

## CHAPTER 2

Prepared according to the guidelines of the Journal of Environmental Quality

### **Multiple cropping on soils treated with a mixture of sewage sludge, lime and fly ash (SLASH)**

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#### **ABSTRACT**

Due to limited prime agricultural land, South Africa is heavily reliant on the use of acidic and nutrient deficient soils to meet the needs for increased food production. The growing South African population has an increased need for food security. Rapid urbanization is producing vast amounts of sewage sludge and electricity generation facilities are producing millions of tons of fly ash. Both waste products need a safe disposal method, beneficial to the user.

Environmental legislation has, however, placed restrictions on the application of sewage sludge to agricultural land. The prime concern being the accumulation of heavy metals and risk of disease.

This pot study describes the beneficial effects of SLASH (60% Sewage sludge, 30% class F fly ash and 10% CaO) incorporation into soils. SLASH incorporation at rates between 5% - 10% of the soil volume, provided prolonged growth enhancement and yield increases over several cropping cycles. Other parameters such as root development, inflorescence production and stem development were also improved by the residual effect of SLASH.

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## INTRODUCTION

South Africa is characterized by a rapidly growing population rate and a poor agricultural resource base (Rethman *et al.*, 1999b). Increased food production is therefore, urgently required to improve both national and household food security (Truter and Rethman, 2000). Sustainable increases in food production are difficult on a limited resource base. Acidic soils in South Africa are quite common, especially in high rainfall areas. It is essential to utilize these areas effectively, to ensure sustainability. In many rural development areas, farmers are not always able to obtain or use lime to treat their acidic or nutrient depleted soils, because they lack appropriate transport infrastructure and equipment, and it can become very expensive. Many factors, as previously mentioned, emphasize the need for amelioration and the possible use of alternative liming materials, which are more economically viable and easily accessible.

Previous work by Reynolds *et al* (1999), to determine the feasibility of converting waste disposal problems in South Africa into a soil beneficiation strategy, have proven viable. The co-utilization of fly ash and sewage sludge with added lime delivered a product termed SLASH (that contains 60 % class F fly ash, 30 % sewage sludge and 10% unslaked lime on a dry matter basis), which has beneficial soil amelioration effects.

In the past several problems with waste disposal have been experienced globally. One of these problems is that sewage sludge, which is often used in agriculture, often contains heavy metals and pathogens. As a result, its use is restricted for agricultural land application. Secondly, fly ash production in countries, which rely on coal for energy, such as South Africa, presents a major problem to those responsible for the consequences and implications of disposing of such a “waste” product (Truter *et al.*, 2001).

As with fly ash, only a fraction of total nutrients (especially N and P) supplied by organic wastes are available to crops in a season, since they must be mineralized from organic to inorganic forms. Despite these limitations, sewage

sludge and animal manures may be the most cost effective supplement for co-utilization with fly ash in crop fertilization. Mixtures of fly ash with organic wastes already have a proven track record (Pitchel and Hayes, 1990; Belau, 1991; Schwab *et al.*, 1991; Sims *et al.*, 1993; Vincini *et al.*, 1994; Sajwan *et al.*, 1995; Wong, 1995; Schumann and Sumner, 2000), but the preparation of mixtures has usually proceeded by trial and error.

Reynolds *et al.*, (1999), Rethman *et al.*, (1999a) and Rethman *et al.*, (1999b) have reported on the manufacture and use of a soil ameliorant for a variety of crops- including corn, beans, potatoes, spinach and a flower crop such as asters. These reports highlighted the use of SLASH to eliminate the potential problems with disease organisms or heavy metal pollutants, while improving soil pH, Ca, Mg and P. The growth and productivity of such test crops was improved markedly under conditions of low fertility (Rethman and Truter, 2001).

This study concentrated on the multiple cropping of soils that had been treated with SLASH. The objective of this study was to determine the long-term residual effect of this waste product mixture on crop production.

## MATERIALS AND METHODS

A pot trial was conducted on the Hatfield Experimental Farm, Pretoria, South Africa (25°45'S 28°16'E), 1327m above sea level. A uniform sandy loam soil was ameliorated with SLASH [a mixture of sewage sludge, fly ash and reactive lime (CaO)] (Reynolds *et al.*, 1999). This mixture of SLASH and soil was placed in 10 litre pots after previous cropping cycles reported by Rethman *et al.*, (1999b).

The work conducted by Rethman *et al.* (1999b) on this soil, reported that this ameliorant had been applied in December 1998, and planted to vegetable and flower crops. These crops represented the first two cropping cycles of the study.

The design used in this study, was a randomized plot design with four treatments (T1 – Control (0% SLASH), T2 – 5 % SLASH, T3 – 10% SLASH and T4 – 30% SLASH) replicated five times under natural temperature conditions. The treatments were calculated as a percentage of the soil volume. Ten kilograms of substrate were weighed out and used as the value from which the

treatments were calculated and then placed into the 10 litre pots. The soils were irrigated regularly, supplementing rainfed conditions, to eliminate moisture as a limiting factor. No additional lime or fertilizer was applied to the treated soils throughout this study.

This study entailed the cropping of four different crop species, including ornamental sunflower, buffelgrass, sorghum and rye as successive 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> cropping cycles.

### **3<sup>rd</sup> Cropping Cycle**

Once the 2<sup>nd</sup> cropping cycle by Rethman *et al.*, (1999b) was completed, the soil from those pots was used in this study. An ornamental sunflower (*Helianthus sp. cv. ORIT*) was used in the 3<sup>rd</sup> cropping cycle. Five seeds were planted and once seeds had germinated, two weeks later, the weaker plants were removed. The three most vigorous plants were left, to ensure a representative number of plants in all the pots. During the growth period and at maturity, the length of sunflowers was measured. As soon as the plants had reached maturity, an inflorescence count was conducted. These observations were to establish whether SLASH, at different levels, contributed to longer stem development or higher flower production. Dry matter production was also measured.

### **4<sup>th</sup> Cropping Cycle**

The sunflower study was followed by a perennial grass species, buffelgrass (*Cenchrus ciliaris*). This grass was selected because it is reasonably susceptible to acid soils. It is a palatable grass commonly used for animal forage in dry areas. (Tainton *et al.*, 1976). As a result of harsh growing conditions, only two harvests were taken. The only parameter measured, was dry matter (DM) production.

### **5<sup>th</sup> Cropping Cycle**

At the beginning of the following summer growing season, the treated soil, still with no additional SLASH application or any other fertilizer, was planted to an annual forage crop, *Sorghum sp. cv. Hypergraze*. Plants were grown from seed. Ten seeds were planted and once seedlings were well established the weaker plants were removed. This was to ensure five strong and healthy plants in all the pots. The DM production was measured in this growing season.

Three harvests were taken, to establish whether plant growth was still benefiting from the SLASH treatments, and at what level the best performance was obtained. The pots were harvested as soon as the best treatment reached flowering stage. This observation was approximately 36 months after the initial application of SLASH. As soon as the production cycle for sorghum was terminated, these plants were lifted in June 2001, to assess the influence of SLASH on root development.

### **6<sup>th</sup> Cropping Cycle**

After the summer growing season, winter rye (*Secale cereale cv. SSR 729*) was planted. Ten rye seeds were initially planted and once they had germinated, the weaker plants were removed, leaving five vigorous plants so that all the pots had the same number of plants. Two harvests were taken. All the pots were harvested when the best treatment reached flowering stage. This, the final DM production observation for the pot study was approximately 42 months after the initial application of SLASH.

### **Statistical analyses**

Data on the sunflower inflorescence count and stem length measurements were not statistically analyzed. All dry matter production data and root study data was statistically analyzed using PROC GLM (1996/1997 and 1997/1998). Statistical analysis was performed using SAS (SAS Institute, 1996) software. LSD's were taken at  $P \leq 0.05$ .

