AgScience
Limited

BioAg Mackenzie Trial
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Executive Summary

New Zealand field trials evaluating BioAg fertilisers in the South Island high country commenced in 2018 where biological fertilisers are untested but are of considerable interest to farmers.

BioAg biologically activated phosphate (BAP) was applied on a low-fertility dryland basin floor site in May 2021 with sulphur and lime. BioAg Soil and Seed was applied in spring in November 2021. BAP and soil and seed were also applied on an adjacent high fertility irrigated site.

Dryland pasture production and species composition were assessed in January 2022, 1.7 months after soil and seed application and eight months after BAP application.
The irrigated site was not assessed as it was cut for silage.

BioAg applications significantly increased dryland pasture composition by 60% and up to 120% with BAP plus soil and seed ($P < 0.01$).
Soil and seed increased production by up to 17%.

BioAg applications altered pasture composition.
Soil and seed increased grass cover by up to 1.5 times and legume cover by 6.7 times. BAP increased legume cover by up to 307 times ($P < 0.001$).
Sown lucerne gave similar establishment and growth responses.

BioAg biological cultures and BAP based fertiliser act by enhancing efficiency of applied nutrients and by increasing plant nutrient availability through microbial mobilization of soil minerals.

1. Introduction

New Zealand field trials evaluating BioAg fertilisers started in December 2016 at lowland sites in Southland and Canterbury[1].

Trials were extended to South Island high country soils at Glenbrook / Westside Station, near Twizel, in the Mackenzie basin in 2018[2]. Initially poor lucerne germination and survival delayed fertiliser application until the 2021 -2022 growing season.[3] The trial was re-drilled and BioAg biologically activated phosphate BAP was applied at an unfertilised dryland site on the 5th May 2021. BioAg Soil and Seed was applied in spring, on the 18th November 2021, in the dryland and an adjacent high –fertility irrigated site. BAP was also applied at the irrigated site (Figures 1, 2).

