Re-Vegetating Mine Land that Has Been Ameliorated with Alternative Soil Ameliorants

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ABSTRACT

One of the major limiting factors for re-vegetating soils disturbed by surface coal mining in South Africa is their potentially acidic and nutrient deficient nature. Liming and fertilizing these soils are accepted as common practice, but recently it has become crucial to investigate the use of other soil ameliorants that can possibly provide a more sustainable system. The use of alternative materials, such as class F fly ash, which have similar properties to agricultural lime, have been researched for approximately 7 years under South African conditions. The addition of an organic material as a treatment together with fly ash, will provide a opportunity to improve the fertility status of these degraded soils over a period of time. Fieldwork initiated in January 2000 on a surface mine in the Mpumalanga province, has provided a number of significant results. The mixture of grass used in the re-vegetation process includes Teff (*Eragrostis tef)*, Rhodegrass (*Chloris gayana*), Bermuda grass (*Cynodon dactylon)*, Smutsfinger grass (*Digitaria erianthra),* and a legume such as Alfalfa (M*edicago sativa).* Soil analyses (P, K, Mg, Ca, $pH_{(H20)}$) were conducted annually, whereas botanical composition, basal cover measurements and dry matter production data was collected seasonally. These results clearly illustrate that the abundance and presence of certain species can be related to the higher fertility levels of the rehabilitated soil. Data collected over the past four years, illustrates how the botanical composition has changed and that soils receiving class F fly ash and sewage sludge had a higher dry matter production, whereas the control (no treatment) had a better biodiversity. Results obtained, support the conclusion that soils receiving fly ash and sewage sludge improve the chemical properties of the displaced topsoil. Therefore, this research illustrates that potential alternative ameliorants, such as class F fly ash and various organic materials, can provide a more sustainable way to solve one environmental problem with another.

INTRODUCTION

The re-vegetation of mine land presents a particular challenge. Cover soils are often acidic and nutrient deficient, which are major limiting factors in re-vegetation programs. It is current practice to amend such soils using lime and inorganic fertilizer. Research over the past few years into the use of a coal combustion by-product, class F fly ash, and an organic material such as sewage sludge, has demonstrated the feasibility of using such materials to amend acidic and infertile substrates [9,7,10.] The objective of this research was to determine if alternative amendments could create a more sustainable system where botanical composition, basal cover, and soil chemical properties are improved. Coal mining impacts large areas in the grasslands of the Mpumalanga Province of South Africa. To mitigate such impacts, it is imperative to restore the once productive soils to the best possible condition.

There have been many investigations, which have studied re-vegetation and soil conditions on restored opencast agricultural land. For successful re-vegetation it is important to ensure a stable, soil environment with respect to physical conditions[12,3], nutrient levels [2,3] and biological soil conditions [1,3].

Coal combustion by-products (CCB's) have been widely used as cost effective amendments for acid soils. It holds true that ashes have several advantages, and their application is recommended[4]. The work conducted at the University of Pretoria has been successful in improving soil acidity and fertility [5,6,8,11.]

METHODOLOGY

A replicated field trial, with an untreated control and nine soil amendments of cover soil (consisting of a mixture of A and B horizons), with an average depth of 60 cm, was conducted at an opencast coal mine at Kromdraai Colliery, Mpumalanga Province, situated at 29°06' N 25°75' E, 1500m above sea level, and receiving a summer rainfall of 600-700 mm and the area experiences dry frosty winters. The treatments involve three levels of fly ash **(FA)**, sewage sludge/ fly ash mixture **(S)** and dolomitic lime **(L)**. The calculated optimum was 50 tons ha^{-1}, 166 tons ha^{-1} and 10 tons ha^{-1} respectively. The other two levels of treatment were 33% above the optimum and 33% below the optimum. The untreated control **(C)** and a standard mine treatment **(SMT)** were included to serve as yardsticks. The quantities of fertilizer and lime used in the standard mine treatment in the establishment year were, 65 kg N ha^{-1}, 203 kg P ha^{-1}, 134 kg K ha^{-1} and four tons of dolomitic lime per hectare, and in the following years a 100 kg N ha-1 was applied.