## RESULTS AND DISCUSSION

### Sunflower (*Helianthus sp. cv. ORIT*)

Mixing fly ash with organic waste products can deliver a mixture, which contains various essential elements required for plant growth. Rethman *et al.*, (1999b) reported that it is evident that SLASH, when applied to infertile soils at a 5% level, has a beneficial effects on the growth and production of asters, spinach, stocks and onions. This is verified by the results obtained for sunflower production parameters.

Fig.1 illustrates what effect SLASH has in general on the primary inflorescence production of the sunflower. On average the 5 % and 10% SLASH levels initially gave much larger inflorescences, and eventually many more of them as well. The ornamental sunflower produces a primary inflorescence, after which it then produces secondary inflorescences. A comparison of the sunflower heights should be taken from the red indicator arrow on the diagram.



Fig. 1. Response of sunflower (*Helianthus sp cv. ORIT*) to SLASH treated soils

Once the sunflowers reached maturity, an inflorescence count was conducted. It was found that the mean number of inflorescence was much higher for the 10% and 30% SLASH levels (Fig. 2).

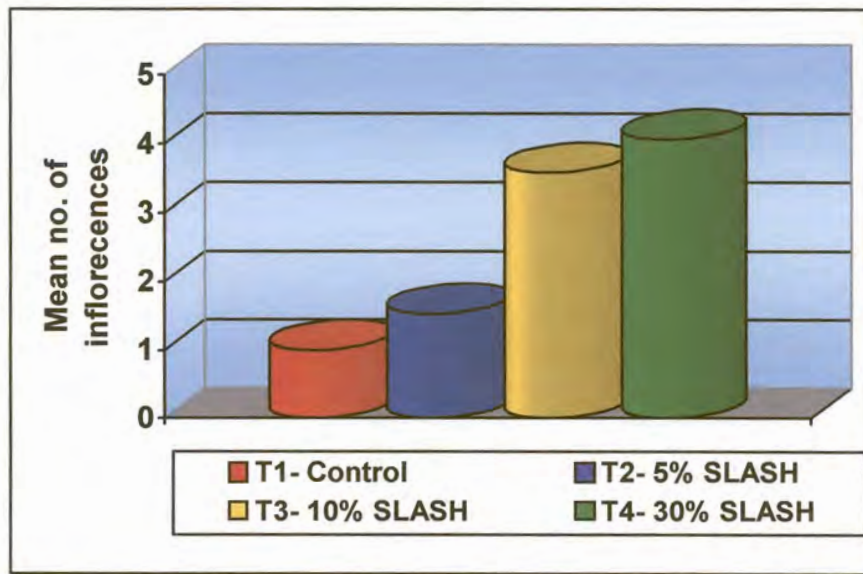


Figure 2. Influence of SLASH on the mean number of inflorescences of sunflower (*Helianthus sp. cv. ORIT*). # Not statistically analysed.

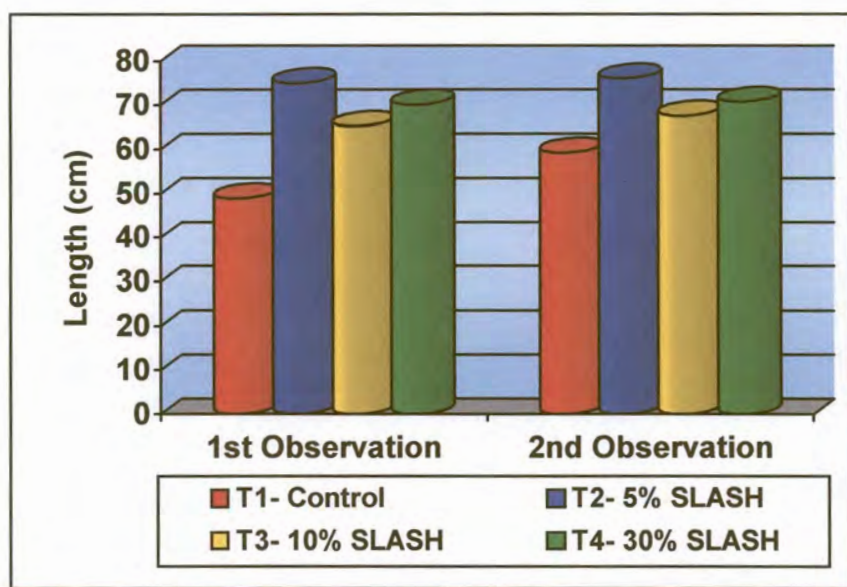
With respect to the influence of SLASH on stem length, the results are illustrated in Fig.3. There were no significant differences between SLASH treatments, although the SLASH treatments gave longer stems than the control. There were two observation dates (30 days apart), and it was evident that the SLASH treatments reached maturity quicker than the control, because there were no significant differences between the two observation dates for the SLASH treatments.

The results shown in Table 1, demonstrate that SLASH has a marked residual effect. In this third cropping cycle sunflowers produced more dry matter on the SLASH treated soils than on the control, with the 5% and 10% treatments giving the best results.

**Table 1: The mean dry matter production (g/pot) and ( $\pm$ MSE) of sunflower (*Helianthus sp.* cv. ORIT) in response to various SLASH treatments.**

Treatments	Relative Wet Mass	Relative Dry Mass
	(g/pot)	(g/pot)
T1 – Control	23.54 <sup>a</sup> ( $\pm$ 2.09)	9.72 <sup>a</sup> ( $\pm$ 2.57)
T2 - 5% SLASH	119.39 <sup>b</sup> ( $\pm$ 9.98)	46.23 <sup>b</sup> ( $\pm$ 9.05)
T3 - 10% SLASH	127.90 <sup>b</sup> ( $\pm$ 12.87))	46.37 <sup>b</sup> ( $\pm$ 13.23)
T4 - 30% SLASH	98.75 <sup>b</sup> ( $\pm$ 20.78)	36.64 <sup>b</sup> ( $\pm$ 19.50)

\* Means with the same letter are not significantly different at  $P > 0.05$ . (Tukeys Studentized Range Test)



**Fig. 3. The mean length measurements (cm) of sunflower (*Helianthus sp.* cv. ORIT) in response to different SLASH levels. # Not statistically analysed.**

### **Buffelgrass (*Cenchrus ciliaris* cv. CPI 71914)**

The forage production of buffelgrass (*Cenchrus ciliaris*), as influenced by SLASH applications, 12 months prior to planting of buffelgrass and after three preceding cropping cycles is shown in Table 2. Although, three cropping cycles had been completed, SLASH still had a marked influence on the buffelgrass production. Surprisingly, given the poorer performance of the thirty percent SLASH treatments for sunflower, the buffelgrass performed the best on this



treatment. This verifies how different crop species respond to the SLASH treatments.

**Table 2: The mean dry matter production (g/pot) and ( $\pm$ MSE) of buffelgrass (*Cenchrus ciliaris*) on soils amended with different levels of SLASH.**

Treatments	1 <sup>st</sup> Harvest Dry	2 <sup>nd</sup> Harvest Dry	Total DM Production
	Mass	Mass	
	10/03/2000	15/6/2000	
	(g/pot)	(g/pot)	(g/pot)
T1 – Control	1.33 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.31)	1.92 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.77)	3.25 <sup>A</sup> ( $\pm$ 0.92)
T2 – 5% SLASH	3.64 <sup>a</sup> <sub>b</sub> ( $\pm$ 0.63)	4.07 <sup>a</sup> <sub>b</sub> ( $\pm$ 0.60)	7.71 <sup>B</sup> ( $\pm$ 1.06)
T3 – 10% SLASH	4.62 <sup>a</sup> <sub>b</sub> ( $\pm$ 0.51)	5.48 <sup>a</sup> <sub>b</sub> ( $\pm$ 0.86)	10.10 <sup>C</sup> ( $\pm$ 0.75)
T4 – 30% SLASH	10.17 <sup>a</sup> <sub>c</sub> ( $\pm$ 2.22)	10.14 <sup>a</sup> <sub>c</sub> ( $\pm$ 2.15)	20.31 <sup>D</sup> ( $\pm$ 2.55)

\*a Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*abc Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*A Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

The response of buffelgrass to the 30 percent SLASH treatment can possibly be ascribed to the residual effect of SLASH, where N is becoming more available over time.

