ADVERSE EFFECTS OF MICRO-VARIANCE IN SOIL pH ON PASTURE PLANT GROWTH, AND MITIGATION USING ALPHA®

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Abstract

Micro-variance in soil pH is observed in many grazed pastures, with typical soil pH variations of 0.5 to 1 pH units. The reliance on an 'average' soil pH on a paddock scale underestimates the risk to production posed by both small and larger sites with low pH and associated aluminium (Al), manganese (Mn) and iron (Fe) toxicity. Application of the carboxylate co-polymer AlpHa® reduces phytotoxic levels of Al, Mn and Fe , as does heavy application of lime, but avoids the adverse effects of over-liming on sites with pre-existing higher pH, thereby allowing the whole paddock to maximise productivity. In this study, the effects of pre-existing soil pH variability on pasture dry matter yield, and the effect of AlpHa® applied at 2l /ha, are examined in a greenhouse trial over the pH range of 4.8 to 5.6, in 0.2 pH unit increments.

Introduction

Aluminium (Al) and manganese (Mn) phytotoxicity inNew Zealand pastures have been identified as major risks to maximum production (Smith *et al.* 1983; Edmeades *et al.* 1991). Al phytotoxicity increases as soil pH falls below 5.5, while Mn phytotoxicity occurs under reducing/water logged conditions. The phytotoxic effects of these metals has traditionally been minimised by the infrequent heavy applications of agricultural lime. Over 90% of New Zealand pasture soils have been identified as requiring maintenance lime (During 1984).

Recent studies (Bishop *et al.* 2012) have shown that these phytotoxicities can also be reduced by low application rates (2L/ha) of the carboxylate co-polymer AlpHa® (Patent Application NZ597821), in both pot and field trials. This product is not to be confused with the poly dicarboxylic acid Avail®, which is promoted as increasing crop yield through reduction in P fixation.

Bishop *et al.* (2012) found a 25% greater increase in ryegrass DM production following the application of 2 L/ha AlpHa® compared to 1000 kg of finely ground limestone in a six week pot trial grown in soil with phytotoxic levels of Al (Dannevirke silt loam, pH 4.3, with rhizospheric Al solution concentration of 4.9 mg/L). In a field trial on water-logged pasture (Tokomaru silt loam, pH 5.8 with phytotoxic levels of Mn (0.35%)and Fe (3.7%), as measured in washed grass roots), the application of 2 L/ha of AlpHa® in conjunction with 2 L/ha of sodium silicate solution increased DM production by 241 kg DM/ha over a 30 day period.

To further understand the reasons for these effects, Bishop et al. (2013) conducted a glasshouse solution culture growth response trial for annual ryegrass(Moata) with solution culture media containing various levels of Al, Mn, Fe and AlpHa™. The results of this solution culture study showed significant increases in herbage growth from all AlpHa® concentrations from 0.2 to 20 uL/L at Al concentrations from 0 to 1.6 mg Al/L. AlpHa® showed a more rate-sensitive effect on herbage growth in the presence of Mn. The two highest concentrations (2 and 20 uL/L) of AlpHa® delayed the onset of Mn phytotoxicity to between 20 and 40 mg Mn/L. AlpHa® offset effects of iron phytotoxicity on herbage growth only at the highest AlpHa®level and lowest Fe level tested, but positive AlpHa® effects on root growth were found at all concentrations of Fe.

Bishop *et al.* (2013) also presented preliminary evidence that the extent of Al phytoxicity in grazed pasture is poorly represented by current commercial soil sampling procedures, which combine a number of soil cores from a paddock to give an average soil pH. As well as giving rise to an artificially high average pH compared to the average of individually tested soil cores, possibly as a result of biological processes (Carran & Theobald 1995), the measurement of pH in this manner gives no indication of pH variability. A major cause of this variability is short and long-term pH changes in urine patches. Normal commercial soil testing procedure intentionally avoids both obvious urine patches or very poorly growing areas, which also leads to underestimation of soil pH variability. The testing of individual soil cores and the statistical analysis of the pH frequency distribution at nine sites demonstrated that soil pH was highly variable within short distances, with the sampling standard deviation varying between 0.29 and 0.83 pH units (Bishop *et al.* 2013). The impact of this micro-variability on pasture yield has not previously been quantified, and there is no published data on either micro-variability in soil pH and soil solution metal concentrations, or on their effects.

While the effects of metal phyto-toxicity on pasture species have been studied using solution culture techniques (Smith *et al.* 1983; Edmeades *et al.* 1991), the application of this to the soil system has not been studied in terms of either soil solution Al, Mn or Fe levels or micro-vareablity in soil pH. A greenhouse trial was therefore conducted to determine the effect of small changes in soil pH on soil solution concentrations of Al, Mn, Fe, and on dry matter yields, with and without the addition of the carboxylate co-polymer AlpHa®.

