A comparison of three methods of magnesium application to grapes

S.N. Trolove[1], S. Wheeler[2], A. Spiers[3].
[1]New Zealand Institute for Crop and Food Research, RD 2., Hastings
[2]Pernod Ricard New Zealand Ltd, PO Box 7095, Napier.
[3]Primaxa Ltd, Private Bag 300988, Albany, Auckland

Abstract

Magnesium (Mg) deficiency is common in vineyards in the Hawke's Bay, Marlborough and, particularly, Gisborne regions of New Zealand. This is thought to be due to high amounts of exchangeable potassium (K) and calcium (Ca) relative to Mg in the soil. Attempts to correct this deficiency using fertiliser have not been successful. This study investigated the fate of applied Mg fertiliser in a sandy Hawke's Bay soil and also compared fertiliser application by trunk injection and foliar sprays as techniques to increase leaf Mg concentrations. Brix and titratable acidity (TA) were also measured to determine whether Mg applications affected berry quality. Soil data showed that most of the Mg applied to this sandy soil remained in the top 30 cm of the soil 18 months after kieserite application. This may explain why the fertiliser application was not effective at increasing leaf Mg concentration – minimal water was applied to the grape vines (to reduce vigour) so much of the water (and hence nutrient) uptake may have been from deep in the profile, which remained unaffected by the added Mg fertiliser. Chardonnay on rootstock 3309 had a higher leaf Mg concentration than chardonnay grown in immediately adjacent rows on rootstock SO4. Foliar sprays increased leaf Mg concentration, although a large number of sprays would be needed if the deficiency was severe. The small increase in leaf Mg, achieved through foliar spraying, had no effect on berry quality. Trunk injection of Mg sulphate did not increase leaf Mg concentration.

Additional Keywords: chardonnay, SO4, 3309, kieserite, foliar spray, trunk injection, brix, titratable acidity

Introduction

Magnesium (Mg) is an essential macro-element for plant growth. Magnesium deficiency can impair export of photosynthate from leaves (Cakmak *et al*., 1994; Hermans 2004), and reduces photosynthetic efficiency (Skinner and Matthews, 1990). Lack of Mg can also increase the incidence of bunchstem necrosis in grapes (Cline, 1987). Little is published on the effect of Mg deficiency on grape quality for wine. Ruhl *et al*. (1992) found no change in several grape juice quality parameters following application of 60 kg Mg ha^{-1}, apart from a significant decrease of 0.02 in pH for a single variety of chardonnay.

Magnesium deficiency is common in vineyards in the Hawke's Bay, Marlborough and, particularly, the Gisborne regions of New Zealand. In many soils this is thought to be due to an imbalance in the ratio of Ca, K and Mg on the soil cation exchange. The authors are unaware of a critical K:Mg ratio for Mg deficiency in grapes. However, for other perennial crops such as citrus, Mg deficiency has been observed when the exchangeable K:Mg ratio was greater than 0.4 – 0.5 (McColloch *et al*.. 1957) and when the Ca:Mg ratio exceeded 7 (Aso and Bustos, 1981). Gisborne soils have a very high cation exchange capacity (CEC) and contain large amounts of exchangeable Ca and K. This means that rates of Mg fertiliser needed to correct the deficiency would be too high to be economic (Morton *et al*., unpublished). However, the light soils, where wine is grown, in Hawke's Bay and Marlborough have a low CEC and therefore it should be possible to apply enough Mg fertiliser to correct the cation ratios and thus ameliorate the Mg deficiency. However, grower experience has been that Mg fertiliser applications have not corrected Mg deficiency in Hawke's Bay, and the reasons for this lack of response of grapes to Mg fertiliser are not known. Possible reasons are that:

(1) Not enough Mg fertiliser has been applied to significantly change the K:Mg and Ca:Mg ratios

(2) Soluble Mg fertiliser is rapidly leached from these light soils, or

(3) The Mg fertiliser stays in the dry topsoil, and does not move deeper down into the soil profile where it can be taken up with water during the dry Hawke's Bay summers.

Rootstock choice can also contribute to the problem. Rootstock SO4 is particularly poor at absorbing Mg from the soil, and is exceptionally good at taking up K (Garcia *et al*., 2001).

Due to the lack of success with solid fertiliser applications, viticulturists have turned to foliar sprays. They do raise leaf Mg concentrations, to some degree, but are not sufficient in badly affected areas.