The dry matter production was measured in each season by harvesting the material and drying it at 65 °C for 48 hours. The basal cover measurement was determined by using the point bridge method. Soil chemical analyses, pH(H_2O), P (Bray 1) and K, Ca, and Mg (Ammonium acetate extraction) were conducted 12, 24, 36 and 48 months, although only data for 12 and 48 months is presented. Soils were re-vegetated with a mixture of Teff (*Eragrostis tef)*, Rhodesgrass (*Chloris gayana),* Bermuda grass (*Cynodon dactylon)*, Smutsfinger grass (*Digitaria eriantha)* and alfalfa (*Medicago sativa).*

Botanical composition, basal cover and dry matter production were also monitored seasonally.

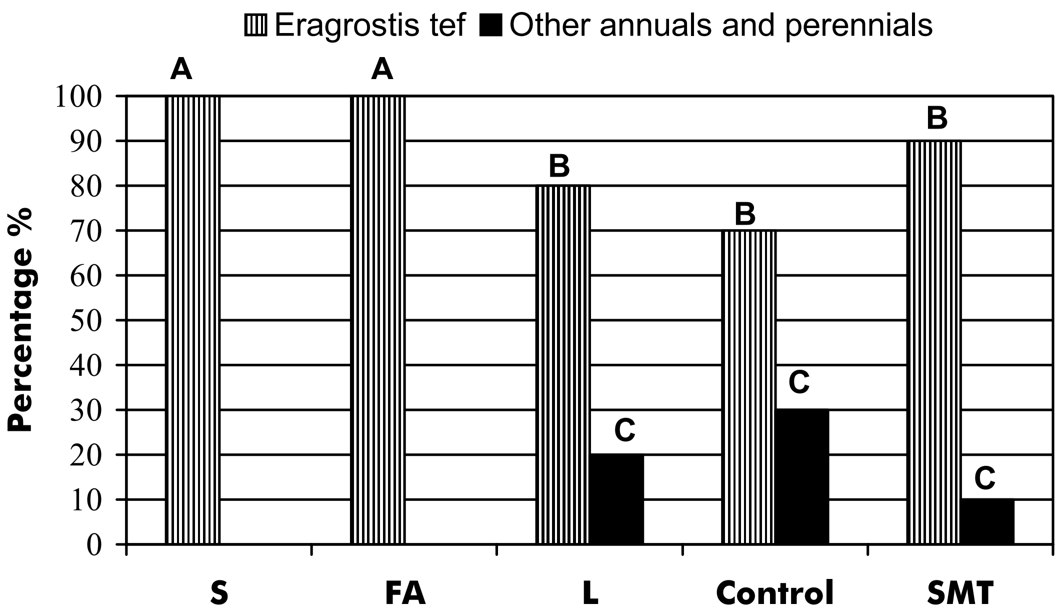
RESULTS AND DISCUSSION

Vegetation analysis

Botanical composition, basal cover and dry matter production were assessed each year with the results for 1999/2000, 2001/2002 and 2003/2004 being presented in this paper.

Botanical composition

Figure 1 clearly indicates that the dominant species in the first growing season was *Eragrostis tef.* This species is an annual and is generally the first to germinate in the mixture of grasses planted. This species, once germinated, creates a microclimate, which is beneficial to the establishment of the perennial grass species in the mixture.



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

Figure1: The influence of treatments on the botanical composition of the re-vegetated mine land in the 1999/2000 growing season.

Two and four years later, however, the perennial species were more prominent, as can be seen in Figure 2 and Figure 3.

It is evident from the observations made four years after establishment (Figure 3), that soils receiving a mixture of fly ash and sewage sludge (S) had a higher percentage of Rhodesgrass, and a higher production (Figure 7,8,9) whereas the control (no treatment) had a greater biodiversity.

