4, 5 t/ha) and reliming in 1996 (nil, 2, 5 t/ha). The youngest emerged blade (YEB) of wheat (*Triticum aestivum*) was sampled prior to anthesis and analysed for Mg, K, Zn, B, Cu, Ca, and Mn by ICP. Magnesium, Zn and K concentrations were low at all sites on the unlimed control treatment (1048-1768 mg/kg, 10-14 mg/kg and 1.68-1.97 %, respectively), and the Zn concentration was significantly reduced by the lime treatment at Ryan from 14 to 10 mg/kg. The results confirmed earlier findings (in Southern NSW) of Mg deficiency, and isolated instances of low Zn and K in plants.

Key words: Deficiency, lime, magnesium, overliming, potassium, soil acidity, zinc.

There has been recent interest in reliming from farmers who began lime application of their properties in the early 1980's. However as a consequence of observed lime responses, farmers may plan to use a similar or higher rate when reliming, than for the initial lime application. The use of a high lime rate, combined with the residual pH effect from the first liming, raises concerns about the potential to overlime soils.

High lime application can induce deficiencies of Cu, Zn, B, Mn and Mg. In southern NSW, low Mg has been noted in wheat when grown on acid soils (17). Aust-ralian reports of lime induced mineral deficiency are confined to lupins in W.A and S.A. (16). Handreck (10) described how cereals are affected by Mn deficiency but symptoms are especially noted in oats, and also in peas and lupins. In our mixed farming system it is possible that lupins in the rotation may be the first species to suffer adverse effects at elevated pH, although Mn deficiency is highly unlikely in our soils.

In this paper, we report on the nutritional status of wheat at three sites where lime was applied at a range of rates in either 1982 or 1983 and again in 1996.

Materials and methods

Three sites in NSW had been located, soil sampled, relimed and sown to wheat (Janz, 60 kg/ha) in the 1996 season. The sites are at Young in central NSW and at Henty in southern NSW on yellow podsolic soils (Dy 3.41, 14; yellow chromosol, 12), and at Ryan (39 km south west of Henty) on a red earth (Gn 2.12; red chromosol). The initial soil pH ($CaCl_2$) in the 0 to 10 cm layer at the sites were 4.3, 4.5 and 4.8, respectively.? These sites were limed once in either1982 (Henty and Ryan) or 1983 (Young) at a range of lime rates. All sites were relimed in 1996 to give factorial combinations of rates of "old" and "new" lime treatments. Lime was incorporated by rotary hoe to a nominal 10cm depth. Additional treatments included high lime rates with a lime mixed with magnesium carbonate mixture (3:1, respectively, by weight), equivalent in neutralizing capacity to the maximum lime rate applied at the site. This mix included added Cu (7 kg/ha Cu as sulphate), Zn (7 kg/ha Zn as sulphate) and B (1 kg/ha B as boric acid), as their availabilities are typically lowered in limed soil. Both the limestone and magnesium carbonate products were fine (99.5 and 95% <250<m<m, respective-ly) and chemically pure (98% $CaCO_3$ and 95% $MgCO_3$). The limestone contained only 0.3% Mg.

At the sites there were two replications of treatments at Ryan, three at Young and four at Henty. At two sites (Ryan and Young) there were six replications of the control (nil "old" and nil "new" lime). This required two error terms at these sites, one for comparison of the control treatment with the limed treatments, and a second term for comparisons within the limed treat-ments. All treatments had basal applications of molyb-denum (80 g/ha of Mo as sodium molybdate), sulfur (15 kg/ha of sulphur as sulphate), and phosphorus (15 kg/ha of P) applied at sowing.