When comparing the results obtained from this fourth cropping cycle to the third cropping cycle, it seems that there is a tendency that the 5% and 10% treatments are gradually becoming depleted, although still maintaining a better yield than the control. This assumption cannot necessarily be accepted, because it is important to consider the possibility of various individual crop/plant responses.

Although a root study was not conducted, a marked visual response was noted, with SLASH dramatically improving root development. Fig.4 illustrates how buffelgrass root development was influenced by the various SLASH treatments relative to the control. This dramatic improvement in root development holds important implications for the erosion control capacity of the species (because of the binding or re-inforcing properties of such root systems) as well as improving the plant's ability to survive harsh environmental conditions.

Fig.4 gives a visual on how the root system of the buffalo grass responded to the SLASH treated soils. It is evident from the diagram that SLASH definitely had beneficial effects on root development, and substantiates the above ground dry matter production results.



**Fig. 4. Root development of buffelgrass (*Cenchrus ciliaris* cv. CPI71914) in soils treated with SLASH.**

### **Sorghum (*Sorghum* sp. cv. Hypergraze)**

Approximately 36 months after the SLASH treatments were initially applied, sorghum dry matter production in the summer growing season was measured. The forage production results for sorghum (Table 3) illustrate that the thirty percent SLASH treatment still delivered the best yield on average. There were no significant differences between the 5 – 30% SLASH treatments. The lowest SLASH treatment (5% SLASH), however, was sixty percent better than the control. These results are presented in Table 3.

Once again, a dramatic improvement in root development was noted. This is illustrated in Fig.5. The average root mass of all the SLASH treatments was 200 percent better than the control. This holds important implications for increases in the water use- and nutrient use efficiency of the species, thereby improving the plant's ability to survive stress conditions.

Table 3: The mean dry matter (DM) production (g/pot) and ( $\pm$ MSE) of sorghum (*Sorghum sp. cv. Hypergraze*) in response different SLASH treatments.

Treatments	1 <sup>st</sup> Harvest Dry Mass 01/02/2001 (g/pot)	2 <sup>nd</sup> Harvest Dry Mass 30/03/2001 (g/pot)	3 <sup>rd</sup> Harvest Dry mass 04/06/2001 (g/pot)	Total DM Production (g/pot)
T1 – Control	2.64 <sup>a</sup> ( $\pm$ 0.84)	4.84 <sup>b</sup> ( $\pm$ 2.35)	0.72 <sup>c</sup> ( $\pm$ 0.36)	8.20 <sup>A</sup> ( $\pm$ 2.33)
T2 – 5% SLASH	5.73 <sup>a</sup> ( $\pm$ 1.46)	5.35 <sup>a</sup> ( $\pm$ 1.16)	2.15 <sup>c</sup> ( $\pm$ 0.69)	13.23 <sup>B</sup> ( $\pm$ 2.08)
T3 – 10% SLASH	6.33 <sup>a</sup> ( $\pm$ 1.37)	7.19 <sup>a</sup> ( $\pm$ 1.22)	2.19 <sup>b</sup> ( $\pm$ 0.86)	15.71 <sup>BC</sup> ( $\pm$ 2.51)
T4 – 30% SLASH	7.56 <sup>a</sup> ( $\pm$ 1.36)	7.28 <sup>a</sup> ( $\pm$ 2.24)	2.51 <sup>b</sup> ( $\pm$ 0.62)	17.35 <sup>C</sup> ( $\pm$ 3.37)

\*abc Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

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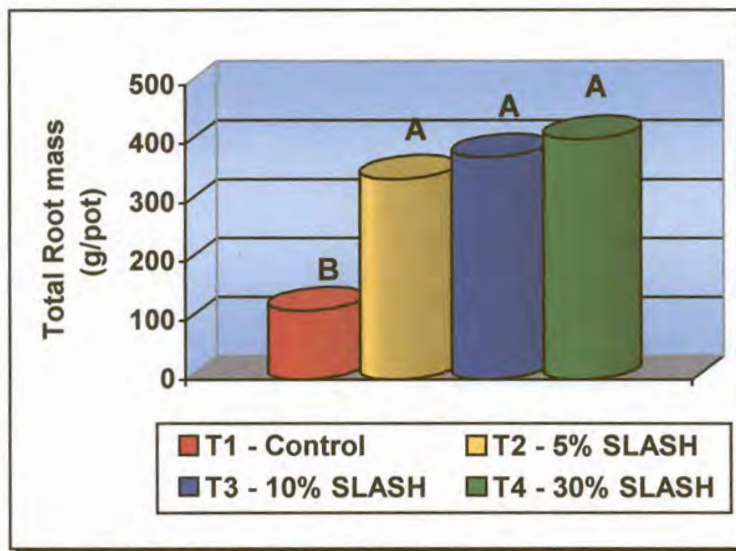


Fig. 5. Root development (g/pot) of sorghum (*Sorghum sp. cv. Hypergraze*) in SLASH treated soils. \* Means with a common character are not significantly different at  $P > 0.05$  (Tukey's Studentized Range Test).

### Rye (*Secale cereale cv. SSR 729*)

Finally, this winter annual forage crop represented the 6<sup>th</sup> cropping cycle of this study. Surprisingly after 42 months of cropping since the initial SLASH application, no significant differences were noted between the SLASH treatments.

The production of the control, for the entire growing season, was however, at least 40% less than the lowest SLASH treatment.

The results presented in Table 4, indicates a decline in production between the first harvest and the 2<sup>nd</sup> harvest. The decline can be ascribed to the fact that this crop is a winter crop and the 2<sup>nd</sup> harvest represents the growth of the crop during the transition phase from winter to spring. With reference to the total dry matter (DM) production of rye (Table 4), it is notable that there were no significant differences between the SLASH treatments.

Nevertheless, the SLASH treatments outperformed the control; giving up to 65% better yield.

It is evident from this final cropping cycle of this study that the SLASH treated soils were beginning to show signs of depletion 36 months after the initial SLASH application.

**Table 4: The mean dry matter production (g/pot) and ( $\pm$ MSE) of rye (*Secale cereale* cv. SSR 729) on soils treated with various levels of SLASH.**

Treatments	1 <sup>st</sup> Harvest Dry Mass 12/10/01 (g/pot)	2 <sup>nd</sup> Harvest Dry Mass 21/11/2001 (g/pot)	Total DM Production (g/pot)
T1 – Control	3.00 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.49)	1.37 <sup>b</sup> <sub>a</sub> ( $\pm$ 0.28)	4.37 <sup>A</sup> ( $\pm$ 0.65)
T2 – 5% SLASH	3.33 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.71)	2.77 <sup>a</sup> <sub>b</sub> ( $\pm$ 1.24)	6.10 <sup>B</sup> ( $\pm$ 1.17)
T3 – 10% SLASH	4.08 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.87)	2.62 <sup>b</sup> <sub>b</sub> ( $\pm$ 0.98)	6.70 <sup>B</sup> ( $\pm$ 1.42)
T4 – 30% SLASH	4.24 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.90)	2.36 <sup>b</sup> <sub>b</sub> ( $\pm$ 0.78)	6.60 <sup>B</sup> ( $\pm$ 1.06)

\*ab Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*ab Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*ABC Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

## CONCLUSION

Disposal of waste products such as sewage sludge and fly ash is of major concern in South Africa and many other countries. Combinations of these and other waste products to develop a beneficial product, has been extensively investigated worldwide. Very little work has, however, been done on the use of such ameliorants in long-term plant production systems to evaluate their residual effects.

