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Responses to Magnesium Fertilisers in Wheat in Mid Canterbury

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Abstract

A magnesium trial was carried out on autumn and early winter sown wheat at three sites near Methven in 2000-01. Treatments included different rates of early winter applied magnesium oxide or kieserite (magnesium sulphate) and in the spring a single rate of these was compared with a spray treatment of Magflo (magnesium oxide suspension). Herbage Mg levels were measured twice in the spring and varied considerably between sites and samplings. Spring herbage Mg content increased with increasing rate of winter applied kieserite in four of the six herbage samplings. Magnesium oxide applied in early winter was not as effective as kieserite in increasing herbage Mg levels. Magnesium applied in the spring was not effective in increasing herbage Mg levels 7-8 weeks later, irrespective of the form of application. There was no significant effect of magnesium treatment on grain yield, grain weight, screenings or grain N or Mg content, despite all sites having low soil Mg levels and at some stage in the spring low herbage Mg levels. It is likely that climatic conditions impacted significantly on the results as in the past leaf symptoms of Mg deficiency have been noted at higher soil Mg levels.

Introduction

Soils in the predominant cropping regions of New Zealand have medium to high levels of exchangeable magnesium and medium to high reserves of magnesium (Metson and Brooks 1975). Hence historically magnesium has not been seen as a major problem in these areas. However, in Mid Canterbury it is not uncommon to find MAF quick test Mg (QTMg) levels <10 especially near Methven where they can be as low as 4. It is known that pasture dry matter responses are likely at QTMg <5 (Edmeades 1999). While no soil data is available for crop responses to magnesium in New Zealand, ADAS in Britain consider soils to be deficient at <25mg/l available Mg (approx QTMg of 4-5), although cereals may not respond until they get to 15mg/l (Archer 1988). In New Zealand it is current practice to aim for QTMg >10 for arable crops and 20-30 for vegetable crops. Herbage magnesium levels are considered low at <0.15% (Reuter and Robinson 1998), although recent local data would suggest these are now set too high. Typical New Zealand wheat crops usually contain 0.11-0.12% (Craighead 1999).

Mid Canterbury is the major cropping district in New Zealand and it is not unreasonable to suggest soil levels are low because of continuous crop removal and farm management practices. Cereals typically remove 5-13kgMg/ha depending on the crops grown. Higher yields, increasing N use, specialist seed and process crops, increasing cropping intensity and the extra demands from winter grazing of cattle suggest these values are now conservative. British work (Chalmers *et al* 1999) suggests new high yielding wheat crops could be removing 15kg Mg in the grain and straw but more importantly could have a maximum uptake at the soft dough stage of 30-35kgMg/ha. In the late spring in 1999 and to some degree 1998, Mg deficient symptoms were quite common in Mid Canterbury. Cereal crops typically showed pale striping often accompanied by light green or yellow beading down the blade of mid to older leaves when held up to the light. Acid soil conditions can also contribute to the problem (Castleman *et al* 1998).

On a previous occasion when Mg deficiency like leaf symptoms were noted PGG staff (M. Kelly pers. comm.) screened a range of proprietary liquid products as single sprays on winter wheat, applied at the late vegetative stages. These were also compared against solid Epsom salt. No product tested satisfactorily raised herbage magnesium levels one and four weeks after spraying, and after four weeks no symptoms were evident in the control crop.

A better option to avoid deficiency symptoms in cereals may be to lift soil Mg levels. On pastural soils it is not difficult to lift levels on Yellow Brown Loams – Allophanic soils (McNaught *et al* 1973) and Recent and local Yellow Brown Earth's – Pallic soils (Craighead 2001b, Strachan pers. comm.). The choice and timing of products is important. Epsom salt is now seldom used as a solid fertiliser as it is considered too soluble particularly for autumn application. Kieserite which has anecdotally been used with some success in kale seed in Mid Canterbury, is widely used in European cropping (Haedter pers. comm.). Draycott *et al* (1975) have shown kieserite to give yield increases in sugar beet. Magnesium oxide is widely used in New Zealand, as it is the most cost effective Mg fertiliser, however it may act too slowly for crops and so its timing may be important.