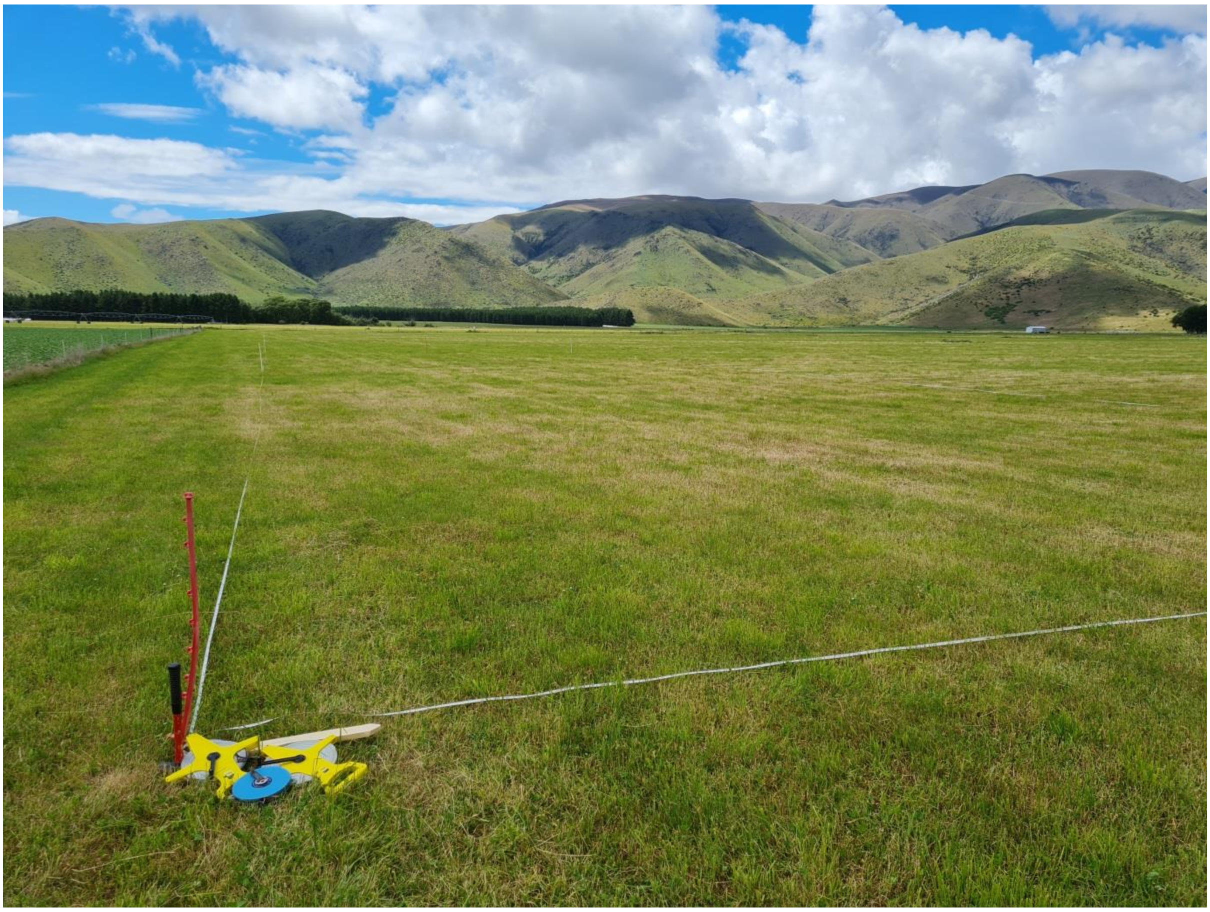

Figure 1. Mackenzie Trial, irrigated site, November 2021.

[1] Espie, P.R. 2019. BioAg New Zealand fertiliser trials 2016 - 2018. AgScience Contract Report, December 2019, 47 pp.
[2] Espie, P.R. 2020. Mackenzie Trial early spring update. AgScience Contract Report, September 2020, 6 pp.
[3] Espie, P.R. 2020. BioAg Mackenzie trial establishment 2021. AgScience Contract Report, November 2021, 13 pp.

Figure 2. Upper: Dryland site, November 2021, fertiliser effect already apparent with hare's foot trefoil. Lower: Plot boundary showing the marked response to BAP by the annual clover hare's foot trefoil and grasses (left) compared with the Hieracium and bare ground (right)when unfertilised .

Pasture production was measured on the 12th January 2022 eight months after BAP application and 1.7 months after soil and seed application. Herbage was weighed after cutting with a rotary mower to 5-6 cm height in a 5 x 2 m plots (Figure 3). Subsamples were taken from every plot for dry matter determination.

The percentage cover of every grassland species present in each plot was also visually estimated before harvesting.

The number of sown lucerne plants was counted in each plot and the height of the three tallest plants, or tallest plants when there were fewer than three plants, was measured.

The irrigated site was not assessed as it had just been cut for silage.

Figure 3. Forage production assessment, dryland low fertility site.

2. Results

2.1 Pasture Composition

BioAg applications significantly altered dryland pasture composition (Figure 4; grass cover, $P < 0.007$; legume cover, $P < 0.0001$).

The full statistical analyses are presented in Appendix 1. To interpret the statistics note that a probability test value of less than 5 occurrences in one hundred ($P < 0.05$) is commonly accepted as a threshold for demonstration of a real effect. Probabilities less than this give even greater confidence the effect is real (e.g. $P < 0.1$, $P < 0.001$). Higher probabilities (e.g. $P < 0.06$, $P < 0.15$, $P < 0.30$ etc.) indicate the effect could arise just by chance and the larger the value the less likely there is a real fertiliser effect.

Fertiliser significantly altered legume cover ($P < 0.00001$). BAP gave a huge increase in legume cover, principally the annual hare's foot trefoil (*Trifolium arvense*, Figures 2, 4). BAP increased legume cover by up to 307 times, both by itself and with all combinations of soil and seed ($P < 0.001$). Consequently this reduced cover of bare soil, resident grasses and weeds ($P < 0.001$).