A technique that has not been tried previously is to inject dissolved Mg salts directly into the trunk of the vine. Trunk injection has been successfully used to treat fungal diseases, and correct micronutrient deficiencies. Scientifically, this technology is interesting because it avoids the need to get the nutrients in through the roots or leaves for vines growing on problem soils. From a practical perspective, injection technology would be helpful if it is quick and could supply enough nutrients to last the plant for several years.

There were two objectives of this research. First, to investigate the fate of applied Mg fertiliser in a sandy Hawke's Bay vineyard soil and second was to compare trunk injection with the two other traditional methods of applying Mg to grapes – solid fertiliser and foliar spraying – for their ability to increase foliar Mg concentrations. Brix and titratable acidity (TA) were also measured to determine whether the Mg applications affected berry quality.

Materials and Methods

Site and vineyard description

The site chosen was an Allied Domecq (now Pernod Ricard NZ Ltd) vineyard near the Tukituki River, Haumoana, Hawke's Bay, New Zealand. The soil type was an Esk fine sand. In places gravels come close to the surface. The site has a history of Mg deficiency. The grape variety used was chardonnay on SO4 and 3309 rootstocks. Planting density was 1,852 plants ha^{-1} and average crop yields were from 6 to 9 t ha^{-1}.

Treatments

- Control: no Mg
- Solid fertiliser: kieserite at 400 kg Mg ha^{-1} split into two equal applications, one soon after bud break and one just prior to flowering. This extremely high rate was chosen since grower experience had shown low rates of Mg were ineffective.

- Five sprays of $Mg(NO_3)_2.6H_2O$ at 0.43 kg Mg ha^{-1} $spray^{-1}$ (giving a total of 2.15 kg Mg ha^{-1}) between 23 November 2005 and 31 January 2006. Sprays were applied between 6.30 and 9.40 a.m. with an airblast knapsack and water at 580 l ha^{-1}. Five sprays at 0.43 kg Mg ha^{-1} is fairly typical of what viticulturists in the Hawke's Bay would apply.
- Injection: vines were injected with Mg sulphate on 29 July 2005. Fifty ml of 20 % $MgSO_4.7H_2O$ was pumped into each vine (giving 1.83 kg Mg ha^{-1}) using a Stemex Stemgun via a single 8 mm diameter hole drilled centrally through 90 % of the stem. Following injection a plastic plug was used to seal the hole. Injection was at pressures varying from 1,700 to 3,400 kPa. Slow pumping ensured that the trunk did not split so that sufficient Mg solution was injected. The injection was done under high pressure and in some cases a few drops emerged from the side of the trunk, suggesting that some damage to the vascular system. Fifty ml was near the maximum amount of solution that could easily be injected.

Design

There were two adjacent experiments, one with 3309 rootstock, and the other on SO4. Each experiment was a randomised complete block design with five blocks. However, leaf analysis showed that the rows had been mislabelled at planting. Two of the blocks that should have been SO4 rootstock had a Mg concentrations that matched the 3309 rootstock, so there were seven replicates of 3309, and three replicates of SO4. Each replicate was a bay of five plants, and leaf samples were collected from the middle three plants.

Sampling

Soil samples (at 15 cm increments down to 60 cm depth) were collected at harvest in 2007 and extracted for exchangeable Ca, Mg and K. In 2006, leaf blades were collected at veraison from all treatments from midway up mature canes. Brix and TA were measured on berries from the control and foliar spray treatments in 2006. These two treatments were chosen because only the foliar spray treatment showed a significant increase in leaf Mg content. In 2007, leaf blades were collected at veraison from the control and solid fertiliser treatments to determine whether there was a slow-acting effect of the fertiliser.

Results

Soil

Application of 400 kg Mg ha^{-1} in spring 2005 gave a large increase in exchangeable Mg in the top 30 cm of the soil 18 months later (Figure 11). A 60 % increase (0.8 meq 100 g^{-1}) was measured in the top 15 cm and a 30 % increase (0.3 meq 100 g^{-1}) in the 15–30 cm layer. Slight increases in exchangeable Mg below 30 cm depth were not statistically significant. There was a highly significant ($P < 0.01$) decrease in exchangeable Ca in the top 15 cm, from 7.6 to 5.6 meq 100 g^{-1}. This leached Ca could not be detected as an increase further down the soil profile, presumably due to the large variability in Ca data due to the presence of free $CaCO_3$ (Figure 11). Decreases in mean exchangeable K in the soil top 30 cm were not statistically significant, but there was a highly significant increase in exchangeable K in the 30–45 cm layer (Figure 11).