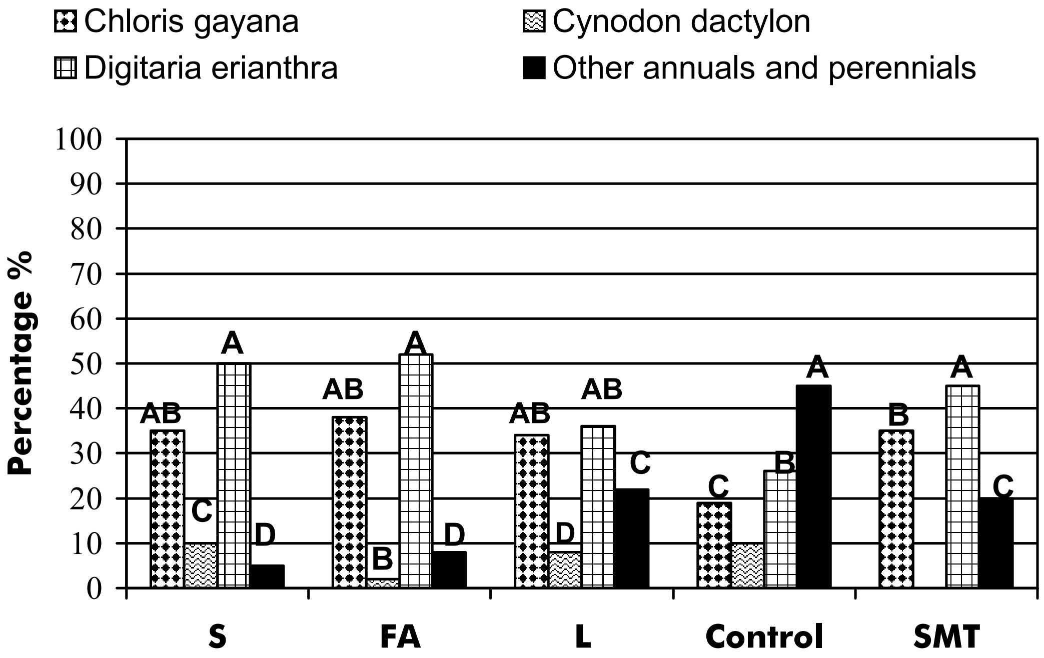


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Figure 2: The influence of treatments on the botanical composition of the re-vegetated mine land in the 2001/2002 growing season.