It is very clear that in the SLASH programme, it is of cardinal importance to examine a wide range of species, or even cultivars, under different levels of intensification (different fertility levels, different water levels, different populations) and on different substrates, to be able to extrapolate conclusions.

From the results obtained in this study, it may be concluded that SLASH does improve the growth rate of various crop species. Furthermore, it has a long-term residual effect, even after cropping the soils intensively over a 36<sup>th</sup> month period. It is evident from the results that, on average, the 5% – 10% SLASH levels delivered the best yields. Another important aspect of the study which became clear, was that SLASH improved the root development of both sorghum and buffelgrass, stimulated a higher production of inflorescence's of the ornamental sunflower, and caused accelerated stem elongation of the sunflower. This enhancement of both below and aboveground biomass can be ascribed to two reasons. Firstly, favorable soil conditions were created by SLASH. Secondly, there was a slow release of essential macro- and micronutrients from the sewage sludge and the fly ash.

When mixing two waste products, an amendment is created which can be more beneficial than either component alone. The reason for using an organic waste such as sewage sludge, is to supplement the bulking agent fly ash with macronutrients, which it lacks. The advantage of combining two different waste products, is that different amending qualities of the individual components are brought together. By doing this, two major problems that are common in highly productive agricultural soils, such as acidity and nutrient deficiency, can be resolved. The other benefit is that a safe disposal method for large quantities of

waste products is created and can be used in areas in close proximity to the raw materials.

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## CHAPTER 3

Prepared according to the guidelines of the European Journal of Agronomy

### **The influence of a mixture of sewage sludge, fly ash and lime (SLASH) on biomass production of two grasses and two legumes**

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#### **Abstract**

South Africa is characterized by a large and rapidly growing population. Sustainable increases in forage production are difficult on the limited resource base. The effective use of acidic soils is also critical in many areas. Air pollution from burning fossil fuels is the major cause of acid rain and together with incorrect management practices results in the physical (e.g. soil erosion, compaction), chemical (e.g. soil acidification, salinization) and biological (e.g. declining biological activity) degradation of soils.

The rapidly increasing cost of nitrogen fertilizers and protein rich forage provided by leguminous forages, makes the use of legumes in agricultural production systems and mine rehabilitation essential. Although South Africa has very limited prime agricultural land, we are reliant on the use of acidic and nutrient deficient soils to meet the needs for highly productive systems.

In the past, sewage sludge application to agricultural soils was a common practice to improve infertile soils. Environmental legislation has, however, placed restrictions on such applications. The prime concern being heavy metal accumulation and risk of disease. Previous research has, however, indicated that sewage sludge, when treated with a mixture of class F fly ash and lime, is characterized by the immobilization of heavy metals and pasteurization of disease organisms.

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This product (SLASH) has been shown to have significant amelioration properties when applied to acidic and nutrient depleted soils, resulting in enhanced crop productivity.

This work describes the beneficial effects of SLASH incorporation into soils, in comparison to an untreated control. It was found that SLASH incorporation rates of 5 – 10% of the soil volume, provided prolonged growth enhancement of Kentucky Bluegrass (*Poa pratensis*), Tall Fescue (*Festuca arundinaceae*), White Sweet clover (*Melilotus alba*) and Crown vetch (*Coronilla varia*). SLASH definitely had beneficial effects on both legume and grass biomass production.

*Keywords:* Acidic soils; Amelioration; Fly ash; Legumes; Sewage Sludge; SLASH;

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## 1. Introduction

In South Africa approximately 28 million tons of ash is produced annually as a result of energy generation to meet the energy requirements of a population of 45 million people and growing. This largely untapped resource, together with the fact that, power utilities, are generally situated in areas with a high agricultural potential, which are being acidified because of the effect of “acid rain” and agronomic practices, makes it’s use a viable proposition. Only a small percentage of this untapped resource of fly ash is currently used in the cement, plastics, rubber and paint industry (Reynolds et al, 2002).

Sewage sludge on the other hand is classified as a toxic waste and it is produced at a rate of 800 tons/day dry mass in South Africa (Reynolds, 1996). These problems emphasize the need for co-utilization of wastes and the identification of possible strategies for the safe disposal and use of such waste products. Nutrient poor and acidic soils in South Africa are becoming more prevalent and many farmers require alternatives to the high priced conventional methods of soil amelioration currently in use (Truter et al., 2001).

The use of fly ash (FA) as a soil amendment is hindered by a lack of macronutrients in the ash and concerns about trace element availability or toxicity. Mixing FA with an organic waste can increase macronutrients while reducing odor and improving material handling properties, but the trace element solubility requires further investigation. (Jackson et al., 1999)

The extreme variability measured in waste materials in terms of total nutrient concentrations, extractable nutrients and the relative nutrient balances is quite common in other studies, and reinforces the urgent need to characterize waste materials before mixing and use in crop fertilization. The potential pitfalls of indiscriminate waste application to soil include (i) potential phytotoxicity from micronutrient excess (especially B); (ii) shortages of essential macro nutrients such as N, P, and K due to low supply; (iii) nutrient deficiencies caused by unfavorable fly ash pH, slow nutrient release, and fixation of other nutrients such as P already present in the soil solution; and (iv) induced nutrient deficiencies from the supply of elements in incorrect proportions. Most of these problems can be overcome by exploiting the complementary nature of fly ash, sewage sludge, and poultry manure, and additional nutritional benefits (especially N-P-K balancing) should be possible by mixing these waste materials together (Schumann and Sumner, 2000).

A soil ameliorant based on fly ash that is supplemented with a small amount of unslaked lime and mixed with sewage sludge delivers a resultant odour free, pasteurized, soil-like product, which has growth enhancing properties, trace minerals from fly ash and organics from the sewage sludge is termed SLASH. (Reynolds et al., 1999)

Reynolds et al., (1999), Rethman et al., (1999a) and Rethman et al., (1999b) have reported on the manufacture and use of a soil ameliorant for a variety of crops- including corn, beans, potatoes, spinach and a flower crop such as asters.

These reports highlighted the use of SLASH to eliminate the potential problems with disease organisms or heavy metal pollutants, while improving soil pH, Ca, Mg and P. The growth and productivity of such test crops was improved markedly under conditions of low fertility (Rethman and Truter, 2001). Furthermore, a study conducted by Truter (2002) on the multiple cropping of soils treated with SLASH to evaluate the long term residual effect of this waste product mixture has shown that substantial yield increases and improved root development occurred in the soils treated with SLASH.

SLASH has also had marked beneficial effects on productivity and root development of forages for as long as two years after initial treatment (Rethman

and Truter, 2001; Truter et al., 2001). While this study emphasized the potential of such soil amelioration for improved forage productivity and root development. It also resulted in considerable interest in the potential use of such waste products to re-vegetate and restore productivity of disturbed soils (Rethman et al., 2000; Truter et al., 2001).

A conclusion drawn from a study of the growth responses of both grasses and legumes to SLASH, within the limited range of species that were evaluated, indicated that grasses (which are dependent on N and P) respond favorably to the N in SLASH, up to the highest levels of application. This N also has the advantage of having good persistence by virtue of its "slow release" properties and/or the favorable C: N ratio created when SLASH is used. In contrast the legume response (which is usually less dependent on applied N) is more closely correlated with pH and P status of the growing medium and optimum levels were much lower than with grasses. Finally it was emphasized that SLASH did not contain a full range of plant nutrients. Even at the high rates used in trials (50 – 600 tons ha<sup>-1</sup>) 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<sup>-1</sup>) 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 (Rethman and Truter, 2001).

The objective of this study was to further evaluate the use of SLASH in soils planted to two perennial legumes and two perennial grasses in terms of long term residual effects.

