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- **Open Forum**
- **On site trial display and presentation of multi-year replicated pasture trial results**
- **Discussion of multi-site leaching trials involving bio-stimulants**
- **Internationally Peer Reviewed Science**

**Refreshments and BBQ at 12pm**
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# Biological Stimulants Increase Fertiliser Efficiency and Pasture Legume Content

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**Keywords:** Biological agriculture; biostimulants; fertiliser efficiency; sustainable agriculture.

**Abstract**

The effects of a soil biological stimulant (SS) and biologically activated reactive phosphate rock (BAP) on pasture yield and botanical composition were examined in a field trial in low-fertility New Zealand rangeland. BAP application significantly increased pasture yield by 60% and BAP plus biostimulant increased yield by 120%. BAP significantly increased resident legume cover by 75% and BAP with biostimulants by 85%. Alfalfa, direct drilled as an indicator test species, increased in establishment from 0 to 3.8 plants $m^{-2}$ with BAP and to 4.2 plants $m^{-2}$ with BAP plus biostimulant. Biostimulant applied alone increased yield by 17%, legume cover by 2% and alfalfa establishment by 0.1 plants $m^{-2}$. These results are consistent with previous trials in high-fertility pastures and may assist in the development of sustainable agriculture.

## Introduction

The projected world population growth requires increased food production. This will require fertilizer inputs, principally nitrogen (N) and phosphorus (P). Improving fertiliser use efficiency and mitigating negative environmental effects from fertilizers are key areas for developing sustainable agricultural intensification (Pretty & Bharucha 2014). We tested two products, BioAg stimulants added to reactive phosphate rock (biologically activated phosphate BAP) and Soil & Seed (SS) biostimulant, which both activate soil microbiology. Previous New Zealand farm and field trials demonstrated BioAg biostimulants gave positive pasture growth responses at lowland high-fertility sites (Haswell et al. 2014, Espie 2019).

We extended field trials to upland low-fertility rangeland near Twizel, Mackenzie basin, in 2020. We tested the hypothesis that biological stimulation of pasture growth also applied in low-fertility rangeland grasslands.

**Methods**

The trial site has mean annual precipitation of 500 mm and annual temperature averages 8.5 $^{0}$C. The soil is free draining Mackenzie silt loam over gravels on fluvioglacial outwash. The soils were cultivated once 17 years previously and fertilized with 450 kg/ha sulphur superphosphate and three t/ha of lime. Topsoil pH is 5.6, total C 2.7%, total N 0.24%, extractable P 29 mg/kg. Alfalfa (*Medicago sativa* cv. Force 10) was drilled to provide a low-fertility aluminum sensitive indicator species to compare with resident species. Experimental design was randomized block, 9 fertilizer treatments in four blocks totaling 36 10 $m^2$ plots. BAP was applied in winter, May 2021, at rate of 250 kg/ha BAP with 50 kg/ha elemental sulphur and 500 kg/ha lime. BAP is a highly reactive Algerian phosphate rock and this combination directly supplied phosphorus (P), sulphur (S) and calcium (Ca). SS was spray applied at 4, 8 and 12 l/ha with boron and molybdenum in spring, November 2021. The fertilizer applications were nil fertilizer (double replication), BAP, BAP with each rate of SS and 3 rates of SS. Pasture production was measured eight months after BAP application and 1.7 months after SS application. Herbage was harvested with a rotary mower to 5-6 cm cut height. Subsamples were taken from every plot for dry matter determination. The percentage cover of every species present in each plot was visually scored. Alfalfa plants were counted and the height of the three tallest plants, or tallest plant(s) if < 3, was measured. R 4.2.1 software was used for statistical analysis.

**Results and Discussion**

BioAg applications significantly increased pasture production from 1,631 kg dry matter (DM) to 3,580 kg DM $ha^{-1}$ (Figure 1; $P < 0.008$). SS increased yield by 17% above untreated grassland. BAP increased production by 60%. BAP plus SS increased production: BAP with 4 l/ha SS increased yield by 120% ($P < 0.018$), BAP with 8 l/ha gave a 110% increase ($P < 0.08$) and BAP with 12 l/ha gave a 75% increase (ns).

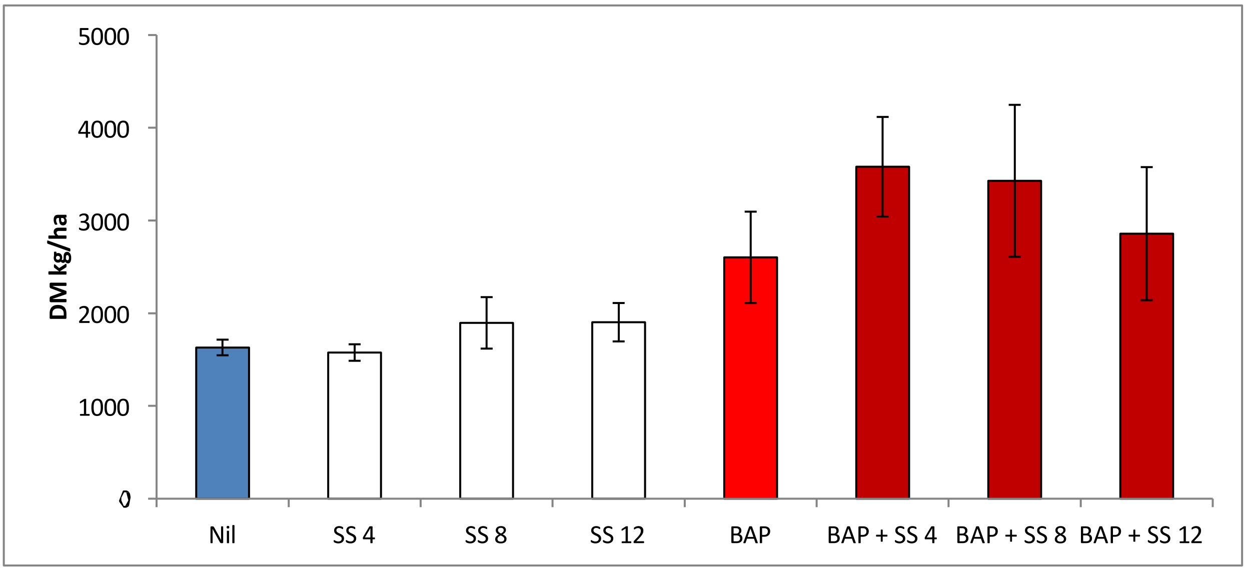



**Figure 1. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on pasture production ± Standard Error.**

BioAg applications significantly changed pasture composition (Figure 2). SS increased grass cover by up to 1.5 times and resident legume (*Trifolium arvense, T. dubium, T. repens*) cover by 6.7 times. Increasing SS application rate progressively increased grass cover by 32%, 43% and 67%. BAP increased legume cover by up to 307 times ($P < 0.001$).