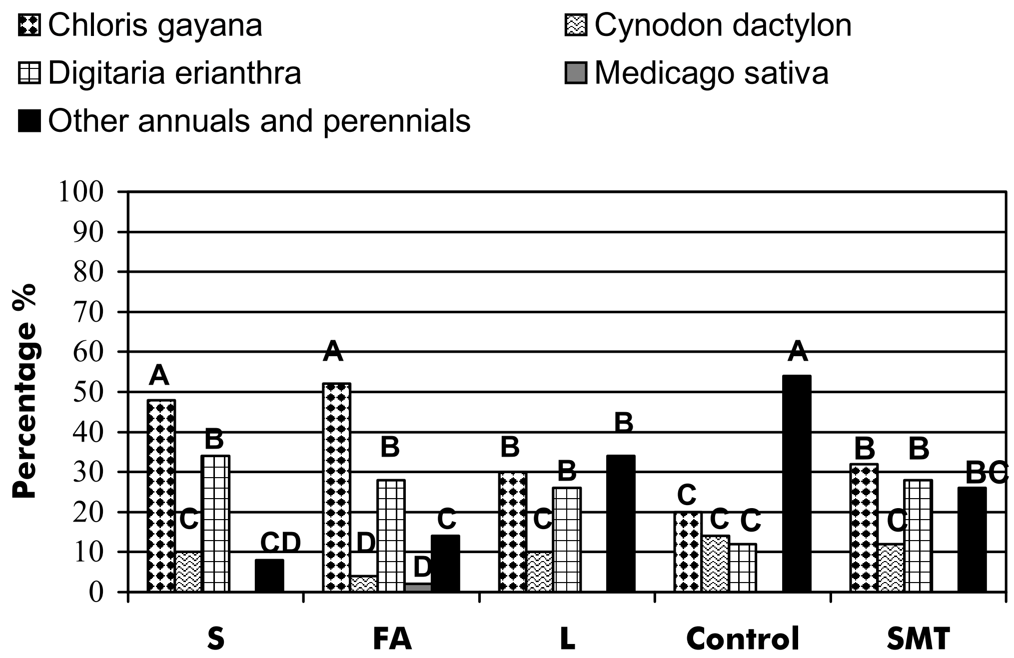

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Figure 3: The influence of treatments on the botanical composition of the re-vegetated mine land in the 1999/2000 growing season.

Basal cover

The percentage basal cover in the 1999/2000 growing season is presented in Figure 4. It is clear, that the there is a significant difference between the fly ash containing treatments and the other treatments. In this growing season the vegetation was dominated by the annual species (*Eragrostis tef*) and it favoured the fly ash treatments.

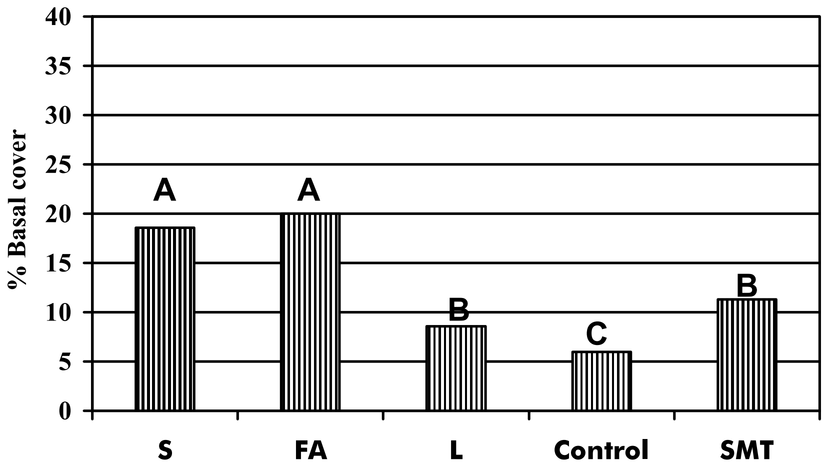

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Figure 4: The effect of different treatments on the basal cover of re-vegetated mine land in the 1999/2000 growing season.

Two years later, in the 2001/2002 season (Figure 5) it is evident that the basal cover had decreased slightly.This is the result of a more stable vegetation consisting mainly of perennial species which are more tufted and spaced apart than the denser stand of *Eragrostis tef* in 1999/2000.

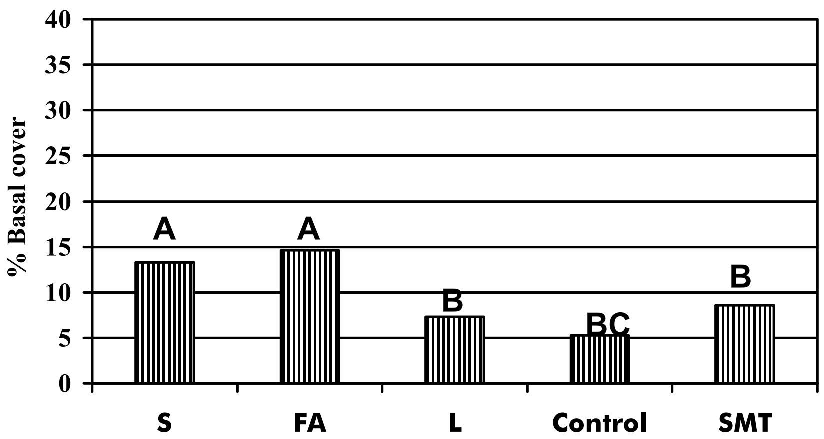

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Figure 5: The effect of different treatments on the basal cover of re-vegetated mine land in the 2001/2002 growing season.