A larger review of Mg in cropping is given in the preceeding paper in this volume (Craighead 2001a).

The objective of this research was to compare two solid Mg fertiliser products at different rates applied to a wheat crop in the autumn against spring applied magnesium fertilisers including a liquid spray as a means of increasing the herbage Mg content and hence the yield and quality of a wheat crop.

Materials and Methods

Site

Three sites to be sown in autumn sown wheat were selected near Methven on the basis of their low soil Mg levels (QTMg 3-4). The sites were; Grant's just outside Methven, on Ruapuna and Mayfield silt loams, previously in borage; and two sites, Ridge's and Wright's, NE of Methven towards the Rakaia River, on Lyndhurst silt loams and following run out pasture and white clover seed crops respectively. All three sites had stony topsoils and were reliant on rainfall for moisture. Base fertility (bar Mg) was good at Grant's and Ridge's but P levels were slightly low (Olsen P 13) at Wright's. Soil pHs were adequate for wheat production. All sites received phosphorus at planting and N and plant protection measures were applied in accordance with normal farmer practice.

The trial was laid down as a randomized block design with four replicates at each site. Plot size was 1.8m x 10m. These were marked out after crop emergence when autumn treatments were applied, further soil Mg tests were taken and plant populations were measured. Magnesium treatments are given in Table 1.

Table 1. Magnesium fertiliser treatments

Treatment	Time of application	Fertiliser type	Rate of application kg Mg/ha
1. (control)	Nil	-	
2.	Autumn	Kieserite	22.5
3.	Autumn	Kieserite	45
4.	Autumn	Kieserite	90
5.	Autumn	Magnesium oxide	22.5
6.	Autumn	Magnesium oxide	45
7.	Autumn	Magnesium oxide	90
8.	Spring	Kieserite	22.5
9.	Spring	Magnesium oxide	90
10.	Spring	Magflo	1.5l/ha x 2^{+}

$^{+}$ two applications 14 days apart, in total 0.9kgMg/ha

Kieserite (granular magnesium sulphate monohydrate) contains 15%Mg and was imported from Kali and Salz, Germany. Magnesium oxide (fertiliser grade calcined magnesite) contains 52%Mg and was imported from China. Magflo is a flowable magnesium oxide suspension, 30%Mg, produced by Agrichem Manufacturing Industries Ltd., Australia. All three are marketed by Ravensdown Fertiliser Co-op Ltd. Spring application rates were dictated by cost and label application rates.

Treatments were applied and herbage was sampled at different times at each site to match crop maturity. Spring treatments were applied after the first herbage sampling at 1st node and the second herbage sampling taken at or just after booting, in late November. Grain was harvested in mid February. Full details are given in Table 2.

Table 2. Soil and Crop details and timing of measurements

	Grant	Ridge	Wright
Initial Soil QTMg	4	3	4
Cultivar	Hussar	Buster	Buster
Sowing Date	14th April	17th May	19th May
Autumn fertiliser application	1st June	15th June	5th July
1st herbage sampling	28th September	5th October	5th October
Spring fertiliser application+	3rd October	18th October	18th October
2nd herbage sampling	27th November	27th November	27th November
Harvest	14th February	14th February	14th February

+ 2nd foliar spray 18th October, 1st November, 1st November respectively

Soil and herbage samples (whole above ground plant) were sent to Analytical Research Laboratories Limited (ARL), Napier for Mg analysis. Plot yields were harvested using a plot header and subsamples kept for grain weight and screenings with further grain sent to ARL for grain N and Mg determination.

Data were analysed with analysis of variance. Contrasts between treatments were made within the analysis.

Results

Rainfall data (Table 3) indicated that soil moisture was unlikely to be a severe restriction to growth. The Grant site (Methven) had slightly better spring rainfall than the Ridge (Greenfield) site.

Table 3. Rainfall at Methven (Grant) and Greenfields (Ridge)+

Month	Methven	Greenfields
April (from 14th)	75	-
May	75	23 (from 23rd)
June	32	60
July	24	23
August	205	162
September	90	69
October	38	42
November	112	77
December	43	85
January	78	n.a.*
February (to 14th)	26	n.a.