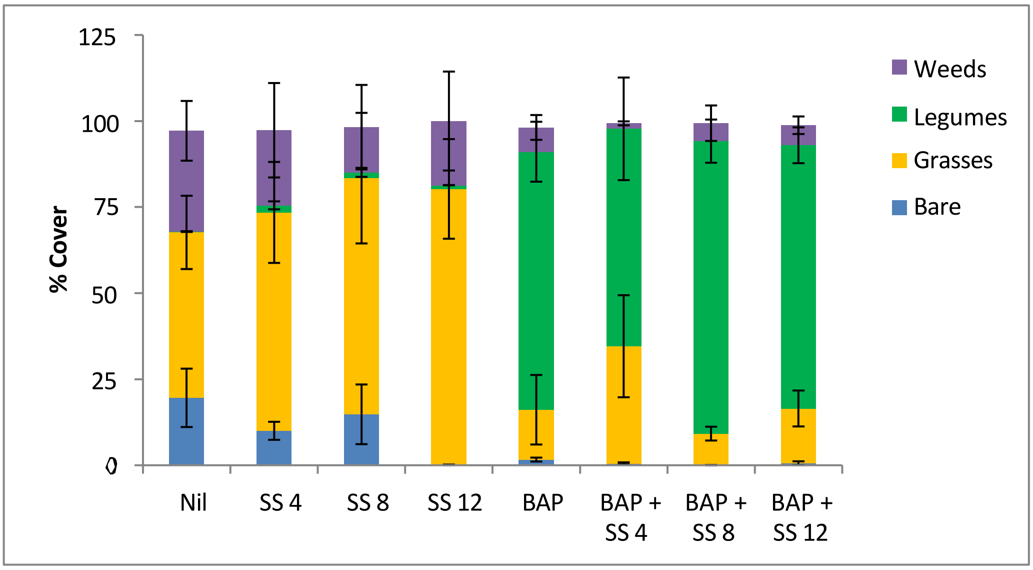



**Figure 2. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on pasture composition ± Standard Error.**

Alfalfa responded in the same way as resident legumes (Figure 3). BAP alone and with SS increased both plant establishment (P < 0.001) and growth (P < 0. 0003). SS alone gave a smaller response.

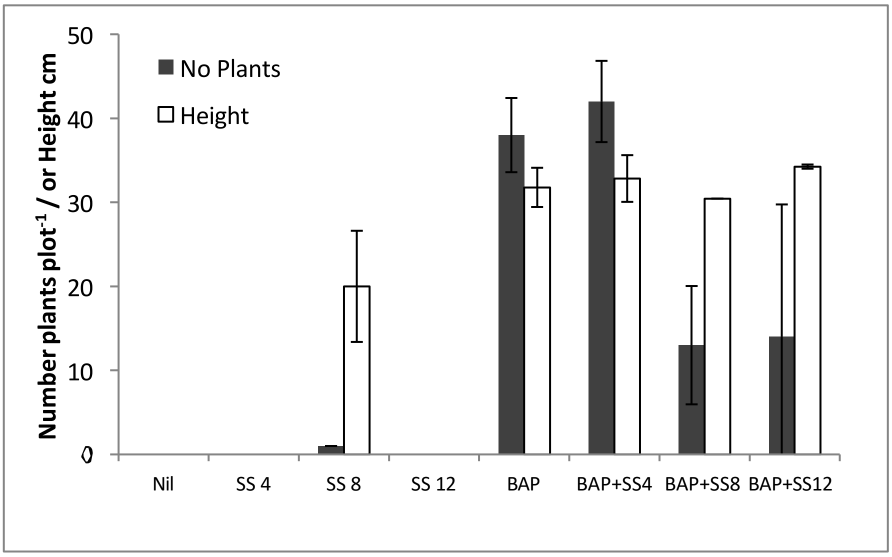



**Figure 3. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on alfalfa establishment and growth ± Standard Error.**

The growth responses show that biological stimulants improved availability of plant nutrients in a nutrient deficient soil. The rapidity of the production and pasture composition responses to SS in less than two months since application is striking. As SS supplied no appreciable nutrients, stimulation of the soil microbiome and interaction with metabolic functions or root morphology are possible modes of action. This approach has enormous potential for the future development of sustainable agriculture (Suman et al. 2022). It is noteworthy that the application of SS, both alone and with the BAP/lime/S mix, increased pasture response and fertilizer efficiency.

The response to the BAP mix shows that P, S or calcium are limiting yield. The response to SS when applied alone suggests it may mobilize some of these nutrients. The increase in production when SS was added to the BAP mix suggests that SS is bringing further microbial stimulation which accesses different nutrient pools or sources and increases plant nutrient availability. One possibility is it may act via enhancing nitrogen supply as this was not present in the BAP mix.

Another possible mode of action is through soil interaction with calcium. Lime was supplied at 500 kg/ha in the BAP mix and this acid soil has high exchangeable aluminum levels which exceed toxicity thresholds for legumes. Thus it is unsurprising that alfalfa or resident legumes were absent or present very low frequency, in unfertilised pasture. The alfalfa and resident legume response to the BAP mix may be due to mitigation of sulphur and/or phosphorus deficiency plus depression of probable aluminum toxicity (McIntosh et al. 1985). The effect of SS in enhancing alfalfa growth suggests it is acting in a similar way to lime in the BAP mix since alfalfa is extremely sensitive to soil acidity with a low tolerance to aluminum. The similar response of sown alfalfa and resident legumes shows that this is directly due to BioAg applications and not due to chance.

**Conclusions**

Application of BioAg soil biostimulant increased pasture production, changed pasture composition and increased the effectiveness of the BAP fertiliser mix.

Stimulation of the soil microbiome is a potential tool for improving fertiliser efficiency, pasture productivity and for developing sustainable grassland agriculture.

**Acknowledgements**

We thank the Williamson families for provision of the site and their interest, Michael Richards and Scott Aronsen for excellent technical support.

**References**

Espie, P.R. 2019. BioAg New Zealand Fertiliser Trials 2016 – 2018, AgScience Contract Report, 46 pp.