Nevertheless, the fly ash treatments (S and FA) were still significantly better than the other treatments. In the fourth year (2003/2004) (Figure 6) the basal cover of all treatments had improved, with the fly ash treatments having an extremely good cover in comparison with the control, lime and standard mine treatments. These results indicate that the fly ash treatments improve the growth and cover of the vegetation on local rangeland.

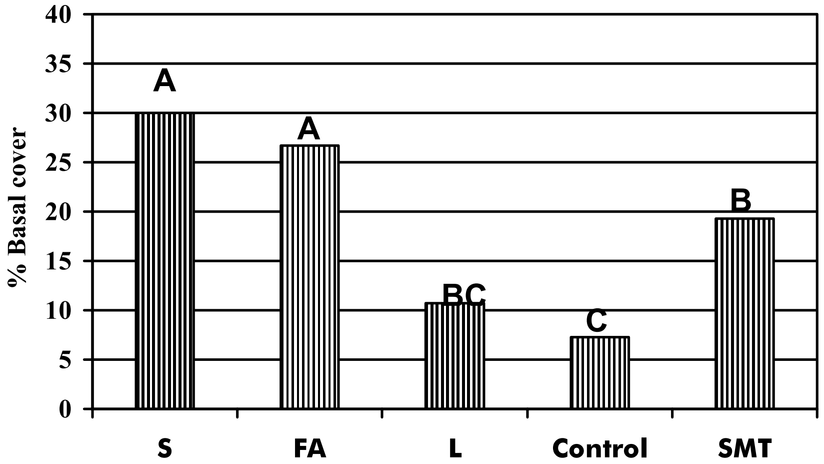

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Figure 6: The effect of different treatments on the basal cover of re-vegetated mine land in the 2003/2004 growing season.

Dry matter Production

Significant differences were evident in the 1999/2000, 2001/2002 and 2003/2004 growing seasons noticed from 1999 to 2004. The trend clearly indicated that both fly ash treatments (S and FA) contributed significantly to the dry matter production of the vegetation (Figure 7, 8 and 9).

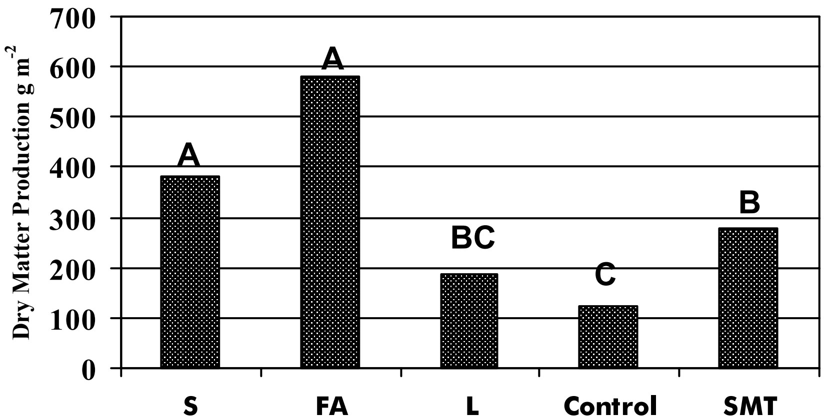

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Figure 7: The dry matter production on re-vegetated soils treated with different soil ameliorants in the 1999 / 2000 growing season.