Method and Materials

Individual pots of Dannevirke silt loan from nil-AlpHa®plots of the previous liming trial in 2012 were analysed fresh in water (1:2 ratio) for pH, and sorted pH groups of pH 4.8, 5.0, 5.2, 5.4, 5.6.Basic soil analysis was carried out by Hill Laboratories (Table 1).

Table 1 Chemical properties of pH micro-variant soil groups analised on air dried soil (Hill Laboratories, Hamilton).

Fresh soil pH groups		4.8	5.0	5.2	5.4	5.6
pH (air dried)		4.6	4.8	4.9	5	5.4
Olsen P	mg/L	21	20	22	21	16
Anion Storage Capacity	%	97	99	95	96	93
Potassium	me/100g	0.58	0.57	0.54	0.53	0.44
Calcium	me/100g	4.4	8.3	6.9	10.3	10.3
Magnesium	me/100g	0.35	0.46	0.38	0.44	0.39
Sodium	me/100g	0.15	0.18	0.15	0.15	0.14
CEC	me/100g	24	27	25	27	25
Total Base Saturation	%	23	35	32	42	45
Sulphate S	mg/kg	599	782	494	568	274
Extractable organic S	mg/kg	<2	<2	<2	<2	7
Aluminium (CaCL2 0.02M)	mg/kg	22.3	11.5	nd	nd	2

Six replicates from each pH group were prepared in 5cm square pots (170g fresh soil) and sown (16/12/2013) with either ten annual ryegrass (Moata), or ten diploid perennial ryegrass and ten white clover seeds. This gave six replicates of each pH for annual ryegrass and perennial ryegrass/white clover mixtures. To half of the replicate pots, Alpha® was added at a rate equivalent to 2l/ha based on the surface area of the pots (0.5 ul per pot or 3.5 ul/kg dry soil). The pots were then randomised in trays and placed in a greenhouse to grow. Soil moisture was maintained between 60 and 80% field capacity. Following germination the annual ryegrass was thinned to 5 plants per pot and all pots received the equivalent of 20 kg P per ha as DAP solution. The pots were clipped to 2 cm on the 20/1, 9/2 and 2/3/2014 to determine dry matter accumulation.

Following the third clip, soil solution samples were obtained by increasing the soil moisture to field capacity for 16 hr, followed by centrifugation at 10G for 30 min to extract macro-pore water. The soil solution was then analysed for pH, dissolved organic carbon (DOC) Al, Mn and Fe, to be reported in following paper Bishop & Quin 2014 (in press).

Results and Discussion

Annual ryegrass (Moata)

Initial evaluation of the dry matter production as a function of pH and AlpHa® showed unusual response to pH for the annual ryegrass with maximum yield being obtained at pH 5.0 (Figure 1). However on further analysis of the soil solutions, this soil group was found to contain atypical, very high dissolved organic matter levels, indicating the likelihood of high initial level of labial carbon in the pH 5.0 soil, which, like AlpHa®, would reduce the toxic effects of Al on plant growth. This group was therefore excluded from the data analysis. With this data excluded, a more consistent growth response to pH is observed, with the addition of AlpHa® increasing DM production up to pH 5.4.