## **2. Material and methods**

A pot trial was conducted at the Hatfield Experimental Farm, Pretoria, South Africa (25°45'S 28°16'E), 1327m above sea level. A uniform sandy loam soil was ameliorated with SLASH (a mixture of sewage sludge, fly ash and reactive lime (CaO)).

Rethman et al (1999b) reported that SLASH had been applied to the sandy loam soil in December 1998, and planted to vegetable and flower crops thereafter. These crops represented the first two cropping cycles of the study. Subsequently, a study was conducted, where the ameliorated soil used for the first two cropping cycles, was removed and placed into 10 litre pots. These soils were then planted to ornamental sunflower (*Helianthus sp. cv. ORIT*), buffelgrass (*Cenchrus ciliaris*), sorghum (*Sorghum sp. cv. Hypergraze*) and rye (*Secale cereale cv. SSR 729*) as successive 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> cropping cycles (Truter, 2002).

Some of the soil that was used for the first two cropping cycles which was eventually removed, (Rethman *et al.*, 1999b) was also planted to sweet clover (*Melilotus alba*), crown vetch (*Coronilla varia*) and Kentucky bluegrass (*Poa pratensis*) in spring/summer of the 1999/2000 growing season, simultaneously to the previously mentioned cropping cycles. Five seeds were planted and once the seedling stage had been reached, the number of seedlings was reduced to two. This study was conducted to eventually evaluate total biomass production for a growing season and to compare production between alternate growing seasons. The objective of the study was to determine if there was any decrease in production over time.

Once the 3<sup>rd</sup> and 4<sup>th</sup> cropping cycles were completed, and the plants were removed before the tall fescue was planted, a further observation was made, and that was a root study. This was to evaluate what the influence of SLASH was on root development of bluegrass and sweet clover. At the start of 2000/2001 season, tall fescue was established in the pots that had been planted to Kentucky Bluegrass and Sweet clover. During this 4<sup>th</sup> cropping cycle and the ongoing 3<sup>rd</sup> cropping cycle of crown vetch, forage yield was the only measurement to be taken, to establish what the long term residual effect of SLASH could be relative to the other treatments. The tall fescue and crown vetch were harvested whenever the best treatment reached the flowering stage. Eight harvests were recorded for the tall fescue over the period October 2000 to January 2002, with ten harvests for the crown vetch over the period December 1999 to January 2002.

The design used in this study, was a randomized plot design. The four treatments that were replicated five times under natural temperature conditions were: T1 – Control (0% SLASH), T2 – 5 % SLASH, T3 – 10% SLASH and T4 – 30 % SLASH. The treatments were calculated as a percentage of the soil volume. Ten kilograms of treated soil was weighed out and used as the value from which the treatments were calculated and then placed into the 10 litre pots. Soils were irrigated to eliminate water from being the limiting growth factor. No additional fertilizer was applied to the treated soils throughout the entire study.

### *2.1 Statistical analyses*

Data for the Kentucky bluegrass density rating and sweet clover seedling count was not statistically analysed. All dry matter production data and root study data was statistically analyzed using PROC GLM (1996/1997 and 1997/1998) and PROC ANOVA (1997/1998). Statistical analysis was performed using SAS (SAS Institute, 1996) software. LSD's were taken at  $P \leq 0.05$ .

## **3. Results and discussion**

### *3.1 White sweet clover (Melilotus alba)*

Seedling survival, forage production and root development of white sweet clover (*Melilotus alba*) as influenced by the level of SLASH application, eight months prior to planting of sweet clover and after two preceding cropping cycles with flowers and vegetables, are shown in Table 1, Fig. 1 & 3. Seedling survival was improved by the addition of SLASH to the soils. The higher the SLASH application the better and quicker the seeds germinated and established themselves.

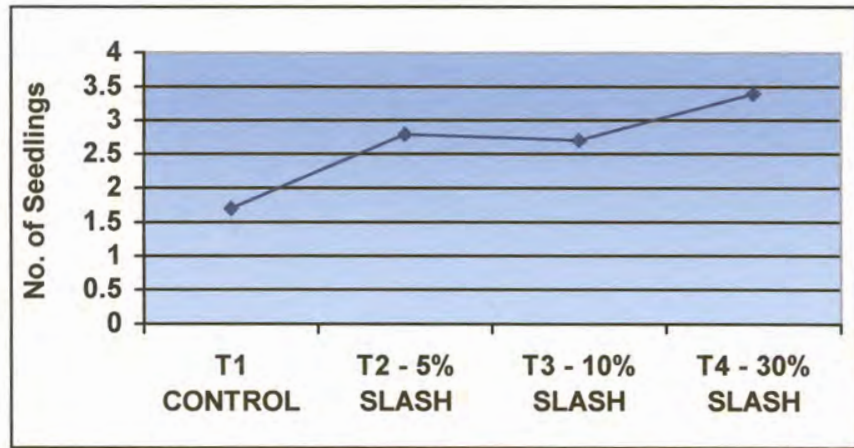


Fig. 1. Influence of SLASH levels on sweet clover (*Melilotus alba*) seedling survival.

# Not statistically analysed.

It is noted from the results given in Table 1, that the initial sweet clover production was relatively slow. It was only after the plants had established themselves properly, that a peak production could be noted for the subsequent harvests 120 days after planting the sweet clover.

Table 1

The mean dry matter (DM) production (g/pot) and ( $\pm$ MSE) of sweet clover (*Melilotus alba*) on soil amended with different levels of SLASH.

Treatments	1 <sup>st</sup> Harvest Dry	2 <sup>nd</sup> Harvest Dry	3 <sup>rd</sup> Harvest Dry	Total DM Production
	Mass	Mass	mass	
	02/12/1999	07/01/2000	29/02/2000	
	(g/pot)	(g/pot)	(g/pot)	(g/pot)
T1 – Control	0.46 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.21)	2.32 <sup>ab</sup> <sub>a</sub> ( $\pm$ 1.56)	4.06 <sup>b</sup> <sub>a</sub> ( $\pm$ 2.24)	6.84 <sup>A</sup> ( $\pm$ 3.83)
T2 – 5% SLASH	9.34 <sup>a</sup> <sub>b</sub> ( $\pm$ 3.04)	17.86 <sup>ab</sup> <sub>b</sub> ( $\pm$ 1.66)	13.52 <sup>b</sup> <sub>b</sub> ( $\pm$ 0.64)	40.72 <sup>B</sup> ( $\pm$ 3.89)
T3 – 10% SLASH	8.34 <sup>a</sup> <sub>b</sub> ( $\pm$ 4.84)	17.42 <sup>ab</sup> <sub>b</sub> ( $\pm$ 5.12)	12.42 <sup>b</sup> <sub>b</sub> ( $\pm$ 1.44)	38.18 <sup>B</sup> ( $\pm$ 10.84)
T4 – 30% SLASH	10.62 <sup>a</sup> <sub>b</sub> ( $\pm$ 3.86)	12.92 <sup>ab</sup> <sub>b</sub> ( $\pm$ 6.73)	14.42 <sup>b</sup> <sub>b</sub> ( $\pm$ 1.83)	37.96 <sup>B</sup> ( $\pm$ 11.79)

\*ab Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*ab Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*AB Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

Substantial differences in production are illustrated in Table 1, although the SLASH treatments did not differ significantly. This significant increase in production can be attributed to two reasons. Firstly, the organic material supplied by the sewage sludge in the mixture enhances plant growth. Secondly, Gutenmann et al., (1981) found that the ash encourages microbial populations. Legumes such as yellow sweet clover (*Melilotus officinalis*) and white sweet clover (*Melilotus alba*) which usually require inoculation with Rhizobia before planting, were found growing voluntarily and abundantly in several fly ash landfills in New York (Gutenmann et al., 1981; Adriano et al., 1980).