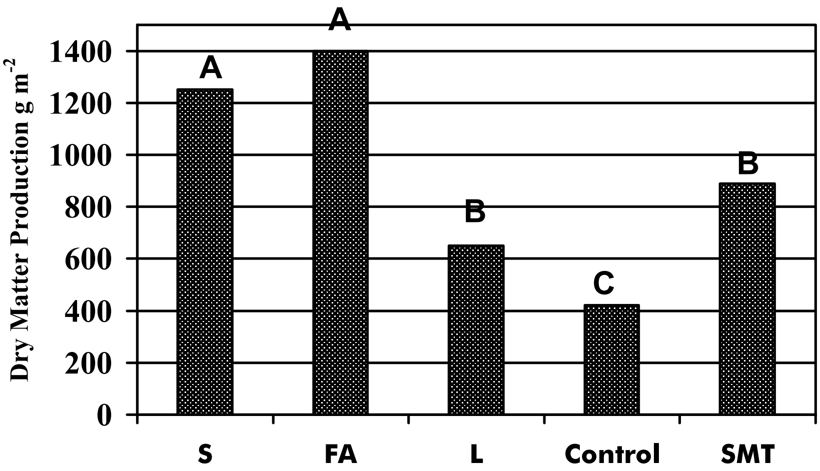

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Figure 8: The dry matter production on re-vegetated soils treated with different soil ameliorants in the 2001/2002 growing season.

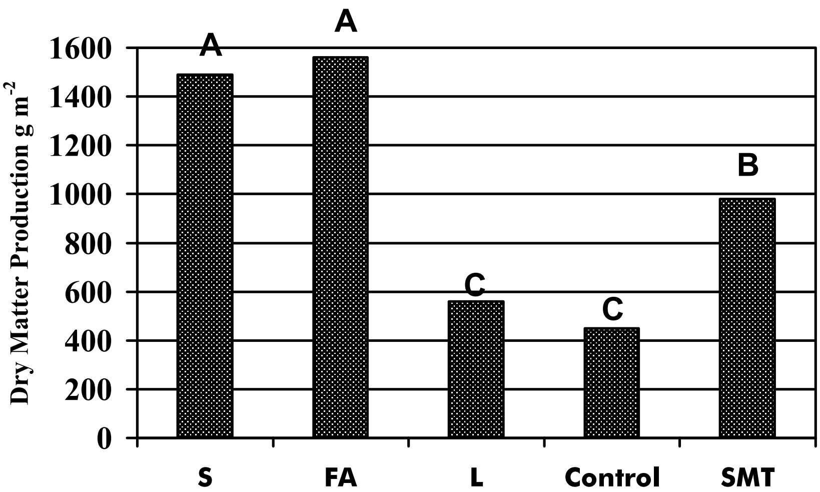

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Figure 9: The dry matter production on re-vegetated soils treated with different soil ameliorants in the 2003/2004 growing season.

Whereas the fly ash treatments had significantly higher DM yields, the lower fertility treatments, such as the lime and the control, had a better variety of species (Figure 2 and 3).

Soil Analysis

With respect to macronutrients the fly ash and sludge/fly ash mixtures increased the P content (Fig. 10) at both 12 and 48 months, relative to the control. The standard mine treatment, however, had the highest K content, because of regular inorganic fertilization. The K content (Figure 11) was markedly improved by the addition of fly ash and sludge/fly ash treatments. This can possibly be ascribed to the competition of Si in fly ash with the P on soil particles, thus, making P more available.

The high Mg levels on lime treatments (Figure 13) are a function of dolomitic lime applied. Nevertheless, the Ca (Figure 12) and Mg (Figure 13) levels of the other treatments relative to the control and standard mine treatment were also significantly better. The pH of the soils (Figure 14) was strongly affected by fly ash and sludge/fly ash mixtures. An improvement of up to 2 pH units was evident 18 months and 48 months after treatment.

Figure 12 and 13 show the significant effect of both the sludge/ fly ash mixture and dolomitic lime on Ca and Mg. The increase Ca levels in Figure 12 is probably a result of CaO included in the mixture for effective pasteurization of sludge.