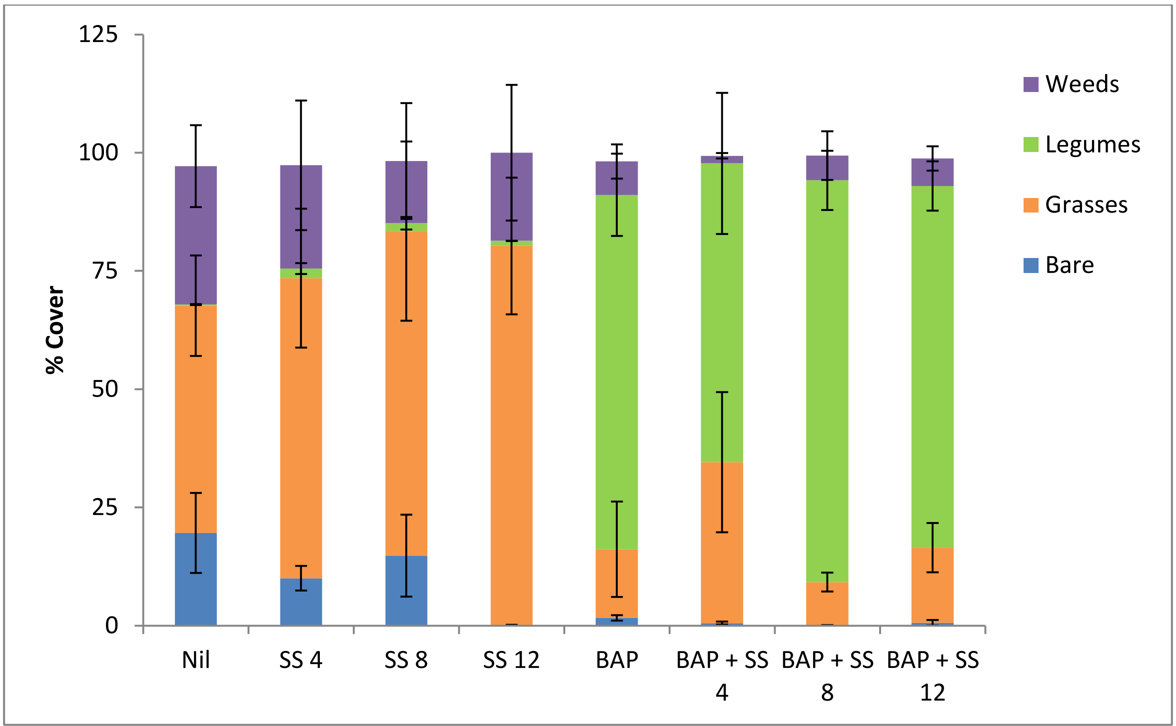

Figure 4. Effect of BioAg applications on pasture composition ± Standard Error of the mean.

Soil and seed applications increased grass cover by 1.5x times and legume cover by 6.7 times compared with unfertilised pasture (Figure 4). Cover progressively increased with application rate by 32%, 43% and 67%. These increases did not statistically differ from unfertilised pasture though nearly did compared with BAP combinations (BAP ($P < 0.056$), BAP+SS8 ($P < 0.052$) and BAP+SS12 ($P < 0.066$).

Soil and seed also increased legume cover, by 4.5x to 8.5 x compared with untreated grassland. Though small in comparison with the increases with BAP, this shows that biological activation with soil and seed is presumably also providing some of the nutrients directly supplied in BAP.

Both soil and seed and BAP combinations reduced the extent of bare ground by up to 96% to 99% and weed by up to 38% or 94%, though these were not statistically significantly different from unfertilised grassland.

The sown lucerne responses almost exactly mirrored the resident dryland legumes.
It strongly responded to BAP in both plant establishment (Figure 5, $P < 0.001$) and growth (Figure 6, $P < 0.0003$). Soil and seed again had a small effect.