The exchangeable K:Mg ratio in the top 15 cm of the unfertilised soil (control) was 0.66:1 (Figure 1), which is unfavourable for Mg uptake (see Introduction). Application of 400 kg Mg ha^{-1} in the previous spring reduced the K:Mg ratio in the top 15 cm to 0.38, which is just within the favourable range. The K:Mg ratio was less than 0.4:1 below 15 cm depth, which is favourable for Mg uptake, but the Ca:Mg ratio was unfavourable in the subsoil. The exchangeable Ca:Mg ratio in the unfertilised soil (Figure 1) rose from 6:1 in the topsoil to 9:1 in the 15–30 cm layer, and to even greater values in the subsoil (although the exact values are not known because of the presence of free $CaCO_3$). The addition of a large amount of Mg fertiliser did little to reduce the Ca:Mg ratio below 15 cm depth, with the Ca:Mg ratio in the 15–30 cm layer decreasing to 7.8:1 in the fertilised treatment.

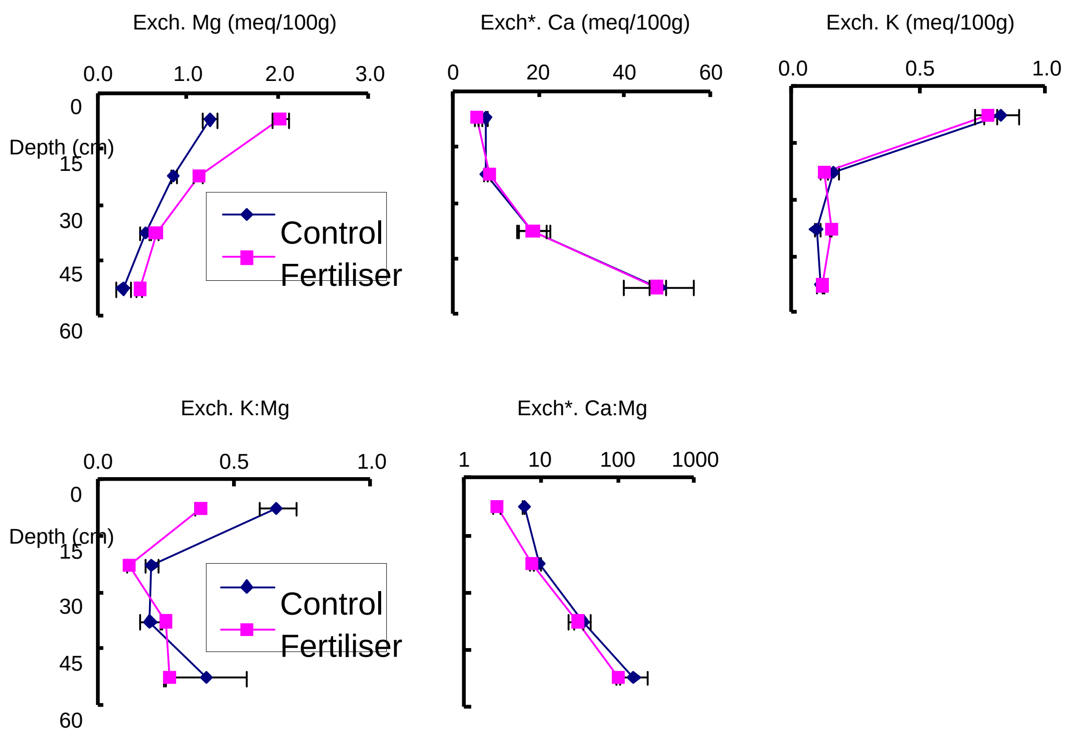

Figure 11: Exchangeable Mg, Ca and K in the soil at harvest 2007 after applying 0 or 400 kg Mg ha^{-1} in spring 2005. The bars are mean ± SE, n = 5. *The high Ca values below 30 cm depth indicate free $CaCO_3$ was present as well as exchangeable Ca.

Leaf

Foliar spraying was the only treatment significantly increased leaf Mg concentration at veraison (Figure).