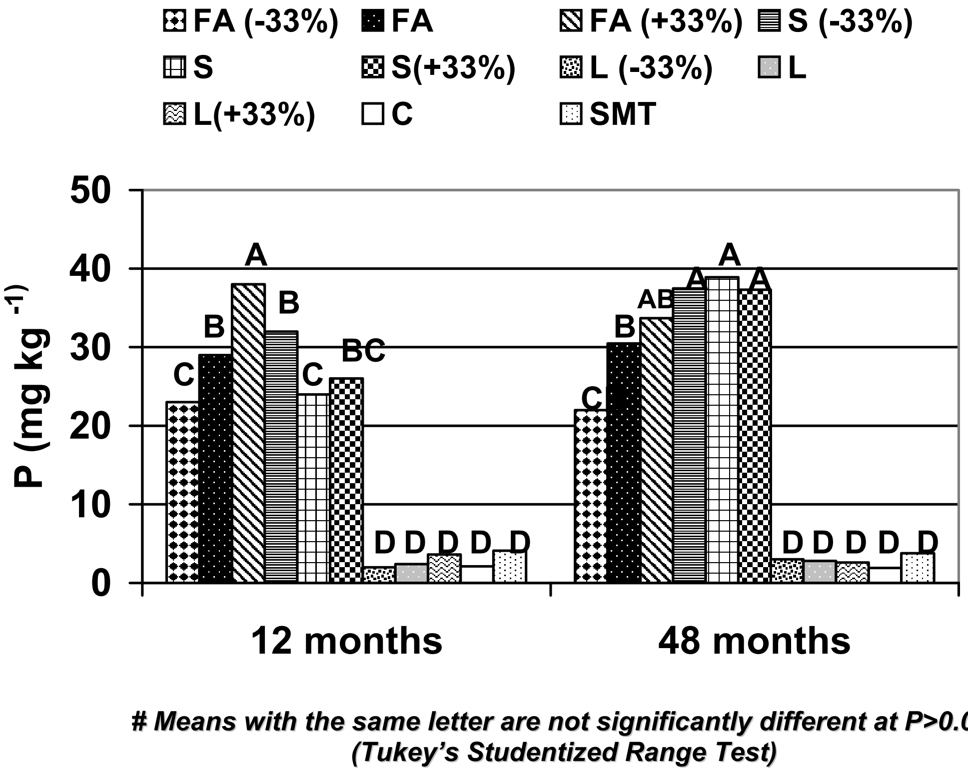

Figure 10: The influence of treatments on the soil P levels at 12 months and 48 months

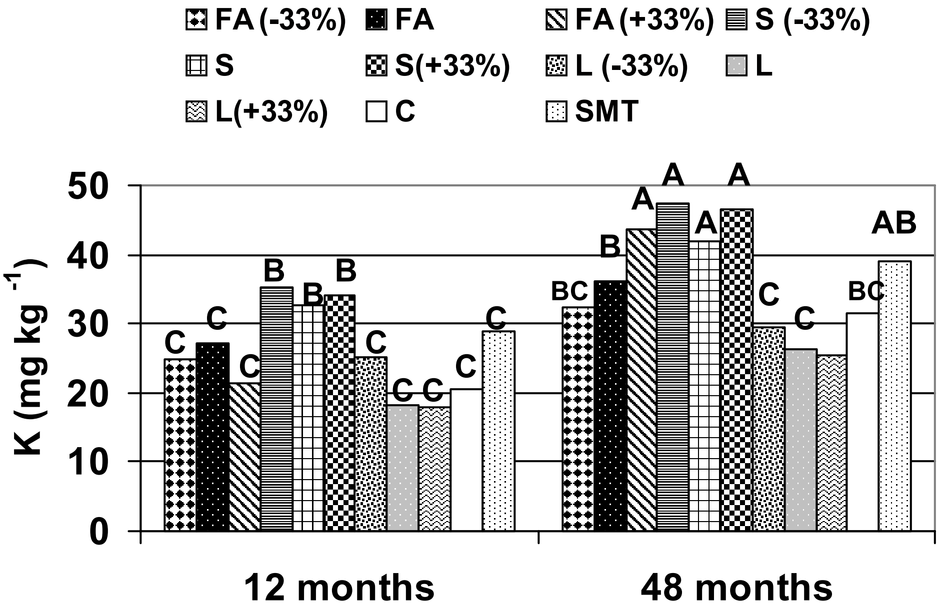

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Figure 11: The influence of treatments on the soil K levels at 12 months and 48 months