It is evident from Fig.2 that the overall production of white sweet clover on the SLASH treated soils was significantly better than the control. This photo highlights and represents the trend, which was notable in all the harvests.



**Fig 2. Sweet clover (*Melilotus alba*) response to SLASH treated soils relative to the control.**

Sweet clover's root development was also notably enhanced by the SLASH treatments (Figures 3 and 4). This is critical if maximum forage production is desired. Although there were no significant differences between the various

SLASH treatments, SLASH treatments gave up to four hundred and forty four percent more root mass.

Fig.3 illustrates how SLASH at all levels contributed to a significantly larger root mass. This well developed root structure is beneficial in many ways, but specifically ensures that a good yield is obtained if all other factors are in place.

Therefore, this Fig. 3 supports the high yields shown in Table 1.

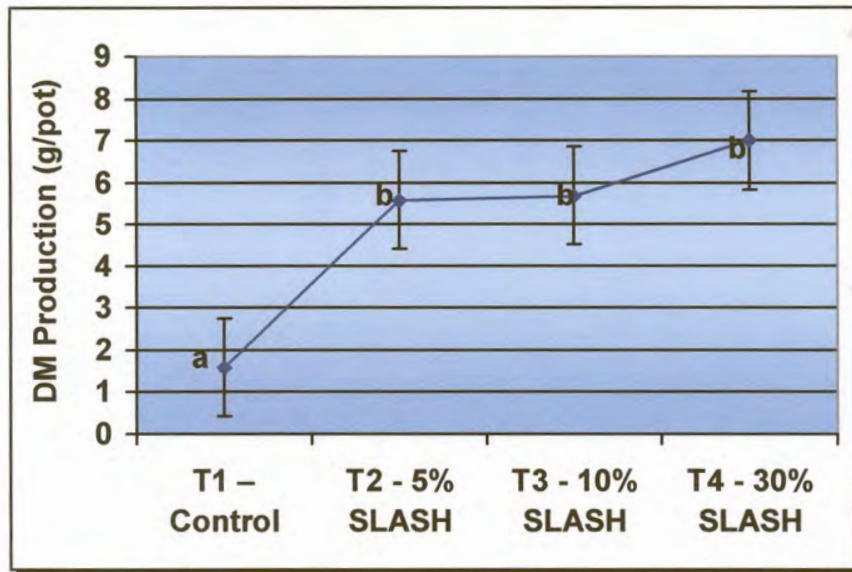


Fig. 3. Root development (g/pot) of sweet clover (*Melilotus alba*) as influenced by SLASH.

# Means with the same letter are not significantly different at  $P > 0.05$ . (Tukey's Studentized Range Test)

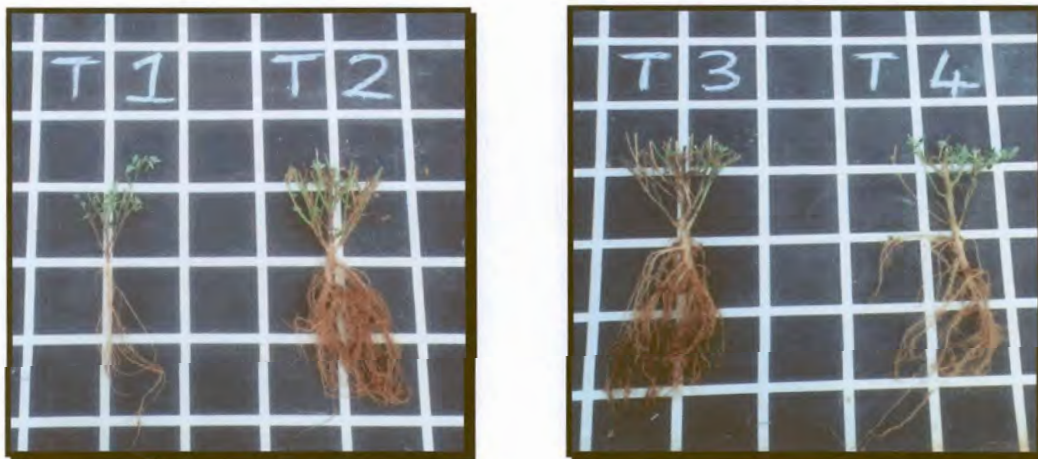


Fig. 4. Sweet clover (*Melilotus alba*) root development on SLASH treated soils.



### 3.2 Kentucky Bluegrass (*Poa pratensis*)

In what was essentially a trial identical to the sweet clover trial, it was confirmed that SLASH treatments had the same continued positive effects on a grass species.

Density, forage production and root development of Kentucky bluegrass (*Poa pratensis*), as influenced by the level of SLASH application, eight months prior to planting of the Kentucky bluegrass and after two preceding cropping cycles with flowers and vegetables, is shown in Table 2 and Figures 5 and 6.

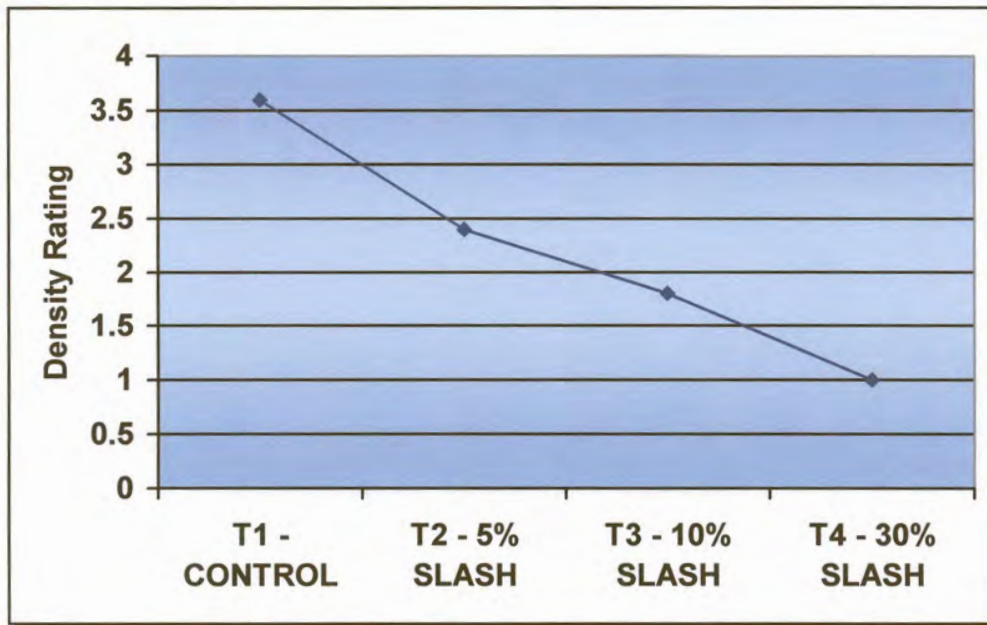


Fig. 5. The influence of SLASH on the density rating of Kentucky bluegrass (*Poa pratensis*).

# Not statistically analysed.

Although SLASH had a depressing effect on the survival of Kentucky bluegrass seedlings, as reflected in the ratings of density, it had a dramatic influence on forage yields with the best SLASH treatments (30%) producing seven hundred and fifty percent more forage than the control (0% SLASH) as shown in Table 2.

Seedlings recovered from the initial setback and forage production for the two lower levels of SLASH immediately improved. The 30% SLASH treatment, where

retarded seedling establishment was most significant, recovered more gradually and yield was only improved in the subsequent harvests. The conditions created by the high SLASH ameliorated soil were not optimum for Kentucky bluegrass although the 30 percent SLASH treatment did deliver the best yields overall.

**Table 2**

The mean dry matter (DM) production (g/pot) and ( $\pm$ MSE) of Kentucky bluegrass (*Poa pratensis*) as influenced by SLASH.