Haswell, S., Frei, A., Frei, I. 2014. A Proof of Concept: Frei Dairy Case Study. 2nd National Conference on Biological farming systems, Rotorua.

McIntosh, P.D., Sinclair, A.G. & Enright, P.D. 1985. Responses of legumes to phosphorus and sulphur fertilisers on 2 toposequences of North Otago soils, New Zealand. *New Zealand Journal of Agricultural Research* 28: 505-515.

McCarthy, A. *et al*. 2018. Global food security – Issues, challenges and technological solutions. *Trends in Food Science & Technology* 77, 11-20.

Pretty, J. and Bharucha, Z. P. 2014. Sustainable intensification in agricultural systems. *Annals of Botany* 114: 1571 – 1596.

Suman, J. *et al*. 2022. Microbiome as a Key Player in Sustainable Agriculture and Human Health. *Frontiers in Soil Science*. doi.org/10.3389/fsoil.2022.821589.

# Conclusions

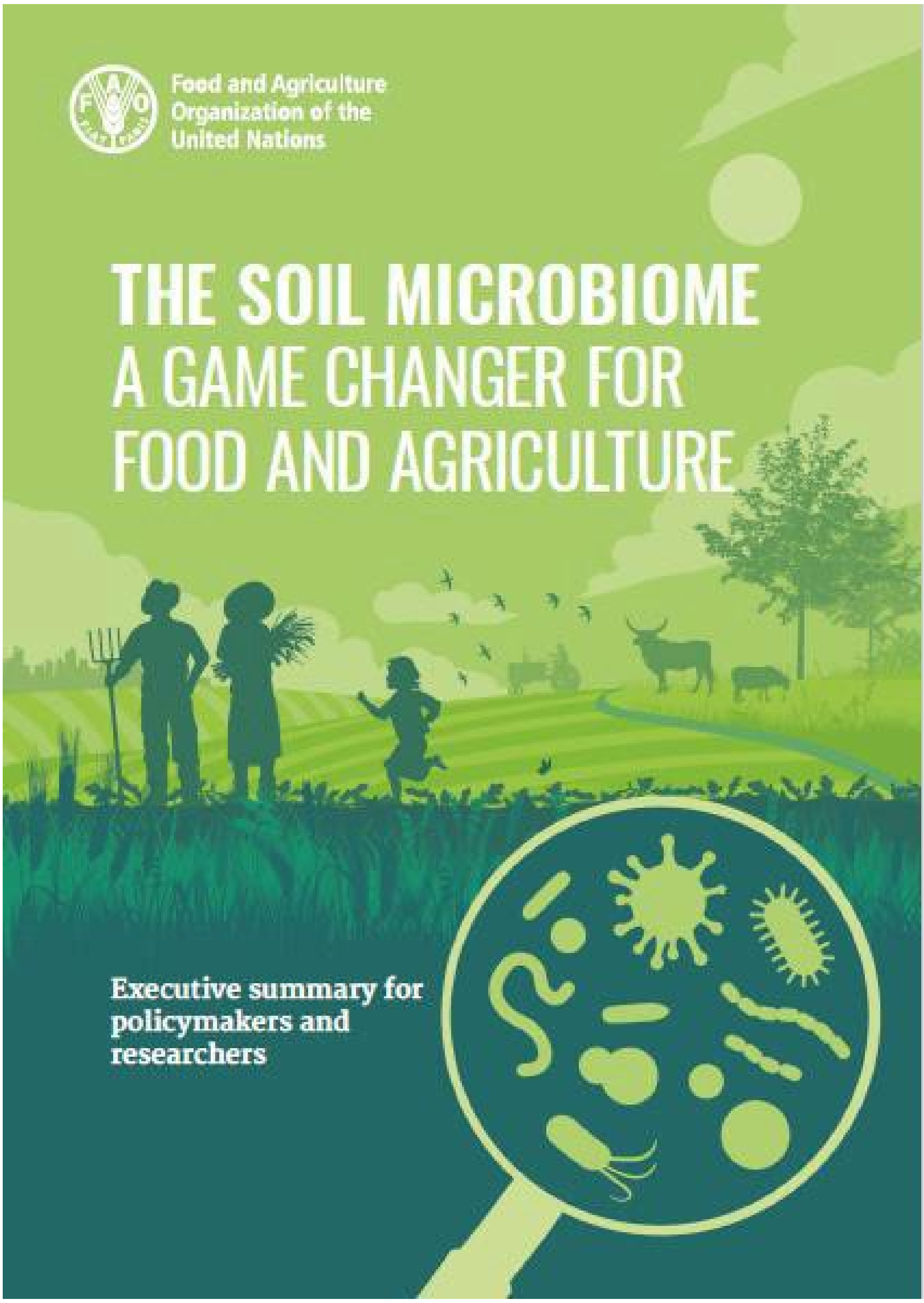
- Biological stimulants increase production and legume composition
- Biological stimulants increase pasture diversity

**Growth response**

- + 17% stand alone bio-stimulant (Soil & Seed)
- + 60% with bio-activated P (BAP)
- + 120% combined Soil & Seed + BAP

**Legume response and pasture diversity**

- 85% increase in legume content
- Reduction of weeds
- Increase in grasses
- Reduction of bare ground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# BioAg Mackenzie Trial Establishment 2021

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AgScience Ltd.
Dunedin

**24 November 2021**

## Executive Summary

New Zealand field trials evaluating BioAg fertilisers commenced in December 2016 in lowland Southland and in Canterbury. These trials have been extended to the South Island high country in 2018.

Unfertilised high country basin floor soils are free-draining, low in fertility with toxic subsoil aluminum levels. With irrigation and soil amendment they are highly productive, but the effects of biological fertilisers is unknown.

A dryland trial site, near Twizel, that has never been fertilised and is representative of Mackenzie basin floor soils, has been precision soil mapped, soil tested, and rabbit fenced. An adjacent irrigated developed high fertility trial site on the same soil allows parallel assessment of BioAg fertilisers.

Initial application was delayed until the 2021 – 2022 growing season to allow good lucerne establishment.

BioAg base biologically activated phosphate was applied at the dryland site on the 5th May 2021. BioAg Soil and Seed was applied in adjacent irrigated and dryland sites in spring, on the 18th November 2021. BAP was also applied on the irrigated site.

The trial will be drilled with lucerne by late November.

This trial will allow assessment of pasture production responses during the 2021 – 22 growing season.

## Contents

## 1. Introduction

New Zealand field trials evaluating BioAg fertilisers started in December 2016 at lowland sites in Southland and Canterbury[1]. Extension to native low-fertility South Island high country soils has now commenced at Glenbrook / West Edge Station's, near Twizel, in the Mackenzie basin.