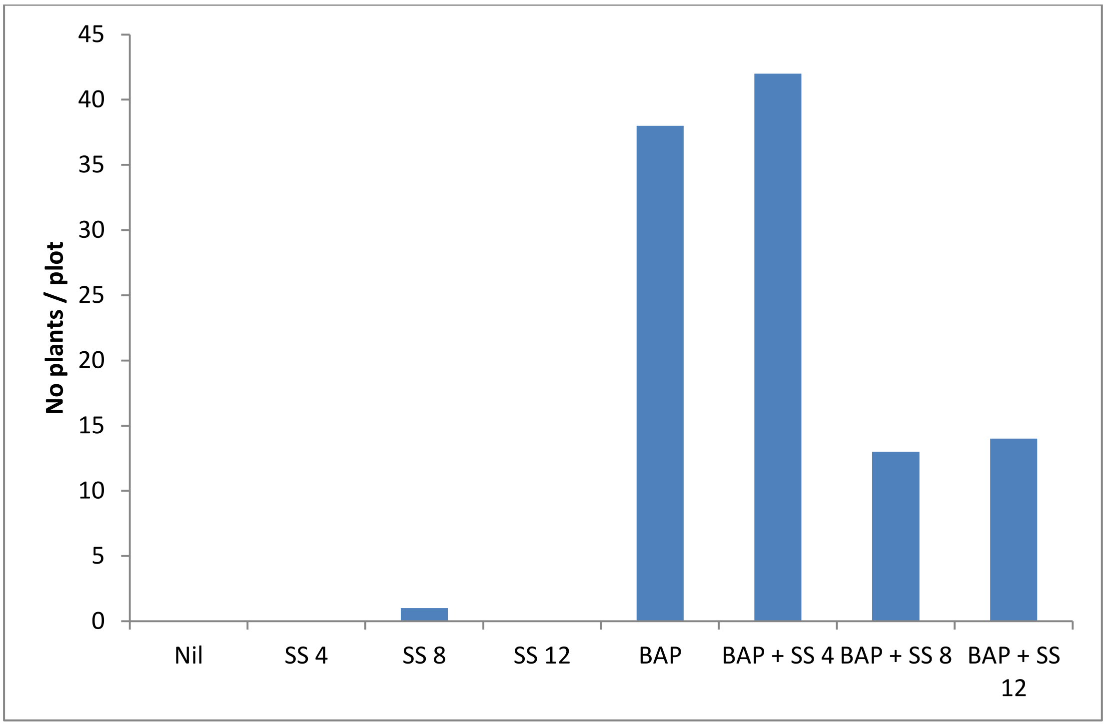

Figure 5. Effect of BioAg applications on lucerne number.

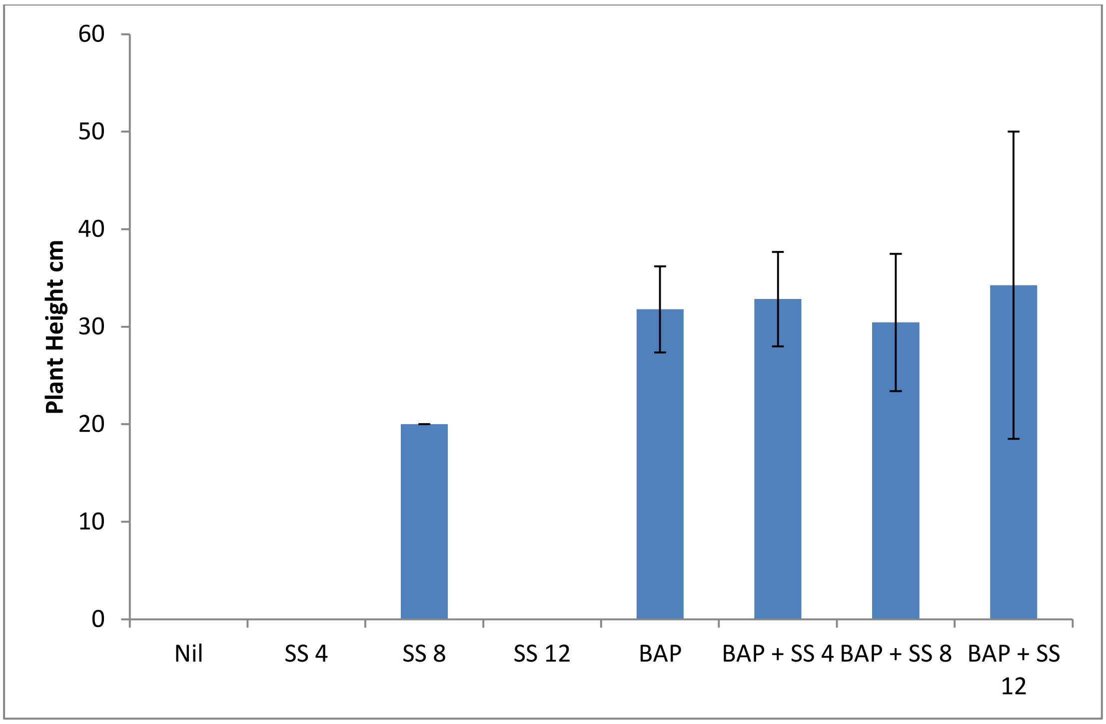

Figure 6. Effect of BioAg applications on lucerne height ± SEM.