Injection of Mg sulphate into the trunk had no effect on leaf Mg concentration. A small increase in leaf Mg concentration, in the fertilised treatment, was evident by veraison in the second season (Figure 12) for chardonnay grown on 3309 rootstock.

However, there was no increase in chardonnay on the SO4 rootstock. Leaves from chardonnay on SO4 rootstock showed signs of extreme Mg deficiency and the margins of some leaves were starting to die. However, it may have been too late to detect differences in leaf Mg concentration because most of the mobile Mg would have already been exported from the leaves.

Berry internal quality

Increasing the leaf Mg concentration by applying foliar sprays had no effect on the Brix, TA or pH of the grape berries (Table 9).

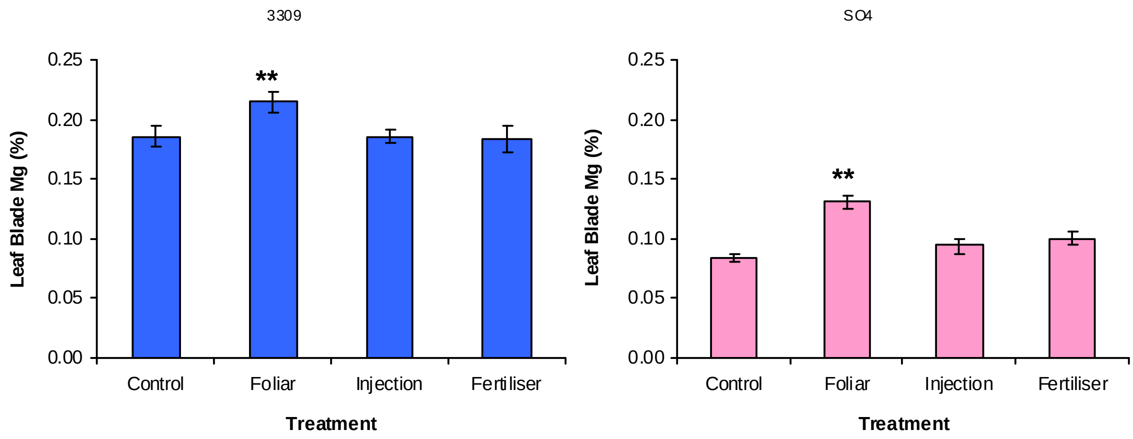

Figure 2: Leaf blade Mg concentration at veraison for chardonnay on two rootstocks: 3309 and SO4. Bars are ± SE Mean; n = 7 for 3309, n = 3 for SO4. ** significantly different from other treatments at P = 0.01.

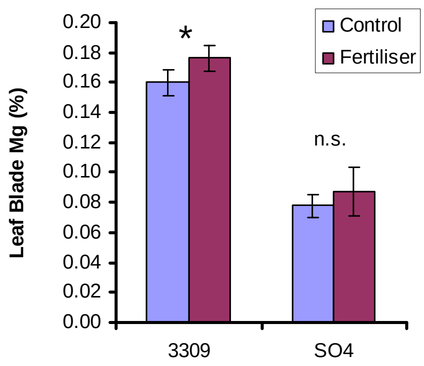

Figure 12: Leaf blade Mg concentration at veraison for chardonnay that received 0 or 400 kg Mg ha^{-1} the previous spring. Bars are ± SE Mean (n = 10) * significantly different at P = 0.05.

Table 9: Brix, titratable acidity (TA) and pH data for chardonnay grown on two different rootstocks from the Foliar and Control treatments in 2006. Differences between the treatments are less than the $LSD_{0.05}$, so no differences are statistically significant.

	SO4			3309		
Treatment	Control	Foliar	LSD	Control	Foliar	$LSD_{0.05}$
Brix	23.0	22.8	1.25	22.8	23.1	0.49
TA	11.0	10.7	1.25	9.54	9.46	0.41
pH	3.13	3.12	0.025	3.16	3.17	0.037

