THE USE OF POLY-CARBOXYLIC ACIDS AND SODIUM SILICATE TO INCREASE FERTILIZER P EFFICIENCY AND REDUCE LIME REQUIREMENTS ON ACID SOILS IN NEW ZEALAND AND VIETNAM

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Abstract:
The application of poly- carboxylic acids (PCA) to acid soils has been shown in field trials in the Mekong delta of Vietnam to increase rice production by up to 557 kg ha^{-1} when applied in association with di-ammonium phosphate (DAP) compared to DAP alone. In New Zealand trials, the application of a low cost PCA AlpHa^{TM} has increased production in acid soils by reducing aluminium toxicity, and may be an alternative to lime application in reducing metal toxicity in pastures.

Introduction:
In many countries of the world, agricultural production is limited by toxicity from metals such as aluminium, manganese and iron. The occurrence of metal toxicity in many cases can be overcome by the addition of lime (calcium carbonate), slaked lime (calcium hydroxide) or other alkaline/liming materials to increase the soil pH and precipitate toxic metals and thus increase plant growth. This phenomenon is commonly termed the "lime response".

Wheeler (1998) demonstrated that the addition of limestone to a soil at rates of 5000kg/ha and 10000kg/ha increased the soil pH (water) from an initial pH 5.26 to pH 5.97 and pH 6.25 respectively in the first year following application. The increase in soil pH reduced surface and subsoil extractable (1M KCl) aluminium from 65mg Al/kg at 0-5cm and 260mg Al/kg at 5-10cm soil depths to <5mg Al/kg. This resulted in increases in pasture production of 7% and 13% over the following four years at the two application rates. The application rates of liming material required are large relative to the toxic metal concentration, which can be toxic at soil solution levels as low as 0.13 mg Al^{3+}/l for clovers (Edmeades et al. 1991), equivalent to about 130 g Al^{3+}/ha in the top 10 cm of soil.

The manipulation of soil pH to resolve metal toxicity is however an expensive practice, due to the large amounts of lime required. Application of liming materials can become very expensive once the cost of the liming material, its cartage and spreading are taken into account, especially in hill country where aerial application is required.

Other methods of reducing metal toxicity to plants have been contemplated. For example, it is known that many aluminium-tolerant plants excrete organic acids such as citric, malonic and oxalic acids which both assist in nutrient solubilisation, and complexation with Al^{3+} (Aimi et al. 2010) to reduce aluminium toxicity in plants. Aimi et al (2010) have also shown that higher weight polymers such as oxidized Kraft lignin (KL) (at levels of > 25mg/l) were

capable of reducing aluminium toxicity (at a level of 0.91 mg Al/l) in radishes without dramatically lowering the total soluble aluminium. This is a similar result to earlier work on Kraft lignin by Katsumata et al. (2001), who found that only 140 mg/l of oxidised KL was required to reduce the toxicity of 5 mg Al/l, resulting in a mass ratio of 28 oxidized KL:1Al. The detoxifying effects of polymeric compounds have also been referenced in a review by Haynes and Mokolobate (2001). The natural polymer of fulvic acid at 40 mg C/l relieved the toxic effects of 0.78 mg Al/l on the growth of maize roots. However there is currently no commercially available product which is specifically designed to ameliorate soil metal toxicity.

The use of anionic polymers (such as poly carboxylic acid compounds and sodium silicates) in agriculture has a long history. In the 1950's polymers such as poly vinyl acetate maleic acid (PVAMA) were used as soil conditioners (Martin 1953). More recently poly maleic acid (PMA) is used as a soil wetting agent for irrigated agriculture. Anionic polymers made up of vinyl and dicarboxylic moieties for use with fertilisers (for example as a fertilizer coating) are commercially available under the trade name AVAIL produced by Specialty Fertilizer Products LLC. These products are primarily designed and promoted to enhance plant growth by enhancing the uptake of phosphate from high-analysis NP fertilizers such as di-ammonium phosphate (DAP). Although expensive, these products have been shown to profitably increase yields and increase fertilizer efficiency in many situations.