### Trial Site and Preparation

The site is at 468 m altitude on unfertilised Mackenzie soils on fluvio-glacial outwash with former stream channels and ridges. Dryland resident vegetation is low-fertility grasses browntop and sweet vernal with the flatweed *Hieracium pilosella*, annual hare's foot clover and a scattering of native fescue tussock (Figure 3, Frontispiece). Irrigated vegetation is ryegrass and white clover. To evaluate the fertiliser effect on improved pasture species, lucerne (*Medicago sativa* was direct drilled to act as an indicator test plant in spring 2018 (Figure 1) and the site was fenced to exclude grazing (Figure 2). The adjacent fertilised irrigated site is white clover - ryegrass pasture (Figure 3).

**Figure 1. Trial lucerne drilling in spring 2018.**

**Figure 2. Trial site netting fence and 10 cm apron to exclude rabbit, hare and stock grazing.**

[1] Espie, P.R. 2019. BioAg New Zealand fertiliser trials 2016 - 2018. AgScience Contract Report, December 2019, 47 pp,

Soil depth to gravel in Mackenzie soils closely corresponds to vegetation patterns, showing the strong influence that soil phases have, primarily through soil moisture and nutrient supply (Figure 3 left).
To assess how soil variability may interact with fertiliser responses, soil phases on the trial site were precision soil mapped.  Electrical capacitance varied from 0.06 dS/m on shallow soil phases to 0.49 dS/m on deep phases, closely corresponding to vegetation patterns (Figures 3, 4).

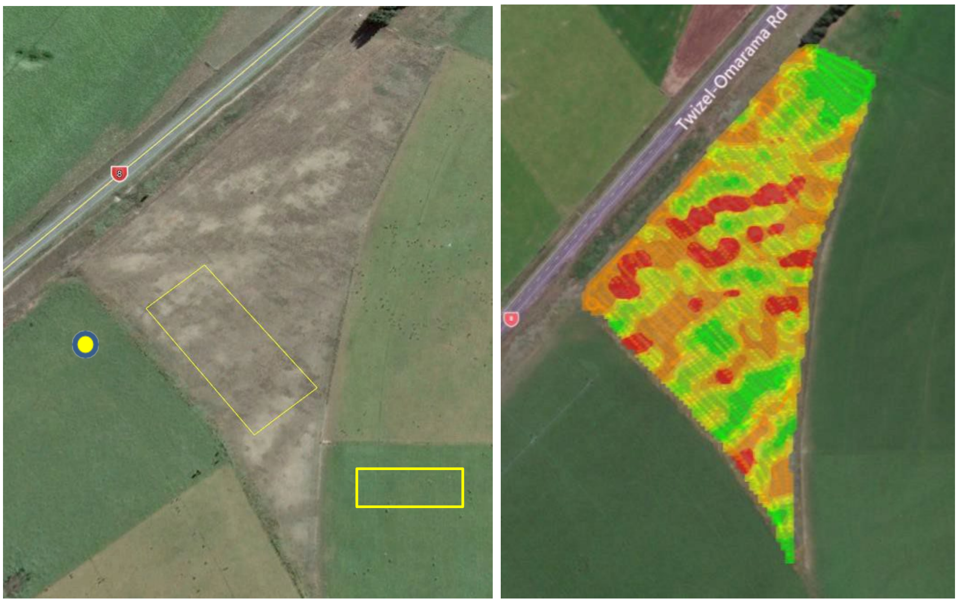



**Figure 3. Left. Site vegetation cover and location of the dryland trial) and irrigated sites.**
**Right. Soil phase mapping.   Red = shallow soil phase to medium (orange and yellow) to deep phases (green).**

**Figure 4. Mackenzie Soil Phases. Left: shallow phase, depth to gravel 20 cm;**
**Right: deep phase, depth to gravel 50 cm.**

## Soil Phase Chemistry

Soil acidity decreased from pH 5.6 in the upper surface to pH 5.5 in the lower topsoil and upper subsoil before increasing to pH 5.8 in the lower subsoil (Figure 5). There was little difference between soil phases, excluding a possible anomalous value on the deep soil phase at 25cm.

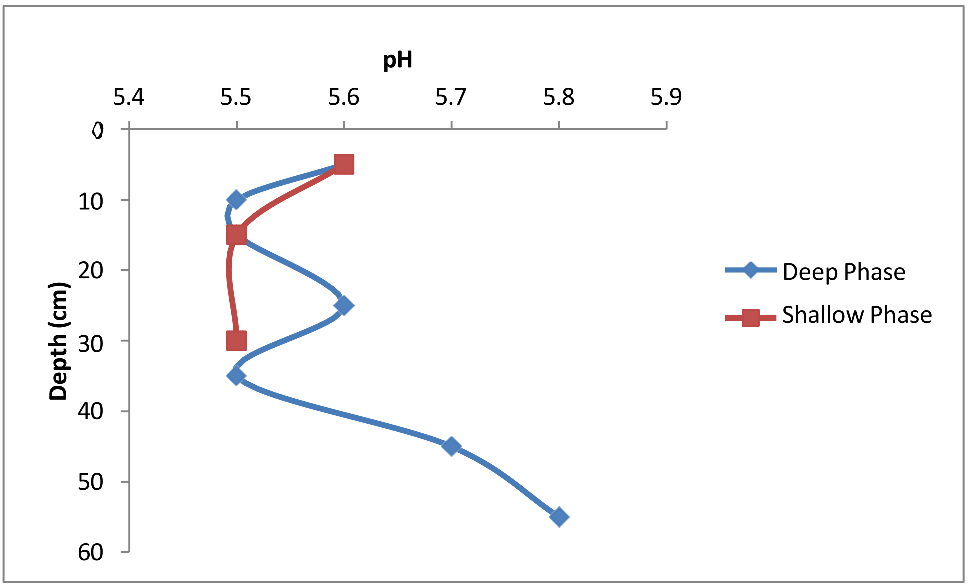



**Figure 5. Change in soil acidity with depth.**

Soil aluminium levels exceeded the levels toxic to legumes in both soil phases and increased down the profile to peak at 10 – 20 cm in both phases (Figure 6). The higher levels in the deep soil phase are due to their higher moisture holding capacity and hence greater weathering with more aluminium released from clay minerals.