Discussion

Soil

One theory as to why Mg fertiliser application did not increase leaf Mg concentrations was that the Mg was being leached, over winter, in these sandy soils. The highly significant decrease in exchangeable Ca in the top 15 cm of soil, and the significant increase in exchangeable K in the 30–45 cm layer shows that application of Mg caused some downward movement of Ca and K in this sandy soil. However, Figure 11 clearly shows that most of the Mg remained in the top 30 cm of the soil 1 months after kieserite application. Most of the Mg remaining in the topsoil may explain why the fertiliser application was relatively ineffective. Although Hawke's Bay has dry summers, minimal water was applied to the grape vines to reduce their vigour; this means that much of the water (and hence nutrient) uptake was from deeper in the profile, which was not affected by the added Mg fertiliser and had an unfavourable Ca:Mg ratio. Beets *et al*. (2004) noted a similar problem in *Pinus radiata*, where Mg fertiliser remained in the topsoil and was ineffective during dry summers because the bulk of water uptake was from deeper down in the profile.

Management

Foliar applications of Mg gave the largest and most immediate increase in leaf Mg concentration of the three treatments. Five foliar sprays increased the leaf concentration of chardonnay on 3309 rootstock to the recommended range of 0.2–0.5 % (Smart *et al*., 1986), but were insufficient for chardonnay when grown on the SO4 rootstock. The response to fertiliser was small and not evident until the second season (first season data not shown). Responses to Mg in perennial crops may take up to three seasons to appear (e.g. Mason, 1963; Embleton *et al*., 1973). At current NZ prices of \$1.05 kg^{-1} for crystalline Mg nitrate, foliar spraying is much cheaper, in terms of percentage increase in leaf Mg per dollar spent, than soil-applied kieserite at \$480 t^{-1} (\$2.26 ha^{-1} for the foliar Mg nitrate treatment *c.f.* \$1,200 ha^{-1} for the kieserite treatment, excluding application costs). To reduce application costs, foliar Mg can be included with other sprays, but it is always important to check the label first. Foliar sprays would not cause any leaching of K from the soil, as appears to have happened with large application of Mg fertiliser. The largest increase in leaf Mg concentration is likely to come from application of solid Mg fertiliser combined with a foliar Mg programme. The economics of applying large amounts of Mg fertiliser needs to be considered, given that Mg had no effect on berry Brix or acidity.

Soil samples from two of the plots growing the 3309 rootstock showed there was no difference in cation concentrations in plots growing the SO4 rootstock in immediately adjacent rows. This suggests that the only major difference between the two blocks was the rootstock. If this assumption is correct, then the management choice that most dramatically affected chardonnay leaf Mg concentration in this experiment was to choose a rootstock that is better at taking up Mg, in this case 3309. Rootstock 3309 has already been shown to be superior to SO4 in taking up Mg when grown in inert volcanic rock fragments (Garcia *et al*., 2001).

This work has confirmed growers experience that foliar sprays are the most effective way to increase leaf Mg concentrations. The next question to be answered is "Is Mg deficiency causing economic losses to viticulturists, or is it merely a perceived problem?" Results of this study agree with those of Ruhl *et al*. (1992) who found Mg deficiency did not affect berry quality. We are unaware any published data on yield. Studies with citrus indicate that yields are reduced one out of every four years in the case of a mild Mg deficiency (Erner *et al*., 2004). To answer the question of the importance of Mg deficiency on yield in grape vines would require a study of approximately 5 years to be undertaken, using large plot areas and sufficient foliar Mg to get the leaves into the recommended concentration range. The number of sprays required to raise leaf Mg percentage to the recommended range at veraison could be estimated based on last season's leaf test value (at veraison) and assuming a similar increase in leaf Mg concentration as achieved for rootstock 3309 in this study.

Conclusions

Chardonnay on rootstock 3309 had a higher leaf Mg concentration than chardonnay grown in immediately adjacent rows on the SO4 rootstock. Foliar sprays increased leaf Mg concentration, although many sprays would be needed if the deficiency was severe. The small increase in leaf Mg concentration from foliar spraying did not change berry Brix or TA. Trunk injection of Mg sulphate did not increase leaf Mg concentration. There was little (10 %) increase in leaf Mg concentration over two seasons following application of a large amount of solid Mg fertiliser (400 kg Mg ha^{-1} as kieserite), thus solid fertiliser is less economic than foliar spraying.

Acknowledgments

The authors are grateful to Kevin Cooper of Haumoana Estate for use of his vineyard. This research was funded by the Agricultural and Marketing Research and Development Trust, and Mg nitrate and berry analyses were sponsored by Allied Domecq (now Pernod Ricard).

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