Leaf samples were collected from a subset of the treatments and included:(a) the unlimed treatment; (b) a commercial rate of lime, *ie.* ranging from 2.0-3.0 t/ha for both initial and second lime applications; (c) a high cumulative lime application, *eg.* 5.0 t/ha applied twice; and, (d) the same high cumulative lime application, with an attempted correction of any induced nutrient deficiencies by application of a magnesium carbonate and trace element treatment in 1996. The specific treatments sampled at each of the three sites are described in the tables. Leaf samples were collected at each of the sites between the 2 and 3 of October, 1996. The youngest emerged blade (YEB) of wheat prior to anthesis (Feekes stage 10 to 10.1; boot to heading) was sampled. Thirty wheat leaves per plot were collected, dried at 80&degree;C, ground, digested in HNO_3 and analysed by inductively-coupled plasma (ICP) spectrometry.

Table 1. The effect by lime and other treatments on the concentration of magnesium (mg/kg), zinc (mg/kg) and potassium (%) in the YEB of wheat prior to anthesis at three sites in NSW.

Treatment and cumulative		Mg			Zn			K	
lime application	Young	Henty	Ryan	Young	Henty	Ryan	Young	Henty	Ryan
a) Control nil (1982/83) + nil (1996)	^{A}1048	1056^{a}	^{A}1768	^{A}10.35	11.40^{ab}	^{A}14.03	^{A}1.68	1.95^{a}	1.97
b) "Commercial" 2.0 t/ha + 2.0 t/ha	^{A}1305^{ab}	1292^{ab}	^{B}1290	^{A}8.63^{a}	10.37^{a}	^{B}9.86	^{B}2.01	2.07^{ab}	1.95
c) High lime rate 5.0 t/ha + 5.0 t/ha	n.a.	1292^{ab}	^{A}1610	n.a.	10.55^{a}	^{B}9.81	n.a.	2.17^{b}	1.85
4.0 t/ha + 5.0 t/ha	^{A}1102^{a}	n.a.	n.a.	^{A}9.09^{a}	n.a.	n.a.	^{B}2.03	n.a.	n.a.
d) High lime with corrective treatment 5 t/ha + (5+Mg+trace elements)	n.a.	1476^{b}	^{A}1471	n.a.	13.57^{b}	^{B}10.26	n.a.	2.27^{b}	1.91
4 t/ha + 5+Mg+trace elements	^{A}1024^{a}	n.a.	n.a.	^{A}10.11^{a}	n.a.	n.a.	^{B}1.95	n.a.	n.a.
(4+Mg+trace elements) + (5+Mg+trace elements)	^{B}1455^{b}	n.a.	n.a.	^{B}16.10^{b}	n.a.	n.a.	^{B}2.13	n.a.	n.a.
LSD ($p = 0.05$) Within lime rates	298	250	ns	3.71	2.36	ns	ns	0.20	ns
LSD ($p = 0.05$) Control v's lime rates	258	250	358	3.21	2.36	2.59	0.29	0.20	ns

Results

Concentrations of Mg in the YEB were low in the unlimed treatment at the two sites on yellow podsolic soils (Young and Henty; 1048 and 1056 mg/kg, respectively), but adequate at the Ryan site (1768 mg/kg; Table 1). The use of high rates of lime had little impact on tissue Mg, but the addition of Mg carbonate in the high lime treatment increased concentrations of Mg at Young.

The concentrations of Zn in wheat on the unlimed plots at Young and Henty were 10.4 and 11.4 mg/kg, respectively, while at Ryan the concentration was slight-ly higher (14 mg/kg). The trend was for the application of lime to lower Zn concentration, and this was signific-ant at the Ryan site. The addition of Zn to heavily limed plots increased Zn concentration and the effect was significant at Young and Henty.

The concentration of K in wheat on unlimed plots was <2.0 % at all sites, and the effect of lime application at two sites (Young and Henty) was to increase the concentrat-ion of K. At Ryan there was no significant effect of lime on concentration of K.

Other nutrients measured in plant tissue on the un-limed treatment were adequate: B (12 - 28 mg/kg), Cu (2.4-8.6 mg/kg), Ca (2.4-4.2%) and Mn (115-184 mg/kg). Lime application at Ryan reduced B and Cu concentrations from 28.5 to 21.8 mg/kg, and 8.6 to 5.5 mg/kg, respectively, however all concentrations were adequate. Lime application significantly increased the concentration of Ca by 1% at Young, and reduced the high Mn concentrations to around 65 mg/kg at all sites.