2.2 Pasture Production

BioAg applications significantly increased dryland pasture production (Figure 7; P < 0.008). Soil and seed applied alone progressively increased yield with application rate up to 17% above untreated grassland. BAP alone increased production by 60%. Soil and seed addition further increased production: 4 l/ha increased yield by 120% (P < 0.018) and BAP with 8 l/ha gave an 110% increase (P < 0.08). BAP with *-12 l/ha gave a 75% increase but high experimental variability limits precise comparison of rate effects (Figure 8).

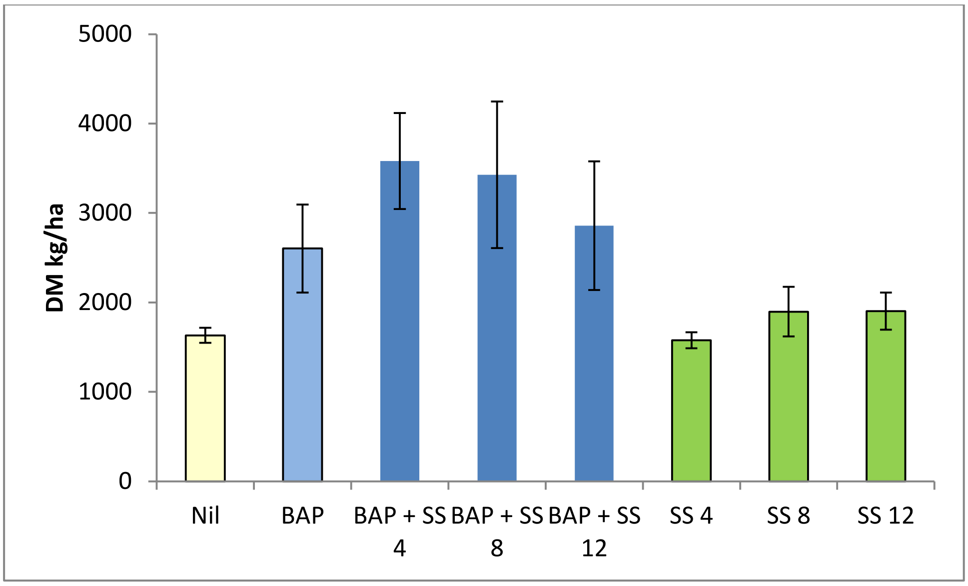

Figure 7. Effect of BioAg applications on low fertility dryland pasture production ± SEM.

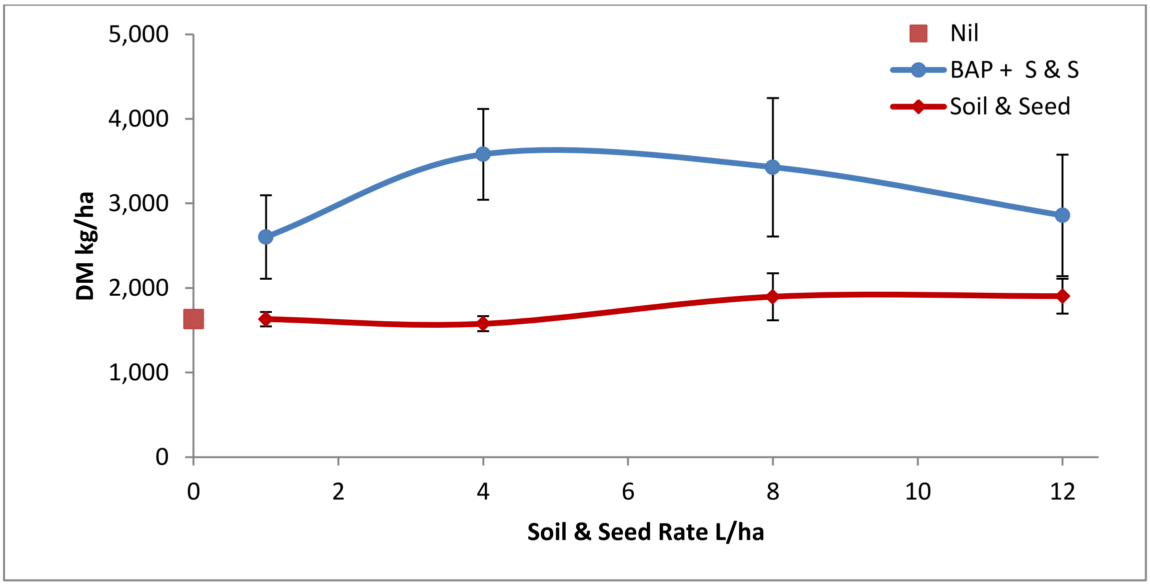

Figure 8. Effect of soil and seed application rate on pasture production ± SEM. Zero rates graphically offset for presentation clarity.

