Biological Stimulants Increase Fertiliser Efficiency and Pasture Legume Content

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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).

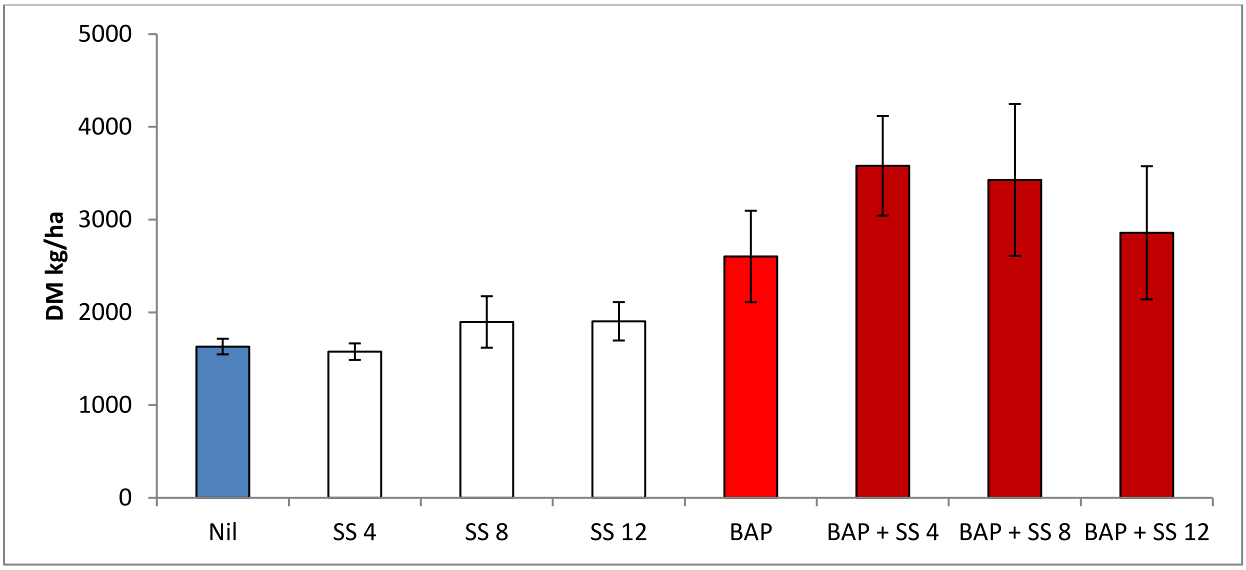

Figure 1. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on pasture production ± Standard Error.

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 ($P < 0.001$).

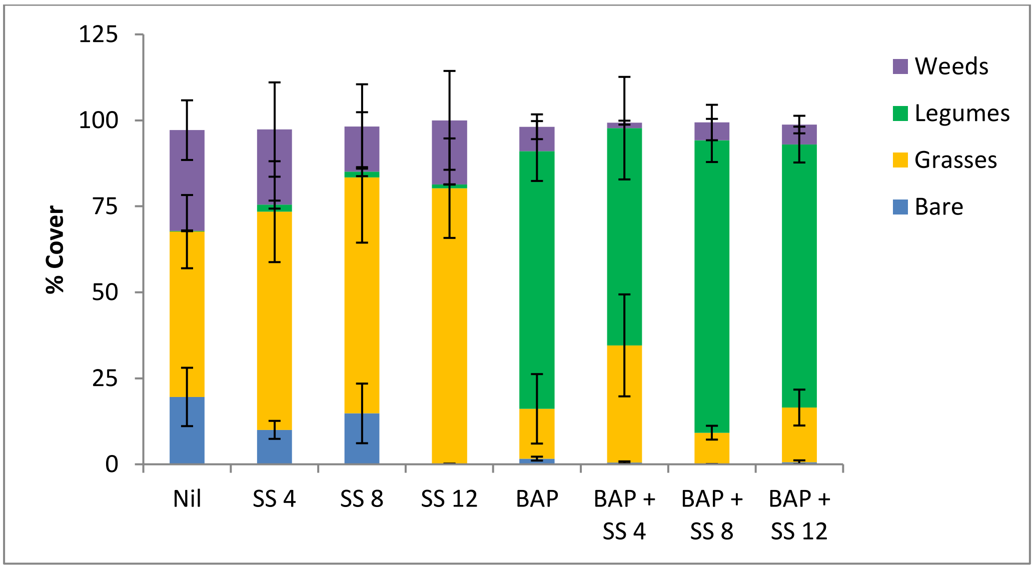

Figure 2. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on pasture composition ± Standard Error.

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.

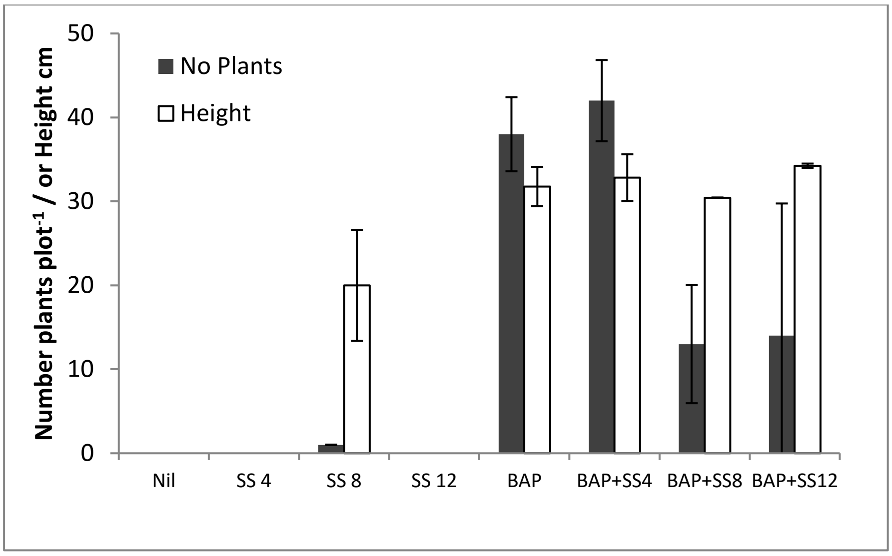

Figure 3. Effect of biologically activated phosphate (BAP) and Soil & Seed stimulant (SS) on alfalfa establishment and growth ± Standard Error.

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.

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