+ Wright rainfall not measured and was assumed to be similar to the nearby Greenfields site

* n.a. = not available

All three sites had slightly patchy emergence. Plant populations were highest at Grant's, (171plants/m^2) and more advanced and taller on any given date due to the earlier sowing date. Some weed spray drift damaged two replicates early in the season and stunted plants. Ridges crop had a population of 140-150plants/m^2 and had patches of poor growth throughout the trial. This damage was attributed to grass grub and delayed development of those plants in the spring. Wrights crop had a plant population of 136/m^2 and looked thin but without any apparent cause. Although these plant populations appear low compared to traditional New Zealand plant populations, they are typical of those recommended for these new British bred cultivars.

There were no visible signs of Mg deficiency or a Mg fertiliser response in terms of height or colour, at any of the three sites.

Herbage Mg content, grain yield (14% moisture), thousand grain weight, screenings, grain N, and grain Mg are detailed in Table 4 (Grant's), Table 5 (Ridge's) and Table 6 (Wright's).

Table 4. Herbage Mg at two sampling dates, grain yield, seed weight and screenings, grain N and Mg content at the Grant site.

Treatment	Sampling 1 herbage Mg (%)	Sampling 2 Herbage Mg (%)	Grain yield (t/ha)	TGW (g)	Screenings (%)	Grain N (%)	Grain Mg (%)
Control	0.082	0.115	10.75	43.6	1.5	1.74	0.080
Autumn							
Kieserite 22.5	0.085	0.118	10.60	43.9	1.4	1.75	0.074
Kieserite 45	0.089	0.123	10.88	42.9	1.6	1.84	0.078
Kieserite 90	0.091	0.115	10.53	43.5	1.4	1.82	0.085
Mag oxide 22.5	0.084	0.122	10.58	42.4	1.3	1.97	0.070
Mag oxide 45	0.081	0.115	10.59	42.7	1.3	1.87	0.073
Mag oxide 90	0.083	0.113	10.48	42.7	1.4	1.79	0.075
Spring							
Kieserite 22.5	0.081	0.111	10.56	43.7	1.5	1.83	0.070
Mag oxide 90	0.082	0.116	10.54	42.4	1.7	1.84	0.078
Magflo	0.080	0.110	10.81	43.7	1.4	1.71	0.079
LSD (27 df)	0.0056	0.0146	0.745	2.00	0.36	0.151	0.0133

Table 5. Herbage Mg at two sampling dates, grain yield, seed weight and screenings, grain N and Mg content at the Ridge site.

Treatment	Sampling 1 herbage Mg (%)	Sampling 2 Herbage Mg (%)	Grain yield (t/ha)	TGW (g)	Screenings (%)	Grain N (%)	Grain Mg (%)
Control	0.118	0.088	6.40	32.8	3.1	1.93	0.062
Autumn							
Kieserite 22.5	0.126	0.087	6.67	34.3	2.8	1.88	0.066
Kieserite 45	0.136	0.093	6.45	35.1	2.7	1.86	0.057
Kieserite 90	0.152	0.101	6.80	33.8	3.3	1.91	0.068
Mag oxide 22.5	0.121	0.090	6.09	31.9	3.2	2.00	0.063
Mag oxide 45	0.118	0.086	6.50	33.6	2.8	1.98	0.070
Mag oxide 90	0.132	0.094	6.77	34.1	2.9	1.93	0.065
Spring							
Kieserite 22.5	0.119	0.086	6.83	36.5	3.0	1.75	0.061
Mag oxide 90	0.123	0.085	6.83	35.6	2.8	1.87	0.066
Magflo	0.117	0.097	6.62	36.2	2.8	1.88	0.064
LSD (27 df)	0.0121	0.0115	1.153	2.856	0.69	0.167	0.0121

Table 6. Herbage Mg at two sampling dates, grain yield, seed weight and screenings, grain N and Mg content at the Wright site.