3. Comments

The positive pasture production response to BioAg soil and seed is consistent with previous trial responses in Southland and Canterbury on developed beef and sheep and irrigated dairy pastures.

This most important result from this trial is that the biological cultures in soil and seed increased production on an unfertilised low fertility high country soil. They also may have assisted with biological activation in the BAP mix, though this cannot be distinguished from the effects of direct P, S and calcium supply. In a nutrient deficient soil this demonstrates the biological cultures have improved functional availability of required plant nutrients. Stimulation of the soil microbiome or direct interaction with pasture species metabolic functions or root morphology are possible modes of action. The rapidity of the response to soil and seed, in less than two months since application, is striking.

It is also noteworthy that increasing the application of soil and seed increased the pasture response, both alone and with biologically active phosphate mix. BAP is a highly reactive Algerian phosphate rock which had already been inoculated with microbial stimulants and it is striking that combination with soil and seed further increased yield above that from the BAP mix directly supplying phosphorus, sulphur and calcium. The response to soil and seed applied alone suggests it may mobilise limiting nutrients which were directly supplied in the BAP mix. The further response when applied with BAP suggests the microbial cultures in soil and seed may enhance the effectiveness of the cultures included with BAP for plant nutrient availability or uptake or that they may supply additional nutrients, possibly N, or micronutrients. It is feasible this may involve mobilisation from soil organic matter or stimulation of different components of the soil microbiome.

The increase in production when soil and seed was added to the BAP mix suggests that soil and seed is bringing microbial stimulation that accesses different nutrient pools or sources and further increases plant nutrient availability. One possibility is it may act via enhancing nitrogen supply as this was not present in the BAP mix.

A speculative, but intriguing possible mode of action, is through interaction with soil calcium. Lime was supplied at 500 kg/ha in the BAP mix and this acid soil has very high exchangeable aluminium levels which exceed toxicity thresholds for legumes such as lucerne. Thus it is unsurprising that lucence was absent from the unfertilised pasture and that resident clover cover was very low. The enormous lucerne and resident clover response to the BAP mix may be due to mitigation of sulphur and/or phosphorus deficiency plus depression of probable aluminium toxicity. The effect of soil and seed in enhancing lucerne growth may suggest it is acting in a similar way as lime in the BAP mix since lucerne is extremely sensitive to soil acidity with a low tolerance to aluminium. This is why it was sown as an indicator species in every plot. The similar response to resident clover species shows that this is due to BioAg applications and cannot be attributable to favourable chance location of resident legumes.

Further research would be required to isolate the relative effect of these factors.

It should also be noted that the wide variation in soil phases on this fluvio-glacial outwash surface will contribute to increased variability in experimental results, decreasing experimental statistical sensitivity. This is seen in the large standard errors of the means and may possibly blunt detection of fertiliser effects or trends.

Despite this, the statistically significant or highly significant species composition and production responses to BioAg applications indicate genuine effectiveness of both soil and seed and BAP based fertiliser.

4. Acknowledgements

I thank Henry and Simon Williamson, Westside and Glenbrook Stations, and their families for their help and hospitality, Steven Haswell and Michael Richards for their assistance with this assessment.

Appendix 1. Statistical analyses

BioAg Fertiliser effects were assessed by analysis of variance (ANOVA) and simultaneous tests for general linear hypotheses comparison of fertiliser treatments (Tukey contrasts) for cover and production data and general linear model using Poisson regression for the analysis of count data using the statistics package R.

BioAg Fertiliser Effect on Bare Soil Cover.

Treatment	Degrees of freedom	Sum Sq	Mean Sq	F value	Pr(>F)
Fertiliser	7	2250	321.5	1.613	0.178
Residuals	25	4984	199.4		

Conclusion: No effect as the probability (P) value is > 0.05.

BioAg Fertiliser Effect on Grass Cover.

Treatment	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Fertiliser	7	18052	2578.8	3.665	0.00739
Residuals	25	17590	703.6		

Conclusion: Fertilisers had a real effect as the probability (P) value is lower than < 0.05.

Multiple Comparisons of Means: Tukey Contrasts

Near statistically significant fertiliser effect comparisons highlighted.