Treatments	1 <sup>st</sup> Harvest Dry Mass 02/12/1999 (g/pot)	2 <sup>nd</sup> Harvest Dry Mass 07/01/2000 (g/pot)	3 <sup>rd</sup> Harvest Dry mass 10/03/2000 (g/pot)	4 <sup>th</sup> Harvest Dry mass 17/04/2000 (g/pot)	Total DM Production (g/pot)
<b>T1 –</b>					
<b>Control</b>	0.10 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.02)	0.42 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.23)	0.88 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.43)	1.08 <sup>a</sup> <sub>a</sub> ( $\pm$ 0.45)	2.47 <sup>A</sup> ( $\pm$ 1.02)
<b>T2 – 5%</b>					
<b>SLASH</b>	2.44 <sup>a</sup> <sub>b</sub> ( $\pm$ 2.21)	2.82 <sup>a</sup> <sub>b</sub> ( $\pm$ 2.05)	2.92 <sup>a</sup> <sub>b</sub> ( $\pm$ 1.61)	2.56 <sup>a</sup> <sub>b</sub> ( $\pm$ 0.71)	10.74 <sup>B</sup> ( $\pm$ 6.19)
<b>T3 – 10%</b>					
<b>SLASH</b>	1.13 <sup>a</sup> <sub>ab</sub> ( $\pm$ 0.67)	2.39 <sup>ab</sup> <sub>b</sub> ( $\pm$ 0.89)	3.34 <sup>b</sup> <sub>b</sub> ( $\pm$ 0.80)	2.98 <sup>b</sup> <sub>bc</sub> ( $\pm$ 0.82)	9.84 <sup>B</sup> ( $\pm$ 2.46)
<b>T4 – 30%</b>					
<b>SLASH</b>	0.68 <sup>a</sup> <sub>ab</sub> ( $\pm$ 0.47)	3.72 <sup>b</sup> <sub>b</sub> ( $\pm$ 0.70)	6.60 <sup>c</sup> <sub>c</sub> ( $\pm$ 0.88)	4.26 <sup>d</sup> <sub>c</sub> ( $\pm$ 0.54)	15.26 <sup>B</sup> ( $\pm$ 2.46)

\***abcd** Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\***abcd** Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\***ABC** Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

An even more marked response was noted, with respect to root development. Increases of up to two thousand one hundred percent were obtained relative to the control. This dramatic improvement in root development holds important implications for the erosion control capacity of the species (because of the binding or re-inforcing properties of such root systems) as well as improving the plant's ability to survive stress situations.

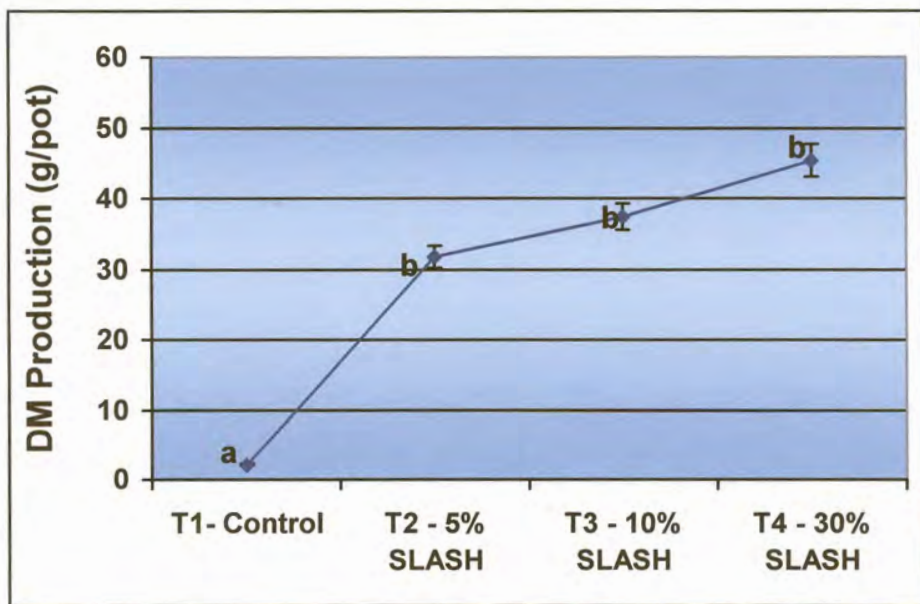


Fig. 6. Root development (g/pot) of Kentucky bluegrass (*Poa pratensis*) as influenced by different levels of SLASH. # Means with a common character are not significantly different at  $P > 0.05$  (Tukey's Studentized Range Test).

### 3.3 Tall Fescue (*Festuca arundinaceae*)

Forage production was the key parameter in the continuation of this trial following the evaluation of Kentucky bluegrass. The influence of SLASH application nineteen months prior to the planting of tall fescue in July 2000, was measured in terms of growth response. Table 3 shows the eight harvests taken, and it is noticeable that the same trends were evident in each harvest. Tall fescue performed well on all SLASH levels relative to the control.

Tall fescue is a perennial forage specie. It can be seen from the results, that the 1<sup>st</sup>, 5<sup>th</sup> and 6<sup>th</sup> harvests, SLASH treatments gave up to 290 % better yields, although they were in the winter season when growth is generally slower. In the winter growing season, longer intervals were taken between harvests and surprisingly more dry matter was produced.

**Table 3: The mean dry matter production (g/pot) of tall fescue (*Festuca arundinaceae*) in response to various SLASH treatments.**

Treatments	1 <sup>st</sup> Harvest Dry Mass (g/pot)	2 <sup>nd</sup> Harvest Dry Mass (g/pot)	3 <sup>rd</sup> Harvest Dry mass (g/pot)	4 <sup>th</sup> Harvest Dry mass (g/pot)	5 <sup>th</sup> Harvest Dry mass (g/pot)	6 <sup>th</sup> Harvest Dry mass (g/pot)	7 <sup>th</sup> Harvest Dry mass (g/pot)	8 <sup>th</sup> Harvest Dry mass (g/pot)	Total Dry Matter Production (g/pot)
T1 - Control	2.98 <sup>a</sup>	1.84 <sup>a</sup>	1.72 <sup>a</sup>	2.32 <sup>a</sup>	2.80 <sup>a</sup>	5.03 <sup>b</sup>	1.84 <sup>c</sup>	14.43 <sup>d</sup>	20.33 <sup>A</sup>
T2 - 5% SLASH	5.61 <sup>a</sup>	3.05 <sup>a</sup>	2.61 <sup>bc</sup>	3.68 <sup>d</sup>	3.83 <sup>e</sup>	5.47 <sup>ab</sup>	2.64 <sup>ef</sup>	15.03 <sup>g</sup>	29.64 <sup>B</sup>
T3 - 10% SLASH	6.33 <sup>a</sup>	3.46 <sup>b</sup>	3.26 <sup>bc</sup>	4.61 <sup>bd</sup>	5.13 <sup>a</sup>	6.62 <sup>ab</sup>	2.90 <sup>e</sup>	15.80 <sup>l</sup>	35.14 <sup>B</sup>
T4 - 30% SLASH	8.69 <sup>a</sup>	4.98 <sup>b</sup>	4.70 <sup>bc</sup>	6.57 <sup>d</sup>	6.18 <sup>b<sup>cd</sup>e</sup>	7.97 <sup>ad</sup>	3.38 <sup>f</sup>	17.44 <sup>g</sup>	45.85 <sup>C</sup>

\*abcdefg Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*abc Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*ABC Column means with common alphabetical supercripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

# No MSE for large data set.

The total DM production (Table 3) for tall fescue over the entire experimental period indicates that all SLASH treatments gave much higher yields than the control. These results emphasize that SLASH definitely has a long-term residual effect.