Discussion

Our observations of low tissue Mg in wheat on the sites with acid podsolic soils confirmed earlier observat-ions. The light-textured acid soils of the central and south western slopes of New South Wales have a low cation exchange capacity and are low in exchangeable Mg; conditions known to to be conducive to Mg deficiency (1). The presence of exchangeable Al (5 to 30% of exchange sites occupied by Al) would further depress Mg uptake by plants. Weir (20) reported extremely low Mg concentrations in wheat (500 mg/kg) from the central and southern slopes of New South Wales. This was associated with soil acidity and symptoms of a general "crop yellowing" problem which extended into north-east Victoria, where again low Mg concentration in plant tissue was identified (7).

The critical leaf concentration for whole shoots ranges from 1000 to 1600 mg/kg with most values bet-ween 1300 and 1600 mg/kg (9, 13, 19, 22). Individual leaves may show deficiency symptoms below 1200 mg/kg (18) although Carr (2) found leaves with 1000 mg/kg Mg to be symptomless. Although the concentrat-ions of Mg in wheat in southern NSW and north-east Victoria appear to be deficient, attempts to demonstrate yield increases in wheat with addition of Mg fertiliser have indicated no response.
At Rutherglen in north-east Victoria the addition of 98 kg/ha of magnesium sulphate did not increase grain yield of wheat (6). In that experiment, the use of lime high in Mg (3% Mg) increased both wheat growth and plant Mg concentration (6). The use of dolomite compared to lime in experiments in southern NSW has indicated responses to dolomite which can be fully explained by the increased soil pH without any addition-al effect of increased Mg supply (17, 3).

Heavy lime applications did not lower the plant tissue Mg in the experiments reported here, even though the lime used was low in Mg and a problem would have been anticipated (1). Amending soils with lime will bring into play factors which increase plant uptake of Mg (increased root exploration and an alleviation of a direct effect of Al on Mg uptake), while the increase of soil Ca would be expected to decrease Mg uptake. The net effect on Mg nutrition in these soils appears to be small. It is likely that Mg deficiency in wheat is transitory, occurring while plants are young and before roots are able to exploit the subsoil Mg.

Low K in wheat has been reported previously in this area on an acid soil (11), but this was regarded as unusual. Our data may indicate a more general problem. The concentrations of K are less than 2% and regarded as low (13, 19, 21). Lime appeared to enhance the concentration of K in wheat at the sites with a podsolic soil. At these sites grain yield was increased by lime application (data not given) so it is likely that crop dry matter, and also total uptake of K were markedly enhanced by lime application. This would presumably operate by increasing root exploration.

The concentrations of Zn reported in this paper are marginal. Tissue concentrations of 15 mg/kg have been suggested as marginal in the USA (19), while in Australia lower concentrations from 5-10 mg/kg are suggested (15). As a plant nutrient zinc is only variably mobile compared to potassium. Symptoms of Zn deficiency occur mainly in young tissues, as there is little movement from old leaves of deficient plants. So sampling the YEB, as we did, was likely to be targeting the minimal leaf concentration in the plant. Low tissue Zn in wheat has been reported at Wagga (D. Heenan, *pers. comm.*) in the long-term rotation experiment SATWAGL. The concentration of Zn was lowered by lime use in two of the three experiments and sustained lime use may aggravate the low Zn status of wheat.

Conclusions

Wheat grown on acid soils had low concentrations of Mg, K and Zn while levels of the other nutrients Ca, Mn, Cu and B appeared adequate. The results confirmed earlier findings with Mg deficiency, and isolated instances of low Zn and K in plants. Whether wheat would be responsive to additions of Mg, K and Zn is unknown, but thought to be unlikely for correcting temporary Mg shortfalls. Zn status in wheat may need to be monitored where lime is used, as the addition of high lime rates depressed Zn concentrations. However, lime application increased K and had no effect on Mg concentrations.

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