Treatment	Sampling 1 herbage Mg (%)	Sampling 2 Herbage Mg (%)	Grain yield (t/ha)	TGW (g)	Screenings (%)	Grain N (%)	Grain Mg (%)
Control	0.099	0.081	7.26	37.2	3.0	1.84	0.067
Autumn							
Kieserite 22.5	0.104	0.085	7.27	36.4	2.7	1.75	0.067
Kieserite 45	0.112	0.099	7.11	37.1	3.0	1.81	0.074
Kieserite 90	0.120	0.100	7.02	36.6	2.8	1.80	0.072
Mag oxide 22.5	0.108	0.085	6.90	35.8	3.2	1.84	0.067
Mag oxide 45	0.096	0.084	7.16	36.8	2.9	1.83	0.068
Mag oxide 90	0.105	0.087	6.99	35.7	2.8	1.80	0.070
Spring							
Kieserite 22.5	0.106	0.082	7.59	37.5	3.0	1.76	0.068
Mag oxide 90	0.098	0.084	6.68	36.3	2.9	1.85	0.069
Magflo	0.095	0.077	7.18	36.8	2.8	1.77	0.068
LSD (27 df)	0.0080	0.0146	0.664	2.06	0.61	0.0965	0.0060

Herbage Mg content varied considerably between sites and samplings, averaging for the first and second samplings 0.084% and 0.116% at Grant's, 0.126% and 0.091% at Ridge's, and 0.104% and 0.086% at Wright's, respectively.

At the first herbage sampling, increasing the rate of kieserite applied in autumn produced significantly increasing ($p<0.01$) Mg levels in the herbage, with up to 29% more Mg than in the control. The greatest responses were seen at this site. All other treatments produced similar Mg levels to the control with the exception of a 12% response at Ridge's to 90kg Mg as magnesium oxide in the autumn.

At the second herbage sampling, there was generally no significant effect of the treatments on herbage Mg, although the same pattern of increasing herbage Mg with increasing rates of autumn applied kieserite occurred at Ridge's and Wright's. At Wright's this was a significant ($p<0.05$) effect.

Grain yield was high at Grant's averaging 10.6t/ha with an average grain weight of 43mg and 1.4% screenings. Ridge's (6.6t/ha) and Wright's (7.1t/ha) were lower yielding with lower grain weights (34.4mg and 36.6mg respectively) and higher screenings (both 2.9%).

At Grant's and Wright's there was no effect of Mg fertiliser on grain yield, grain weight or screenings. At Ridge's there was some evidence ($p<0.05$) of an increase in grain weight over the control for the spring Mg treatments but there was no effect of form of Mg in the spring. This had no great carryover into yield.

There was no significant effect of Mg fertiliser treatment on %N or %Mg in the grain. Average concentrations of N and Mg at each site were, Grant's 1.82%N and 0.076%Mg, Ridge's 1.90%N and 0.064%Mg, and Wright's 1.80%N and 0.069%Mg.

Magnesium uptake in the grain was low and varied from 4kg Mg/ha at Ridge's to 8kg Mg/ha at Grant's.

Discussion

Yields

Yields of Buster (Ridge and Wright sites) were similar to the four year average for Methven (FAR 2000) but much lower than the 2000 season average for this cultivar. Buster has historically slightly outyielded Hussar (Grant site) at Methven. Both are true English wheats and require winter vernalisation to maximise yields (FAR 2001) so the month later sowing date would also have reduced Buster yields at Ridge's and Wright's. Also Grant's site is a heavier soil receiving more and more consistent rain and therefore is capable of higher yields. The lower plant populations and plant establishment in cooler conditions did not help the crops at the Ridge and Wright sites, made worse by the early grass grub damage at Ridge's.

Herbage Standards
In all instances, control Mg levels were below the optimum 0.15% recommended by Reuter and Robinson (1998) and at times below the 0.11-0.12% typically found in New Zealand wheat crops (Craighead 1999). There are reports that Mg deficiency symptoms may not be noted until levels fall to 0.09-0.10% and it is not clear whether yield is even affected when levels drop to 0.08% (Scott and Robson 1991, M. Carver pers. comm.). The results here would support these conclusions. It is interesting that on the two lowest Mg sites herbage levels decreased quite dramatically between herbage samplings whereas at the Grant site they actually increased. Reasons for this could include the earlier sowing at Grant's enabled deeper rooting and more accessibility to subsoil Mg, and that genetically Hussar was better able to utilise Mg compared to Buster. The previous monitoring of the ACE trials (Craighead 1999) shows that over a range of cultivars the herbage Mg content in healthy crops is generally maintained through the spring and if anything slightly improves up to ear emergence.

