PLANT RESPONSES ON SOILS AMELIORATED WITH WASTE PRODUCTS[1]

by

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Abstract: The South African mining industry has been the backbone of the country's economy for much of the past century. Mining has, however, had major impacts on both agricultural resources and the urban environment. Rehabilitation of such impacted soils, which are often characterized by high acidity and low fertility, requires major inputs to ensure the successful establishment and sustainability of a protective and restorative vegetation. The safe use of biosolids has been made feasible by combining it with coal combustion products. The resultant product (SLASH) has been shown to have a positive effect on the pH, Ca, Mg and P of a moderately acid agricultural soil and on the production of a range of vegetable and flower crops. With a view to using such a product in the rehabilitation of impacted soils, SLASH was applied to an infertile soil and a range of forage species, used in different revegetation programs, were used as test crops. These included an annual cereal crop (Triticale –*Triticum x Secale*), commonly used to ensure early stabilization of minelands and/or as a stubble mulch for the establishment of perennial species, as well as perennial legumes (Sweet Clover – *Melilotus alba* and Crown Vetch – *Coronilla varia)* and grasses such as Kentucky Bluegrass – *Poa pratensis*, Tall Fescue – *Festuca arundinaceae* and Buffelgrass – *Cenchrus ciliaris).* SLASH had marked beneficial effects on productivity of forage as well as root development for as long as two years after initial treatment.

Additional Key Words: biosolids, flyash.

Introduction

Thousands of hectares are disturbed annually by surface mining operations in South Africa. To date the emphasis has been placed on the use of lime and inorganic fertilizers in rehabilitating such mineland. There is, however, a chronic shortage of organic matter in these soils and the use of ley pasture crops, or organic fertilizers, are therefore, a priority in such strategies. Reynolds et al. (1999) mixed sewage sludge, flyash and lime (30% : 60% : 10% on a dry matter basis) to produce a product (SLASH) which is safe in terms of both disease organisms and potential heavy metal pollution. Similar products, based on the alkalinization of biosolids, have also been evaluated in the USA and Australia. The use of SLASH to ameliorate soils for the production of flowers and vegetables has been a priority area of research (Rethman et al., 1999). Preliminary results on the potential use of SLASH in rehabilitation programs (Rethman et al., 2000) have indicated that there is considerable scope for using such strategies as an alternative disposal method for such waste products. This paper expands on this theme, including the effect of SLASH on an annual cover crop, perennial grass crops and potential legumes for revegetation programs.

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Materials and Methods

Trial 1 – This investigation , incorporating five levels of SLASH (0%, 2.5%, 5.0%, 7.5% and 10% by weight) incorporated to a depth of 20 cm had five replications. One year after the treatments were applied, during which period vegetable and flower test crops were harvested, soil samples were taken for analysis, and Triticale was planted in the autumn of 2000. This crop was harvested on three occasions in the winter

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(June), spring (August) and early summer (October). After oven drying to constant mass at 60° C the dry matter production was determined. This trial was conducted in raised beds outdoors.

Trial 2 – In this trial perennial grasses (Kentucky Bluegrass, Buffelgrass and Tall Fescue) and legumes (Sweet Clover and Crown Vetch) were used as test crops to determine the persistence of SLASH treatment effects. SLASH, at concentrations of 0%, 5%, 10% and 30% by weight, was originally incorporated into a moderately acid but infertile sandy soil in December 1998. After multiple cropping with flower and vegetable crops the treated soil was used in replicated (x5) pot trials, conducted outdoors with Bluegrass (240-420 days after treatment), Buffelgrass (360-520 days after treatment) and Tall Fescue (440-660 days after treatment). Perennial legumes, which are important components of many revegetation programs, were represented by Sweet Clover (240-420 days after treatment) and Crown Vetch (400-660 days after treatment). Evaluation parameters included (a) forage production (single harvest from Buffelgrass, two harvests from Tall Fescue, three harvests from Bluegrass and Sweet Clover and four harvests from Crown Vetch) on an oven dry basis; and (b) root mass (determined after final harvest of Bluegrass and Sweet Clover) by oven drying above ground forage clipped at a height of 6 – 7 cm, and root material which was washed clean after the destructive final harvest.

Results and Discussion

Soil analyses

The influence of SLASH treatments on soil analyses is reflected in Table 1. SLASH had marked and persistent effects on pH, P, Ca, Mg and C. Although the maximum values were achieved at different levels of SLASH incorporation (2.5% in the case of pH; 5.0% in the case of P and soil C; 7.5% in the case of Mg and 10.0% in the case of Ca) it would appear that the optimum level of SLASH incorporation would be in the region of 5%, or 100 t SLASH/ha.

Table 1. Soil analyses one year after the incorporation of SLASH

% SLASH	pH (H_2O)	P (ppm)	Ca (ppm)	Mg (ppm)	C %
0	7.0	9	380	60	0.3
2.5	8.8	60	2830	96	1.0
5.0	8.6	85	5130	124	1.3
7.5	8.6	86	6680	145	1.0
10.0	8.6	66	7130	145	1.0

Triticale

The response of Triticale to different levels of SLASH, measured in terms of dry forage produced from three harvests is illustrated in Table 2. Despite this being the third crop to be harvested in 18 months there was still a marked response to the highest level of SLASH incorporation. This response cannot be ascribed to either pH or P (see Table 1) but may be due to the persistent and long term effects of N from the sewage sludge. Despite N being lost during the manufacture of SLASH (Reynolds et al., 1999) the N remaining apparently had a most desirable slow-release action. This might also be ascribed, in part at least, to the markedly higher C content of SLASH treated soils. This results in a better C:N ratio in the soil, than would be expected from inorganic N fertilizer.