There is still however a need for an improved product and/or method which will effectively ameliorate soil metal toxicity on acid soils efficiently and cost-effectively, to reduce the amount of liming material that is normally applied for this purpose.

In this paper we present the results from trials investigating the growth response of a low cost polymer PMA (AlpHa) and a sodium poly-silicate (SSD) on pasture as an alternative to lime application in New Zealand, and AVAIL on rice production in Vietnam.

Pasture Response to PMA, SSD and Lime:
(NZ Pat App 597821)

To determine the effective "lime response" of PMA (AlpHa^{TM}) and sodium poly-silicate(SSD) a pot trial was conducted on Perennial Ryegrass (*Lolium perenne*) grown in an acidic allophanic soil (Dannevirke silt loam, pH 4.3) with a rhizospheric Al solution concentration of 4.9 mg/l. The soil (250g) was placed in 5cm square space saver tubes with the addition of one transplanted Ryegrass seedling prior to the application of the five replicates treatments of:

- Lime flour at 50,100,200,500 and 1000 kg/ha,
- AlpHa^{TM} (PMA produced by Advanced Agricultural Additives (NZ) Ltd., applied at 2 l/ha as a 1:1000 diluted solution.
- Sodium poly-silicate (SSD) applied at 2 l/ha as a 1:1000 diluted solution.

Dry matter production was measured at two week intervals by clipping the plants to a height of 3cm, followed by drying at 65^{o}C.

Results:
Result from this trial are only preliminary at this stage, a number of pots were lost when the greenhouse suffered damage in a storm.

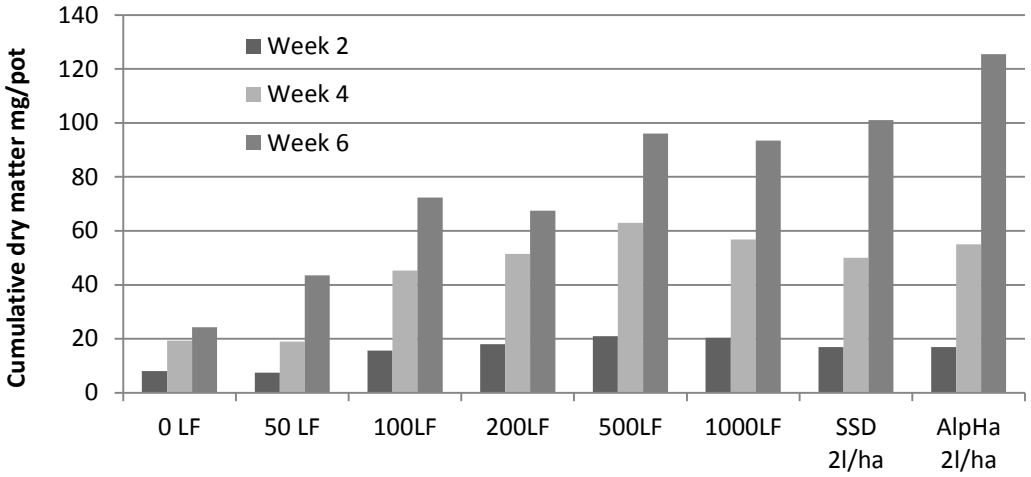

Figure 1. Cumulative dry matter response of Ryegrass to the addition of lime flour (LF) at rates of 0 to 1000kg/ha at 2 weeks, 4 weeks and 6 weeks, compared to the addition of sodium poly-silicate (SSD) and AlpHa^{TM} at 2 l/ha.