Magnesium cost and release
The results suggest kieserite is the best magnesium product to use to lift herbage levels, as previously suggested by Haerdter (pers. comm.) and Draycott *et al* (1975). While Draycott *et al* (1975) found kieserite effective in spring, this work suggests kieserite should be applied in autumn or early winter if soil testing shows low magnesium levels. Epsom salts which was not tested would likely be a better spring proposition as it is much more soluble, although it is not very cost effective. Magnesium oxide is a more cost effective product than kieserite as it is three times as concentrated and slightly cheaper per tonne of product. This means more product could be used to partly offset its slower availability of Mg, although in these trials this was only really apparent on the most responsive site, Ridge's. Over time the remaining Mg would have also become plant available, so we would anticipate soil magnesium levels would have been higher for the next crop where 90kg/ha MgO was used in comparison to 22.5kg/ha of kieserite.

In this trial the fertilisers were broadcast after plant establishment. If autumn treatments were applied preplant and soil incorporated the extra time and reactivity within the soil should hasten Mg release. This would further make high rates of magnesium oxide in autumn a viable option, especially if one aim was to raise the base fertility for future farming. However Haerdter (pers. comm.) suggests kieserite does not need to be soil incorporated to work effectively. The trial results suggest that even if Mg deficiency symptoms were already noted before a magnesium problem was identified then even foliar application of magnesium is unlikely to be effective in solving the problem. This supports the previous conclusions by PGG (M. Kelly pers. comm.). Sprays only provide a small amount of Mg and given that Mg is a macro-element and is required in reasonable amounts foliar applications will at best only be of short term benefit.

Soil and climatic conditions
Symptoms of magnesium deficiency were not observed in the spring of 2000 despite soil Mg levels being very low, especially at Ridge's. The New Zealand pastoral data and English cropping data would have suggested that all three sites would be responsive to magnesium. While magnesium deficiency can be present at the levels encountered,

Archer (1998) suggested that cereals may not respond to Mg until levels get as low as 15mg/l (approx QTMg 3). This does not adequately explain why symptoms have been observed in other seasons at higher soil Mg levels.

Data from Winchmore Research Station show that the spring of 2000 was warmer and wetter than 1998 and 1999 and this led to ideal spring growth. Slightly cooler weather in October and November continued this pattern and delayed the rapid transistion to hot, dry summer conditions. In contrast, in particular in 1999 and to some degree 1998, early growth was intermittent because of cool conditions. Magnesium deficiency symptoms were not widespread in 2001 despite a cool but dry spring, probably because the season remained cool but wet until the new year and rapid growth changes did not occur.

The use of nitrogen through this period would also impact on magnesium uptake differently. The warm, adequate moisture conditions in 2000 would aid magnesium uptake, as most N would be taken up in the nitrate form. By contrast in the 1998 and 1999 seasons, the cooler temperatures generally coupled usually with damp conditions means more nitrogen is likely to remain in the ammonium form for longer and so compete with magnesium for uptake (Mulder 1956). The apparent transient nature of Mg leaf symptoms could equally be explained by the fact that at the end of crop vegetative growth, soil temperatures are sufficiently warmer and soils drier which will enhance Mg uptake. Also their roots are presumably deeper and better able to forage for Mg, these Yellow Grey Earth's may have better exchangeable subsoil Mg compared to topsoil Mg, a feature of many of these soils (Metson and Brooks 1975). It is also likely that maximum magnesium uptake has occurred by this point since herbage Mg levels in healthy crops still remain near their peak, 0.11-0.16%Mg.