Bluegrass

The yields of both above (forage yield) and below ground (root mass) components of this species were very strongly influenced by the level of SLASH application (Table 3). The % increase in forage production, which holds implications for forage availability as well as improving the protection against rain drop erosion offered by canopy cover, was in the region of 750%.Even more remarkable was the increase in root mass (2000%), which will have a strong effect on the anti-erosive capacity of such vegetation, a major factor in many rehabilitation projects.

Table 2. Forage yield of Triticale from three harvests in the 2000 growing season

% SLASH	Forage yield (g DM/pot)
0	60.0
2.5	82.3
5	102.5
7.5	110.1
10	143.8

Table 3. Influence of level of SLASH application on the vigor of Kentucky Bluegrass

% SLASH	Forage yield (g DM/pot)	Root mass (g DM/pot)
0	1.3	2.2
5	8.2	33.8
10	6.9	37.5
30	11.0	45.4

Buffelgrass

This was the only sub-tropical species among the test crops evaluated. It was, therefore, interesting to note that the response to SLASH was even more linear than that of Bluegrass (Table 4), with yield responses being recorded up to the highest level of SLASH. In an unusually cold winter for this area this sub-tropical species suffered considerable cold damage. Although results were variable, SLASH treatments were, on average, 10% more vigorous than the control in the spring and the 30% treatment was nearly 60% more vigorous.

Tall Fescue

Because this species was planted nearly 18 months after the original SLASH incorporation it was fully expected that the residual effect of that treatment would be minimal. In fact the treatment effect recorded (Table 5) varied from 100%to 165% better than the control, despite crop removal by three prior cropping cycles and the possible losses through leaching over this extended period with liberal applications of irrigation. This confirms that SLASH has a long term, slow release action.

Table 4. Production of Buffelgrass as influenced by the level of SLASH application

% SLASH	Forage yield (g DM/pot)
0	1.3
5	3.6
10	4.6
30	10.2

Table 5. The response of Tall Fescue to SLASH incorporated ~ 18 months prior to planting

% SLASH	Forage yield (g DM/pot)
0	4.8
5	12.5
10	9.8
30	12.7

Sweet Clover

The responses of this species to SLASH (Table 6) were not nearly as dramatic as those recorded with Bluegrass, which had identical treatment, both prior to and during this observation period. There were still marked responses (in both top and root growth) to SLASH but the response was probably more strongly influenced by P than N as legumes fix their own N.

Crown Vetch

This species was established using rhizomes and apart from the initial slow establishment it was uncertain whether the plants would fix their own nitrogen or whether they would respond in a similar way to grasses. The results illustrated in Table 7 indicate that, as with Sweet Clover, there was a marked response up to 5% level of SLASH, which corresponds with the influence of SLASH on the P status.

Table 6. Influence of SLASH levels on Sweet Clover

% SLASH	Forage yield (g DM/pot)	Root mass (g DM/pot)
0	7.1	1.6
5	40.7	5.6
10	38.2	5.7
30	25.4	6.7

Table 7. Influence of SLASH on Crown Vetch

% SLASH	Forage yield (g DM/pot)				
	1st	2nd	3rd	4th	Total
0	2.6	3.3	2.6	3.1	11.6
5	8.5	22.1	10.4	14.1	55.1
10	3.7	26.4	10.9	13.9	54.9
30	7.2	24.3	9.3	12.2	53.0

short season crops, where the soil is cultivated between each cropping cycle these split applications might be incorporated into the soil. Certainly in terms of traditional wisdom this would be the preferred strategy for liming material and/or phosphatic fertilizer. With perennial crops it might, however, be a consideration to include a comparison of heavy basal applications, incorporated at establishment, with lighter annual or bi-annual top dressings. These latter scenarios would have specific application to many mineland reclamation projects.

The other finding was the basic difference between the responses of grasses and legumes to SLASH. Within the limited range of species evaluated thus far, it appears that grasses (which are dependent on N and P) respond favourably, up to the highest levels of application. The SLASH also has the advantage of having good persistence by virtue of its "slow release" properties and/or the favourable C:N ratio created when SLASH is used. In contrast the legume response (which is usually less dependent on applied N) is more closely

Finally it must be emphasized that SLASH does not contain the full range of plant nutrients. Even at the high rates used in these trials (50 – 600 t/ha) regular monitoring of the soil and crops should be employed as the basis for determining the need for supplementary fertilization. If low levels (100's kg/ha) are recommended, because of the high cost of transport, it is unlikely that the product will have any meaningful effect on pH, mineral status or organic matter content of the soil. At this stage, therefore, it is recommended that SLASH only be incorporated, as a component of soil amelioration, on sites in relative close proximity to the waste raw materials used in its manufacture.

Conclusion

The major finding of this phase in an ongoing program, on the effects of SLASH on different species, are that despite the negative effects of high application rates on the first crops after treatment reported by Rethman et al. (2000), this product has a strong positive influence for at least 22 months after incorporation. The optimum level is, as a result very difficult to calculate, especially in the multiple cropping systems used in this program. The ideal would probably be to have single heavy applications (as used in this program) in contrast to more frequent lighter applications. In the case of

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