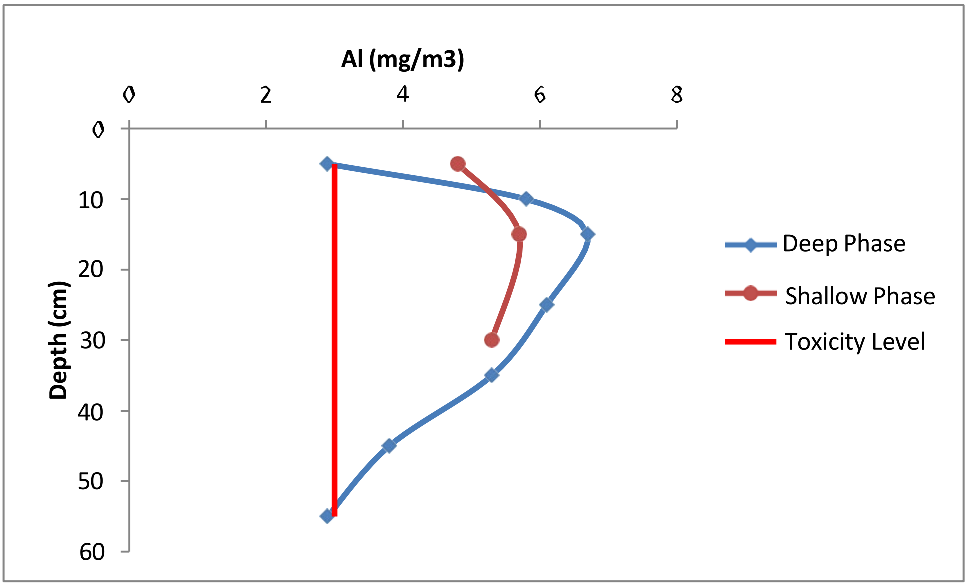



**Figure 6. Change in soil aluminum with depth.**

Soil carbon levels were slightly higher in the deep soil phase, consistent with more moisture and biological growth. As usual, they decreased with depth in both phases (Figure 7).

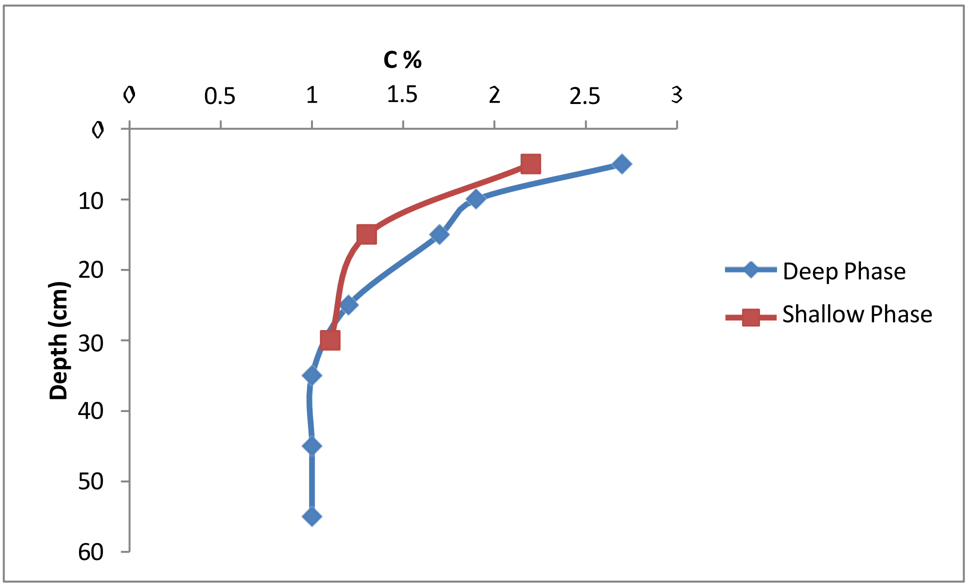



**Figure 7. Change in soil carbon with depth.**

Total nitrogen levels followed a similar depth trend to carbon in both phases (Figure 8)

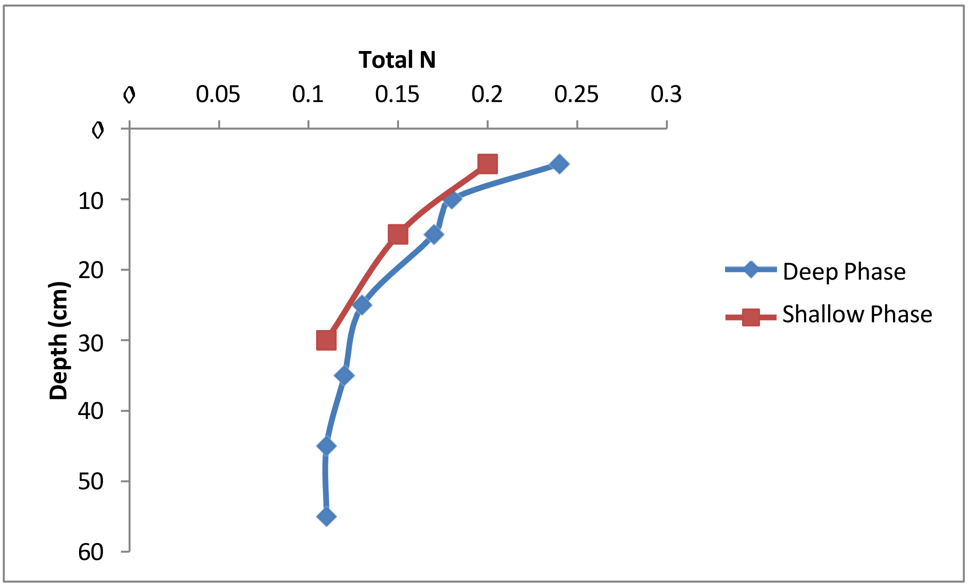



**Figure 8. Change in total nitrogen with depth.**

The carbon to nitrogen ratios decreased in both soil phases with a rise at 30 cm in the shallow phase due to its low N at this depth, possibly related to the major change in soil texture here to gravel (Figure 9).