In summary, given that spring climatic conditions appear to dictate whether symptoms are likely to occur and that these can occur over a range of soil magnesium levels (up to QTMg 10), it is impossible to predict whether Mg deficiency symptoms are likely to occur. While the effect on final crop yield is still unknown, but may be less than initially thought, given that other crops grown on the farm may be more responsive to magnesium, such as potatoes and brassica seed crops and that stock performance is likely to suffer at low soil and plant magnesium levels, then the simplest way to overcome potential magnesium deficiency in wheat may be to lift the base fertility of the farm. This would allow the use of the cheaper forms of magnesium as autumn maintenance dressings, products such as magnesium oxide or if liming is also required, dolomite (10%Mg).

Conclusions

Kieserite applied in the autumn was effective in increasing herbage Mg content at four of the six samplings, but the effect did not carry through to grain yield or quality. The other Mg fertiliser treatments had no significant effect on herbage Mg content or on grain yield or quality. The results would suggest that applying Mg fertilisers to wheat to increase yield or quality may not be justified.

However, the problem of Mg deficiency in wheat is seasonal and in seasons where symptoms are more widespread (this has occurred in at least two of the last four seasons, 1998/99 –2001/02), kieserite in autumn may have been justified.

Further, application of Mg fertilisers to wheat may be justified in order to improve soil Mg status for subsequent crops that are more sensitive to low soil Mg levels and for pasture where low herbage may affect animal performance. Assuming these crops and pasture behave similarly to wheat then the Mg should be applied in the autumn to be effective.

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References

Archer, J. 1988. Crop nutrition and fertiliser use. 2nd edition, Farming Press Ltd., Ipswich, United Kingdom.

Castleman, L.J.C.; Scott, B.J.; Slattery, W.; Conyers, M.K. 1998. Nutritional status of wheat on acid and limed soils in southern NSW. *Proceedings of the 9th Australian Agronomy Conference, 20-23 July, Paper No. 230. Eds* D.L. Michalk and J.E. Pratley

Chalmers, A.G.; Sinclair, A.H.; Carver, M. 1999. Nutrients other than nitrogen, phosphorus and potassium (NPK) for cereals. Home Grown Cereals Authority (HGCA) Research Review No. 41, United Kingdom.

Craighead, M.D. 1999. Ravensdown cereal nutrient monitoring. Ravensdown Fertiliser Co-op Ltd., Seadown Open Day Proceedings, November, 1999.

Craighead, M.D. 2001a. Magnesium Requirements for Cropping in New Zealand – a review. *Agronomy New Zealand* ***31*** (in press).

Craighead, M.D. 2001b. The impact of fertiliser magnesium and potassium on the seasonal herbage Mg concentration in some South Island dairy pastures. *Agronomy New Zealand* ***31*** (in press).

Draycott.A.P.; Durrant, M.J.; Bennett, S.N. 1975. Availability to arable crops of magnesium from kieserite and two forms of calcined magnesite. *Journal of Agricultural Science* ***84*** *475-480.*

Edmeades, D.C. 1999. The magnesium requirements of New Zealand pastoral soils: a review. Edmeades Consultants Ltd, Hamilton.

FAR 2000. Arable update, cereals. 'Autumn wheat cultivar evaluation – Canterbury' No.61 March 2000. Foundation for Arable Research, Lincoln.

FAR 2001. Arable update, cereals. 'Sowing rates and times for autumn wheats' No.85 April 2001. Foundation for Arable Research, Lincoln.

McNaught, K.J.; Dorofaeff, F.D.; Karlovsky, J. 1973. Effect of some magnesium fertilisers on mineral composition of pasture on Horotiu sandy loam. *New Zealand Journal of Experimental Agriculture **1** (4) 349-363.*

Metson, A.J.; Brooks, J.M. 1975. Magnesium in New Zealand soils II. Distribution of exchangeable and 'reserve' magnesium in the main soil groups. *New Zealand Journal of Agricultural Research, **18** 317-335.*

Mulder, E.G. 1956. Nitrogen magnesium relationships in crop plants. *Plant and Soil **7** 341-376.*

Reuter, D.J.; Robinson, J.B. *Eds* 1998. Plant analysis: an interpretation manual. 2nd edition, CSIRO Publishing, Australia.

Scott, B.J.; Robson, A.D. 1991. Distribution of magnesium in wheat (*Triticum aestivum* L.) in relation to supply. *Plant and Soil **136** 183-193.*