Linear Hypotheses:					Estimate	Std. Error	t value	Pr(>|t|)
BAP+SS12	-	BAP	==	0	1.416	18.757	0.076	1
BAP+SS4	-	BAP	==	0	20.197	18.757	1.077	0.9549
BAP+SS8	-	BAP	==	0	-5.42	20.259	-0.268	1
Nil	-	BAP	==	0	33.449	16.244	2.059	0.461
SS12	-	BAP	==	0	65.547	20.259	3.235	0.0564
SS4	-	BAP	==	0	48.829	20.259	2.41	0.2762
SS8	-	BAP	==	0	54.207	18.757	2.89	0.1152
BAP+SS	-	BAP+SS12	==	0	18.781	18.757	1.001	0.9692
BAP+SS8	-	BAP+SS12	==	0	-6.836	20.259	-0.337	1
Nil	-	BAP+SS12	==	0	32.033	16.244	1.972	0.514
SS12	-	BAP+SS12	==	0	64.131	20.259	3.165	0.0659
SS4	-	BAP+SS12	==	0	47.413	20.259	2.34	0.3079
SS8	-	BAP+SS12	==	0	52.791	18.757	2.815	0.1339
BAP+SS8	-	BAP+SS4	==	0	-25.617	20.259	-1.264	0.9014
Nil	-	BAP+SS4	==	0	13.252	16.244	0.816	0.9903
SS12	-	BAP+SS4	==	0	45.35	20.259	2.238	0.3596
SS4	-	BAP+SS4	==	0	28.632	20.259	1.413	0.84
SS8	-	BAP+SS4	==	0	34.01	18.757	1.813	0.613
Nil	-	BAP+SS8	==	0	38.869	17.958	2.164	0.4004
SS12	-	BAP+SS8	==	0	70.967	21.658	3.277	0.0517
SS4	-	BAP+SS8	==	0	54.248	21.658	2.505	0.2355
SS8	-	BAP+SS8	==	0	59.627	20.259	2.943	0.1039
SS12	-	Nil	==	0	32.098	17.958	1.787	0.6291
SS4	-	Nil	==	0	15.379	17.958	0.856	0.9871
SS8	-	Nil	==	0	20.758	16.244	1.278	0.8967
SS4	-	SS12	==	0	-16.719	21.658	-0.772	0.993
SS8	-	SS12	==	0	-11.34	20.259	-0.56	0.999
SS8	-	SS4	==	0	5.378	20.259	0.265	1

BioAg Fertiliser Effect on Legume Cover.

Treatment	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Fertiliser	7	44445	6349	36.66	0.0000000001
Residuals	25	4330	173		

Conclusion: Fertilisers had a real effect as the probability (P) value is far lower than < 0.05.

Multiple Comparisons of Means: Tukey Contrasts

Significant (boldface) or near significant fertiliser effect comparisons highlighted.

Linear Hypotheses:					Estimate	Std. Error	t value	Pr(>|t|)
BAP+SS12	-	BAP	==	0	1.5076	9.3056	0.162	1
BAP+SS4	-	BAP	==	0	-12.5226	9.3056	-1.346	0.87
BAP+SS8	-	BAP	==	0	10.1464	10.0512	1.009	0.968
Nil	**-**	**BAP**	==	0	-74.5278	8.0589	-9.248	**<0.001**
SS12	**-**	**BAP**	==	0	-73.6848	10.0512	-7.331	**<0.001**
SS4	**-**	**BAP**	==	0	-72.7179	10.0512	-7.235	**<0.001**
SS8	**-**	**BAP**	==	0	-73.3607	9.3056	-7.884	**<0.001**
BAP+SS4	-	BAP+SS12	==	0	-14.0303	9.3056	-1.508	0.793
BAP+SS8	-	BAP+SS12	==	0	8.6388	10.0512	0.859	0.987
Nil	**-**	**BAP+SS12**	==	0	-76.0355	8.0589	-9.435	**<0.001**
SS12	**-**	**BAP+SS12**	==	0	-75.1925	10.0512	-7.481	**<0.001**
SS4	**-**	**BAP+SS12**	==	0	-74.2256	10.0512	-7.385	**<0.001**
SS8	**-**	**BAP+SS12**	==	0	-74.8684	9.3056	-8.046	**<0.001**
BAP+SS8	-	BAP+SS4	==	0	22.6691	10.0512	2.255	0.351
Nil	**-**	**BAP+SS4**	==	0	-62.0052	8.0589	-7.694	**<0.001**
SS12	**-**	**BAP+SS4**	==	0	-61.1622	10.0512	-6.085	**<0.001**
SS4	**-**	**BAP+SS4**	==	0	-60.1953	10.0512	-5.989	**<0.001**
SS8	**-**	**BAP+SS4**	==	0	-60.8381	9.3056	-6.538	**<0.001**
Nil	**-**	**BAP+SS8**	==	0	-84.6743	8.9094	-9.504	**<0.001**
SS12	**-**	**BAP+SS8**	==	0	-83.8312	10.7451	-7.802	**<0.001**
SS4	**-**	**BAP+SS8**	==	0	-82.8643	10.7451	-7.712	**<0.001**
SS8	**-**	**BAP+SS8**	==	0	-83.5072	10.0512	-8.308	**<0.001**
SS12	-	Nil	==	0	0.843	8.9094	0.095	1
SS4	-	Nil	==	0	1.8099	8.9094	0.203	1
SS8	-	Nil	==	0	1.1671	8.0589	0.145	1
SS4	-	SS12	==	0	0.9669	10.7451	0.09	1
SS8	-	SS12	==	0	0.3241	10.0512	0.032	1
SS8	-	SS4	==	0	-0.6428	10.0512	-0.064	1