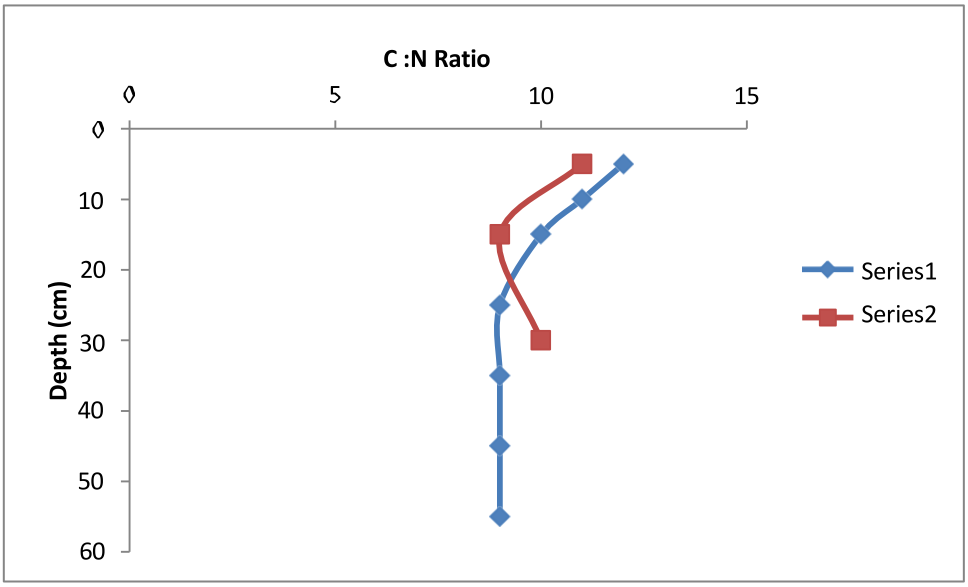



Figure 9. Change in the carbon to nitrogen ratio with depth.

Soil phosphorous levels were similarly higher in the uppermost deep soil phase and then decreased with depth in both profiles (Figure 10). The increase in P in the shallow soil phase at 30 cm may also be related to the major change in texture to gravel (Figure 3).

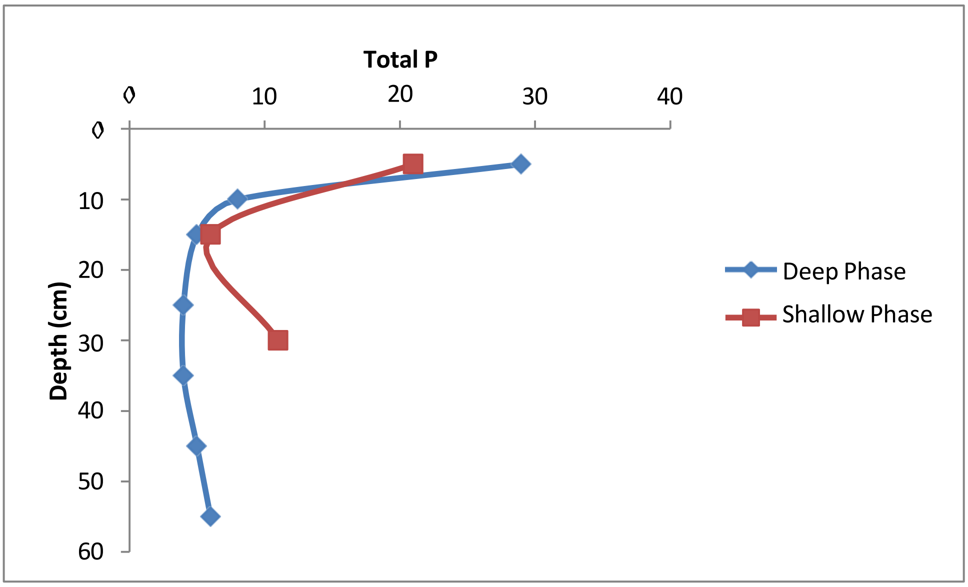



Figure 10. Change in soil total phosphorous with depth.

The metal cations potassium (K), calcium (Ca) and magnesium (Mg) also followed similar phase and depth trends down the profile: with Mg levels notably lower in the shallow phase (Figure 11).