### 3.4 Crown Vetch (*Coronilla varia* cv. *Penngift*)

Crown Vetch showed a marked response to the SLASH treatments. From Tables 4 and 5 it can be seen that the various treatments performed substantially better than the control in both summer and winter growing seasons. The markedly better response of this legume, compared with tall fescue, may be attributed to the fact that like lucerne it is very sensitive to pH, Ca and P levels, all of which were markedly improved by SLASH.

Fig. 7 clearly illustrates the abundant growth of Crown Vetch on the soils treated with SLASH (T2-T4) relative to the control (T1). Visually there seems to be no difference between the SLASH treatments, although differences are reflected in the yield results.



**Figure 7: Crown Vetch (*Coronilla varia*) growth on SLASH treated soils relative to the control.**

The 1<sup>st</sup> and 7<sup>th</sup> harvest (Table 4), which represents the first harvest of the winter growing season, gave much higher yields. This is because a large amount of this growth took place in the transition phase between autumn and winter when growing conditions were still suitable. Nevertheless, the SLASH treatments also gave significant higher yields than the control in the harsh conditions of winter.

There were no significant differences between SLASH treatments. Surprisingly enough, there seemed to be a sluggish response to the 10% treatment, but this may be attributed to a poor initial establishment of crown vetch plants. The results, from both Table 4 and Table 5, highlight the long-term residual effects of SLASH. It can be noted that even 36 months after the initial SLASH application, high DM production was still maintained.

Table 4

The mean dry matter production (g/pot) of crown Vetch (*Coronilla varia*), in two consecutive winter growing seasons as influenced by SLASH.

Treatments	Winter Growing Season 2000			Winter Growing Season 2001		
	1 <sup>st</sup>	2 <sup>nd</sup>	Total DM Production	7 <sup>th</sup>	8 <sup>th</sup>	Total DM Production
	Harvest Dry Mass	Harvest Dry Mass		Harvest Dry mass	Harvest Dry mass	
	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)
T1 - Control	3.29 <sup>a</sup> <sub>a</sub>	2.59 <sup>a</sup> <sub>a</sub>	5.88 <sup>A</sup>	1.36 <sup>a</sup> <sub>a</sub>	1.15 <sup>a</sup> <sub>a</sub>	2.51 <sup>A</sup>
T2 - 5% SLASH	21.76 <sup>a</sup> <sub>b</sub>	11.50 <sup>b</sup> <sub>a</sub>	33.63 <sup>B</sup>	26.09 <sup>a</sup> <sub>b</sub>	4.07 <sup>b</sup> <sub>a</sub>	31.21 <sup>B</sup>
T3 - 10% SLASH	19.67 <sup>a</sup> <sub>b</sub>	9.25 <sup>b</sup> <sub>b</sub>	28.33 <sup>B</sup>	16.52 <sup>a</sup> <sub>c</sub>	5.45 <sup>b</sup> <sub>a</sub>	20.92 <sup>B</sup>
T4 - 30% SLASH	24.08 <sup>a</sup> <sub>b</sub>	10.27 <sup>b</sup> <sub>b</sub>	34.35 <sup>B</sup>	16.51 <sup>a</sup> <sub>c</sub>	9.24 <sup>b</sup> <sub>a</sub>	25.75 <sup>B</sup>

\*ab Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*abc Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*AB Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

# No MSE for large data set.

Table 5

The mean dry matter production (g/pot) of Crown vetch (*Coronilla varia*), in two consecutive summer growing seasons, as influenced by SLASH.

Treatments	Summer Growing Season 2000/2001				Summer Growing Season 2001/2002			
	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	Total Dry Matter Production	9 <sup>th</sup>	10 <sup>th</sup>	Total Dry Matter Production
	Harvest Dry mass	Harvest Dry mass	Harvest Dry mass	Harvest Dry mass		Harvest Dry mass	Harvest Dry mass	
	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)	(g/pot)
T1 - Control	3.51 <sup>a</sup> <sub>a</sub>	5.96 <sup>a</sup> <sub>a</sub>	8.01 <sup>a</sup> <sub>a</sub>	5.87 <sup>a</sup> <sub>a</sub>	26.35 <sup>A</sup>	23.15 <sup>a</sup> <sub>a</sub>	12.48 <sup>a</sup> <sub>a</sub>	35.63 <sup>A</sup>
T2 - 5% SLASH	12.77 <sup>a</sup> <sub>b</sub>	19.18 <sup>a</sup> <sub>b</sub>	22.50 <sup>a</sup> <sub>b</sub>	24.12 <sup>a</sup> <sub>b</sub>	79.56 <sup>B</sup>	45.54 <sup>a</sup> <sub>b</sub>	24.98 <sup>b</sup> <sub>b</sub>	70.15 <sup>B</sup>
T3 - 10% SLASH	9.03 <sup>a</sup> <sub>ab</sub>	13.73 <sup>a</sup> <sub>b</sub>	19.16 <sup>a</sup> <sub>b</sub>	22.87 <sup>b</sup> <sub>b</sub>	63.80 <sup>B</sup>	46.26 <sup>a</sup> <sub>b</sub>	21.67 <sup>b</sup> <sub>b</sub>	68.29 <sup>B</sup>
T4 - 30% SLASH	12.29 <sup>a</sup> <sub>a</sub>	18.52 <sup>a</sup> <sub>b</sub>	24.81 <sup>b</sup> <sub>b</sub>	27.66 <sup>c</sup> <sub>b</sub>	83.28 <sup>B</sup>	43.01 <sup>a</sup> <sub>b</sub>	21.21 <sup>b</sup> <sub>b</sub>	64.22 <sup>B</sup>

\*ab Row means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*ab Column means with common alphabetical subscripts do not differ significantly ( $P > 0.05$ ) (Bonferroni Test)

\*AB Column means with common alphabetical superscripts do not differ significantly ( $P > 0.05$ ) (Tukey's Test)

# No MSE for large data set.

#### 4. Conclusion

It is currently of cardinal importance to start considering the efficient utilization of waste products. The pre-eminent environmental issue of waste disposal problems is becoming more serious by the day. Alternative uses of waste products, such as fly ash and sewage sludge, have definite agricultural potential. These waste product mixtures like SLASH, N-Viro soil and other mixtures, based on the same principles of production, are excellent additives and amendments for acidic and nutrient poor soils.

It is very clear from the SLASH programme, that it is of cardinal importance to examine a wide range of species, or even cultivars, under different levels of intensification (different fertility levels, different water levels, different populations) and on different substrates, to be able to extrapolate conclusions.

Crop production responses of all the different plant species throughout the trial period, gave consistently good results. Once again the 5% and 10% SLASH treatments proved to be superior, resulting in prolonged growth enhancement. The two grasses used in this study gave significantly better results on SLASH treatments than on the control. This can be attributed to the essential macronutrients, which are “slowly released” by the organics from the sewage sludge. In addition to the macronutrient supply, the equilibrium of nutrient supply was maintained by the micronutrients, which were supplied by the fly ash in the combination.

The two legumes used in this study, had virtually the same response to SLASH. It is important to establish a legume with Rhizobia to ensure a symbiosis, which will benefit the growth of the plant. From this work it can be concluded that fly ash on it's own, as found by Gutenmann et al., (1981), and in combination with an organic waste encourages microbial populations. Root development was also enhanced by of SLASH, with well-developed root structures resulting. This is very important to ensure good yields and to stabilize soils.

From the results obtained during this study, it can be concluded that SLASH has long-term residual effects. The rate of nutrient release is not predictable, but

it can be stated that such a mixture is characterized by "slow release" of nutrients.

The rationale behind such waste mixtures is that the mixture itself is a superior soil amendment to either component alone. The use of an organic waste addresses the deficiency of macronutrients in fly ash, while fly ash can act as a bulking agent for the organic wastes, substantially reducing odor, and offsetting soil acidity problems that may arise through continued land application of organic wastes.

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