The preliminary results show that the initial application of AlpHa^{TM} at a rate of 2 l/ha has produced 25% more dry matter than the initial application of 1000 kg/ha of lime flour after six weeks, while the application of sodium poly-silicate (SSD) at 2 l/ha has produced equivalent results to the 1000kg/ha Lime Flour. These results indicate that small applications of AlpHa^{TM} and poly-silicates are an alternative to fine limestone applications in the amelioration of Al toxicity in acid soils. This trial is being repeated to establish the statistical significance of the results.

In addition to this liming equivalence trial, a small field trial has been undertaken on poorly drained permanent pasture to determine if an increase in pasture production can be observed following the application of a mixed AlpHa^{TM}/SSD (1: 1 mixture by volume) product at (2l/ha of AlpHa^{TM} and SSD).

Field trial of AlpHa/SSD
(NZ Pat App 597821)

In grazed pasture systems there is a high degree of spacial variability due to urine and dung returns following grazing and soil compaction etc. These can make it difficult to assess the effectiveness of treatment applications. To help overcome these problems the trial of AlpHa^{TM}/SSD was carried out using close proximity one meter square plots arranged as matched pairs.

The site in Tokomaru on Tokomaru silt loam had been grazed for the last three years by calves up to yearling cattle (mixed beef, steers and heifers)and has been uncultivated for the

last 20 years, comprising a mixed pasture of ryegrass, red and white clover, cocksfoot and butter cup (due to poor drainage). Examination of the grass roots in the soil revealled strong mottling along the root soil interface and encapsulation of the root system in older grasses by redox deposited minerals. These observations indicated that this site could be responsive AlpHa^{TM}/SSD treatments, as PMA's are also commonly used in water treatment to prevent accumulation of iron precipitation in irrigation systems.

The trial area was initially mown to 5 cm high on the 17/12/2011 and marked out into six 1 m wide, 8 m long strips separated by 0.5 m. Three alternate strips were then sprayed with 0.66 l of water containing 3.2 ml of AlpHa^{TM}/SSD solution each, to give a application rate of 4 l/ha. The strips were then divided into 1 m sections, giving a total of 24 paired replicates of control (Nil-AlpHa^{TM}/SSD) and adjacent AlpHa^{TM}/SSD treatment. Fertilizer was applied on 20/12/2011 at 100 kg N/ha and 11 kg P/ha as SOA and DAP.

The plots were harvested on the 16/1/2012 and 27/2/2012 and dry matter accumulation determined.

Results:
The Tokomaru trial site showed an overall increase in dry matter of 95 kg DM /ha (P= 0.18) or 3.2 kg/ha/d in the first harvest and 94 kg DM /ha or 2.3 kg DM/ha/d (P= 0.09) for the AlpHa/SSD formulation above the control.

Table 1. Dry matter production and accumulation data for the first two harvests form the AlpHa^{TM}/SSD applied at 4l/ha verses control. Established on the 17/12/2011, on Tokomaru field site using 24 paired replicates.

Harvest date	**Dry Matter**		**Dry mater accumulation rate**	
	17/01/2012	27/02/2012	17/01/2012	27/02/2012
	kg/ha	kg/ha	kg/ha/d	kg/ha/d
AlpHa/SSD	2955	1783	98.5	44.6
Control	2860	1877	95.3	46.9
Difference	95	93	3.2	2.3
Paired T-Test results	0.18	0.09	0.18	0.09

Preliminary conclusion from New Zealand based trials
Initial trial results; indicate that application of AlpHa^{TM} and SSD reduced lime requirements by 1000 fold on a solids basis. A number of additional trials will be carried out confirm these results on a wider range of soils. The application of AlpHa^{TM}/SSD to the Tokomaru grazed pasture site showed the potential of PCA's and poly-silicates to improve production in water logged soils. Further work with pot trials to be carried out over the next year to gain a fuller understanding of these effects.