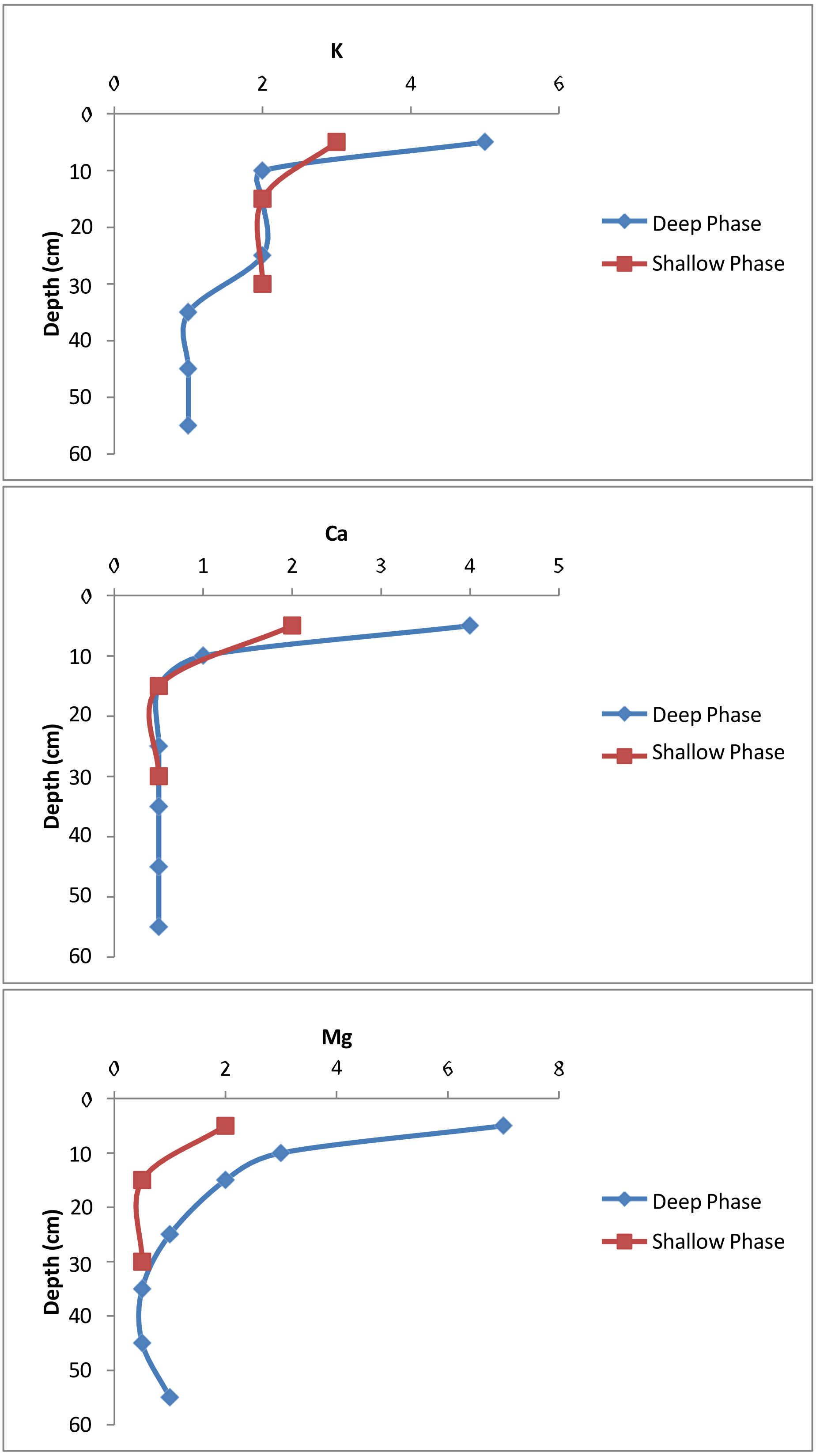



**Figure 11. Change in soil cations with depth (MAF Quick Test units).**

Topsoil chemistry differences between the irrigated and dryland sites are shown in (Table 1).

The dryland unfertilised site is more acidic, with notably lower potassium, calcium, sulphur and micronutrient manganese, zinc, cobalt and boron levels.

### Table 1. Irrigated and Dryland topsoil chemistry.

| **Management** | **Irrigated** | **Dryland** |
|---|---|---|
| **Pasture** | **Improved** | **Native** |
| pH | **5.9** | 5.6 |
| Potassium | **0.4** | 0.24 |
| Calcium | **4.1** | 2.1 |
| Magnesium | **0.4** | 0.38 |
| Sodium | **0.05** | 0.05 |
| CEC | **9.3** | 12 |
| BS% | **50.5** | 29 |
| Phosphorus (Olsen) | **21.0** | 18 |
| Sulphur ($SO_4$) | **8.8** | 2 |
| Carbon | **2.6** | 2.8 |
| Organic matter | **4.5** | 4.8 |
| Iron | **133.8** | 129 |
| Managanese | **18.5** | 9 |
| Zinc | **0.8** | 0.5 |
| Copper | **0.9** | 0.9 |
| Boron | **0.5** | 0.3 |
| Cobalt | **0.3** | 0.02 |
| **Cation % of BS** | | |
| Potassium | **3.8** | 2.6 |
| Calcium | **42.0** | 23 |
| Magnesium | **4.5** | 4.1 |
| Sodium | **0.3** | 0.1 |
| **MAF Units** | | |
| Potassium | **8.0** | 5 |
| Calcium | **5.5** | 3 |
| Magnesium | **10.5** | 8 |
| Sodium | <2 | <2 |

## Experimental Design and Establishment

The trial will examine the interaction between BioAg Biologically Active Phosphate (BAP) and Soil and Seed (S&S) fertilisers and responses on dryland and irrigated pastures.

BAP is a highly reactive Algerian phosphate rock which has been inoculated with microbial stimulants that increases plant nutrient availability. BAP contains 13% total phosphorous with citric solubility of 37% and formic solubility of 64%. Soil and seed is a liquid biological culture containing micro-organisms which increase the functional availability of nutrients and minerals.

For the low fertility dryland site 250 kg of BAP was mixed with 500 kg lime and 50 kg of elemental sulphur and applied at a rate of 800 kg/ha in winter to match commercial soil recommendations. It was hand applied in winter together with a single rate of Actibor, supplying boron, at 1.5 kg/ha to allow time for incorporation before spring application of Soil and Seed (Figure 12). Soil and Seed was spray applied at four rates (0, 4, 8 and 12 l/ha) in a factorial design on the 18$^{th}$ November 2021 (Table 2).

The irrigated site as had been previously limed and fertilised with high P levels, so a BAP was applied in spring with Soil and Seed, at the same rates as previously, on the 18$^{th}$ November 2021 (Figures 12, 13).

Dryland BAP and Soil and Seed were applied in a randomised block design with Actinobor in four blocks, totalling 36 dryland plots. On the irrigated site a single application of BAP was applied with four rates of soil and seed in five blocks, totalling 20 plots. There was a 1 m buffer strip between dryland plots and a 2 m buffer strip between irrigated plots.

**Table 2. Fertiliser application rates.**

| Fertiliser | Rates |
|---|---|
| Soil and Seed | 0, 4, 8, 12 l/ha |
| Biologically Active Phosphorus Mix | 800 kg/ha + 0, 4, 8, 12 l/ha S&S |
| Actibor | 1.5 kg/ha |