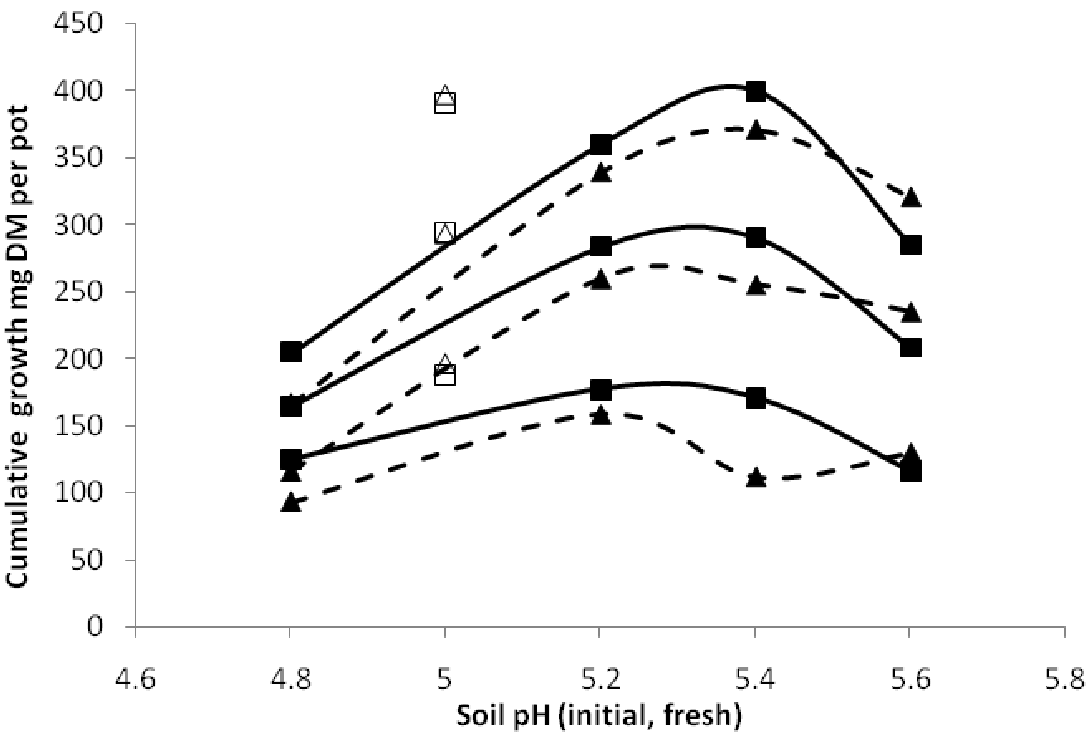

Figure 1. Cumulative dry matter production of annual ryegrass (Moata) as a function of initial soil pH for the first three clips, with AlpHa® (■) and without(▲). Hollow symbols represent excluded data due to high dissolved organic matter levels.

Perennial ryegrass and white clover mix

Again with the removal of the pH 5.0 group, the growth response of perennial ryegrass and white clover to pH was consistent, with DM decreasing with pH from 4.8 to 5.4, then declining again. The minimum at pH 4.8 was likely due to soluble Al toxicity, and the decline at pH 5.6 (which increased to 6.2 during the trial) is likely due to the reduction in availability of cationic micro- nutrients at higher soil pH.

Unlike the case with Moata tetraploid ryegrass, the application of AlpHa® had no significant effect on DM production with the perennial ryegrass/clover mix, production of which was dominated by the perennial ryegrass in the initial three harvests. This ryegrass appears to be less responsive to both pH and to AlpHa®.

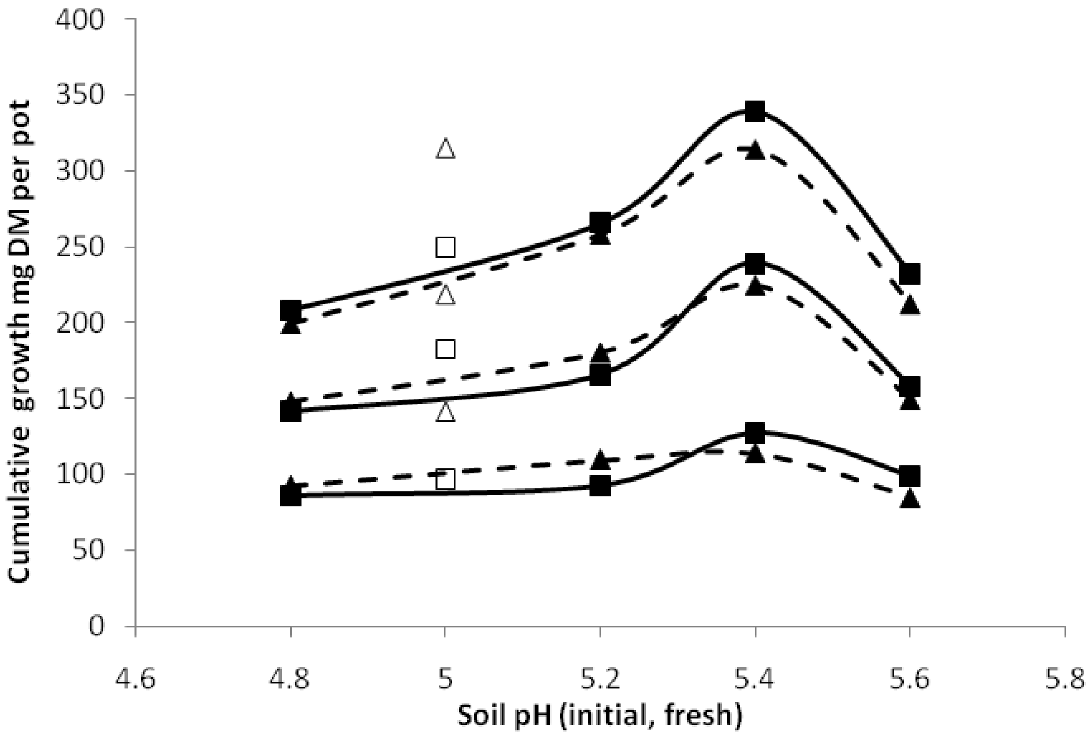

Figure 2. Cumulative dry matter production of mixed pasture perennial ryegrass and white clover as a function initial soil pH for first three clips, with AlpHa® (■) and without(▲). Hollow symbols represent excluded data due to high dissolved organic matter levels.

Conclusions

The growth of both annual and perennial pasture ryegrass species, but particularly the former, were adversely affected by low soil pH. The application of the carboxylate co-polymer AlpHa® was found to reduce these adverse effects, particularly in case of the annual ryegrass Moata.

In a subsequent paper, the authors describe the effects of soil solution and herbage Al, Mn and Fe concentrations on plant growth, and assess the ability of Alpha® to reduce metal phytotoxicity (Bishop & Quin 2014).

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