Rice production in Vietnam:
Vietnam is one of the world's leading rice producer, growing 40 million tonnes per year on 7.7 million hectares of mainly paddy fields, consuming 309,000 t of P annually (FAO stats 1999). The Mekong delta is one of the largest areas with nearly 1.9 million hectares of paddy

rice production, of which 0.8 million hectares are affected by acid sulphate soils (ASS), with pH's as low as 3.5 but more commonly around 4.5 to 4.9. The low soil pH's increase the solubility of metals and can result in fixation of phosphate as iron and aluminium compounds which reduce the plant availability of the phosphate (Ren et al. 2004). In addition to the reduction in phosphate availability both Fe and Al may become phytotoxic (Ren et al. 2004; Tanaka et al. 1966). The addition of organic matter at 1.2 to 10 t/ha (Ren et al. 2004; Qin et al. 2011; Wang et al. 2011) has been shown to reduce exchangeable Al, improve P uptake and production on ASS. However this requires large volumes of material to be transported and added to the soil. This can be potentially avoided by the addition of PCA to the P fertilizer. Two products (PCA1 and PCA2) have been tested in the Mekong Delta region by the Mekong Delta Rice Research Institute. The results of trials in 2011 have shown that on P responsive soils, both PCA1 and PCA2 coated on to DAP at 2 l/t reduced the phosphate requirement to achieve optimum yield by approximately 50%. (figure 2.)

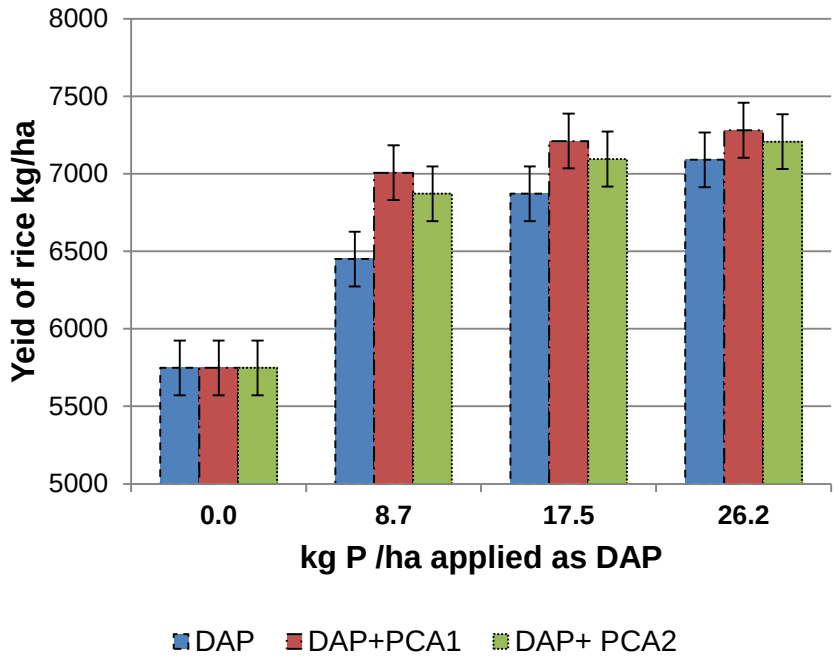

Figure 2. Rice response data for the addition of di-ammonium phosphate (DAP) with and without coating with polycarboxylic acids PCA1 and PCA2 at 2l/t of DAP. Trials conducted by Mekong Delta Rice Research Institute (Dr Tan Sy Pham, 2011 per. com.).

The results show that the application of either PCA1 or PCA2 allow the reduction of P application from 17.5 to 8.7 kg/ha without reduction in rice yield.

Summary

The application of AlpHa^{TM} or SSD as a lime substitute can reduce the application mass by up to 1/1000 that of lime flour. However the stability of SSD is limited to highly alkaline conditions which could prevent it use with lime and many other fertiliser products. The application of the combination of AlpHa^{TM} and SSD to soil prone to water logging has shown increases in production of up to 5% over the summer period.

The combination of PCA's with DAP has shown to be an effective way of increasing pasture and rice production in soils affected by low pH or poor drainage without the capital costs of drainage or capital applications of lime.

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