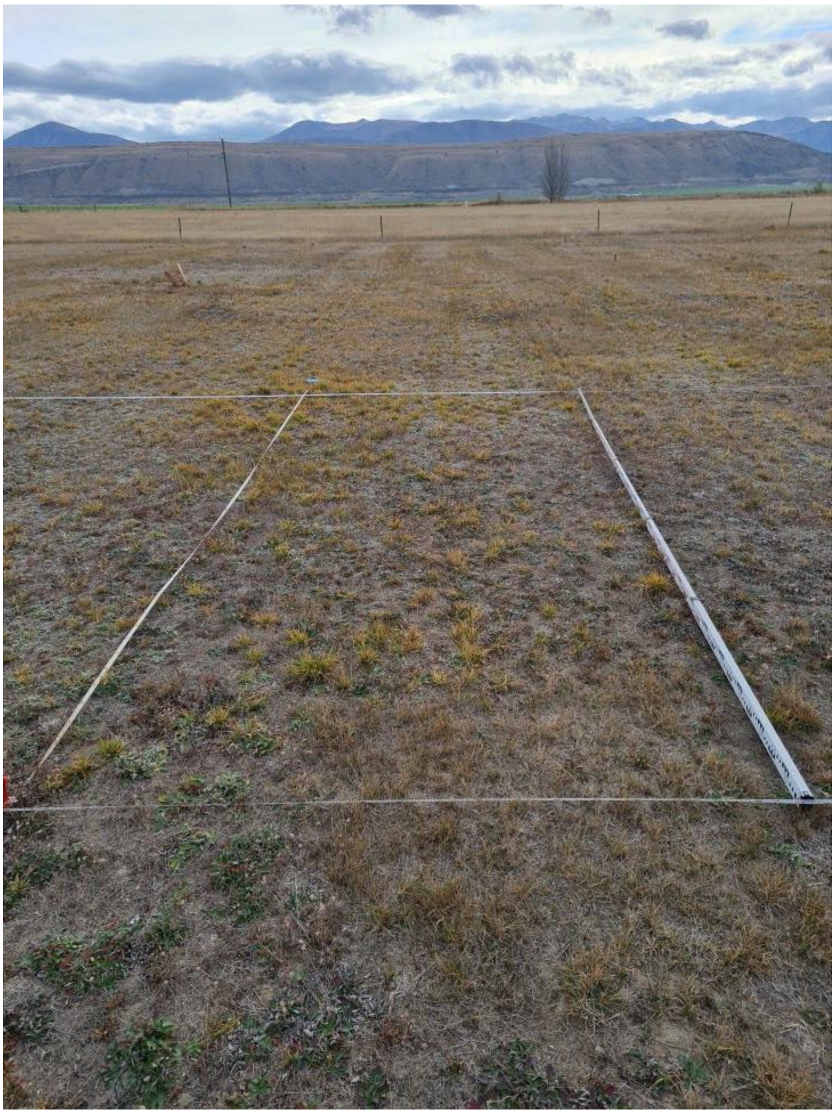


Figure 12. Glenbrook dryland fertiliser application plot 2 x 5 m, May 2021.

Figure 13. Glenbrook irrigated site, November 2021.

**Figure 14. Soil and Seed irrigated site application, 2 x 10 m plots, November 2021.**

## Comment

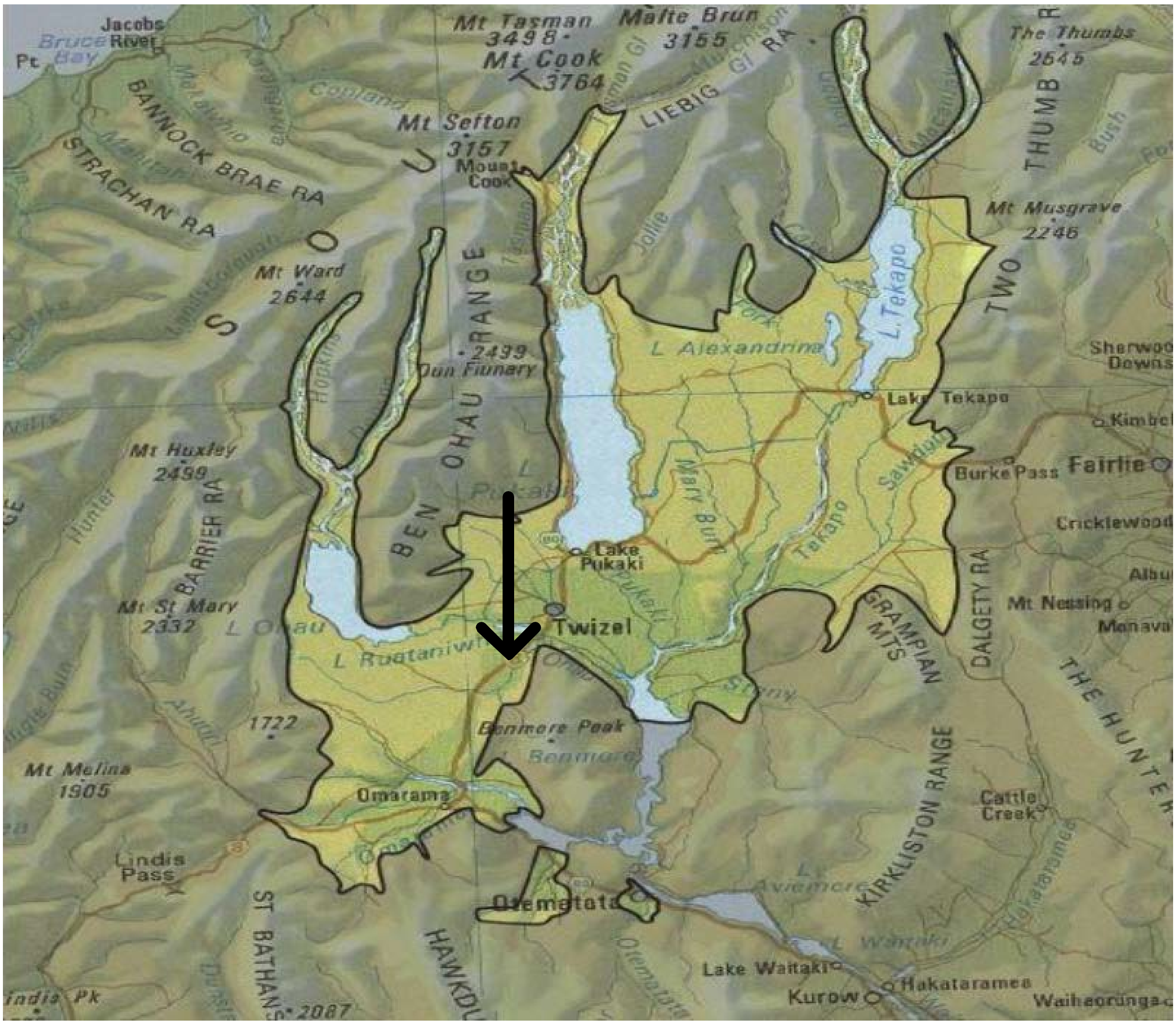
The trial of high country BioAg fertilisers for low-fertility dryland and high-fertility irrigated pastures has been successfully established.

Drilling the dryland indicator test species lucerne is scheduled for late-November and will provide an additional indicator of fertiliser effect.

Pasture fertiliser response will be measured by mowing and by assessing lucerne establishment and growth later this season.

## Acknowledgements

I thank Steven Haswell, BioAg Ltd. and Henry and Simon Williamson for their interest and assistance with this trial.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Mt Cook 3764
Mt Sefton 3157
Mount Cook
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The Thumbs 2545
TWO THUMB RA
Mt Musgrave 2246
BANNOCK BRAE RA
STRACHAN RA
Mt Ward 2644
BEN OHAU RANGE
2439 Dun Fiunary
L Alexandrina
L. Tekapo
Lake Tekapo
Mt Huxley 2499
BARRIER RA
Lake Pukaki
Twizel
Burke Pass
Fairlie
Cricklewood
Mt St Mary 2332
L Ohau
L Ruataniwha
GRAMPIAN MTS
DALGETY RA
Mt Nessing
THE HUNTERS
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Benmore Peak
Mt Melina 1905
Omarama
KIRKLISTON RANGE
Cattle Creek
Lindis Pass
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L Waitaki
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