BioAg Fertiliser Effect on Pasture Production.

Treatment	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Fertiliser	7	18183159	2597594	3.565	0.00853
Residuals	25	18214617	728585		

Conclusion: Fertilisers had a real effect as the probability (P) value is lower than < 0.05.

Multiple Comparisons of Means: Tukey Contrasts

Significant (boldface) or near significant fertiliser effect comparisons highlighted.

Linear	Hypotheses:				Estimate	Std. Error	t value	Pr(>|t|)
BAP+SS12	-	BAP	==	0	255.275	603.566	0.423	0.9998
BAP+SS4	-	BAP	==	0	977.456	603.566	1.619	0.731
BAP+SS8	-	BAP	==	0	825.504	651.926	1.266	0.9008
Nil	-	BAP	==	0	-971.673	522.704	-1.859	0.5848
SS12	-	BAP	==	0	-699.534	651.926	-1.073	0.9557
SS4	-	BAP	==	0	-1026.54	651.926	-1.575	0.7567
SS8	-	BAP	==	0	-706.58	603.566	-1.171	0.9315
BAP+SS4	-	BAP+SS12	==	0	722.181	603.566	1.197	0.9239
BAP+SS8	-	BAP+SS12	==	0	570.229	651.926	0.875	0.9854
Nil	-	BAP+SS12	==	0	-1226.95	522.704	-2.347	0.3048
SS12		BAP+SS12	==	0	-954.809	651.926	-1.465	0.8153
SS4		BAP+SS12	==	0	-1281.82	651.926	-1.966	0.5171
SS8		BAP+SS12	==	0	-961.855	603.566	-1.594	0.7461
BAP+SS8	-	BAP+SS4	==	0	-151.952	651.926	-0.233	1
Nil	**-**	**BAP+SS4**	==	0	-1949.13	522.704	-3.729	**0.0185**
SS12	-	BAP+SS4	==	0	-1676.99	651.926	-2.572	0.2095
SS4	-	BAP+SS4	==	0	-2004	651.926	-3.074	0.0798
SS8	-	BAP+SS4	==	0	-1684.04	603.566	-2.79	0.1408
Nil	-	BAP+SS8	==	0	-1797.18	577.871	-3.11	0.074
SS12	-	BAP+SS8	==	0	-1525.04	696.938	-2.188	0.3873
SS4	-	BAP+SS8	==	0	-1852.05	696.938	-2.657	0.1797
SS8	-	BAP+SS8	==	0	-1532.09	651.926	-2.35	0.303
SS12	-	Nil	==	0	272.139	577.871	0.471	0.9997
SS4	-	Nil	==	0	-54.871	577.871	-0.095	1
SS8	-	Nil	==	0	265.093	522.704	0.507	0.9995
SS4	-	SS12	==	0	-327.01	696.938	-0.469	0.9997
SS8	-	SS12	==	0	-7.046	651.926	-0.011	1
SS8	-	SS4	==	0	319.964	651.926	0.491	0.9996