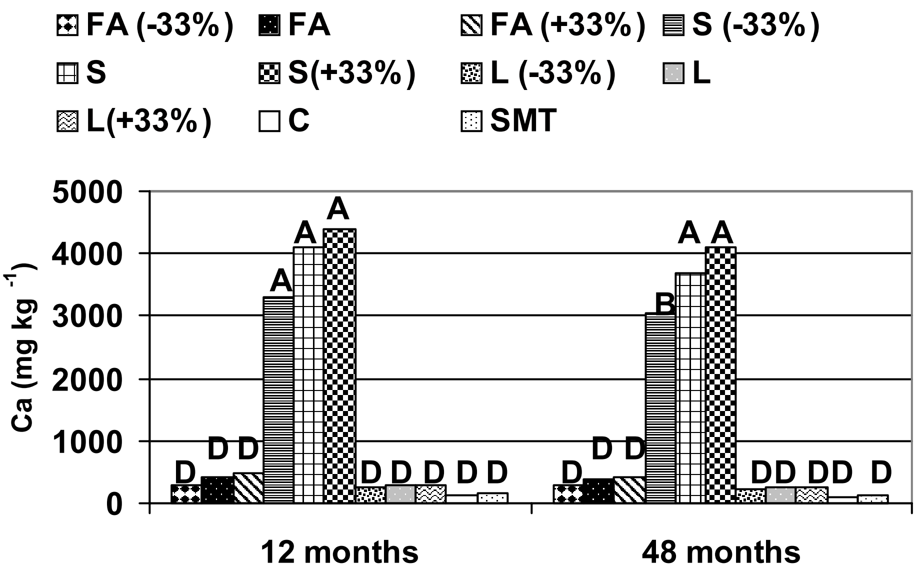

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Figure 12: The influence of treatments on the soil Ca levels at 12 months and 48 months

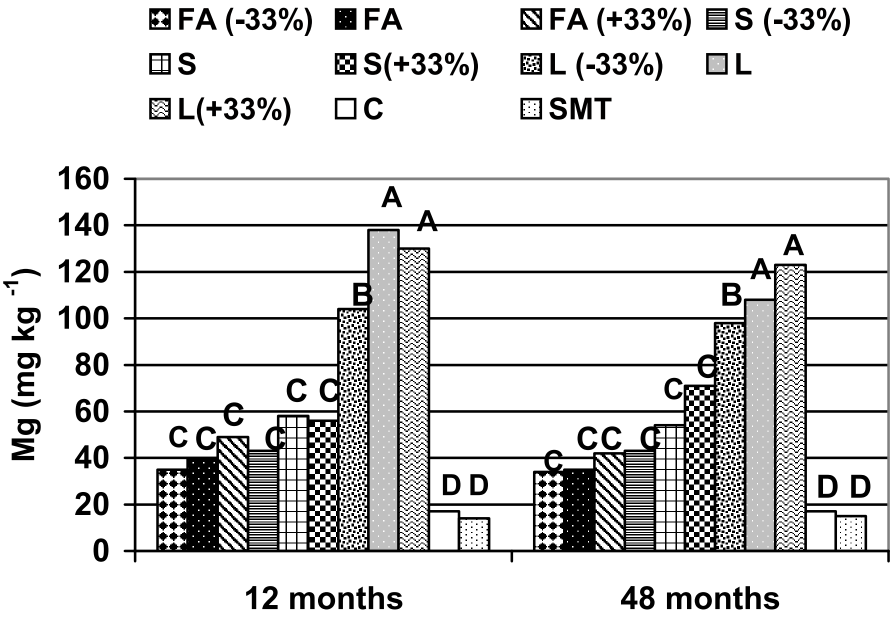

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Figure 13: The influence of treatments on the soil Mg levels at 12 months and 48 months

It is interesting to note that the pH of the treated soil increased slightly over time. This effect highlights the potential of fly ash to maintain pH as the glassy phase of the fly ash goes in to dissolution and releases its alkalinity continuously. There is a marked residual effect of fly ash and fly ash mixtures.

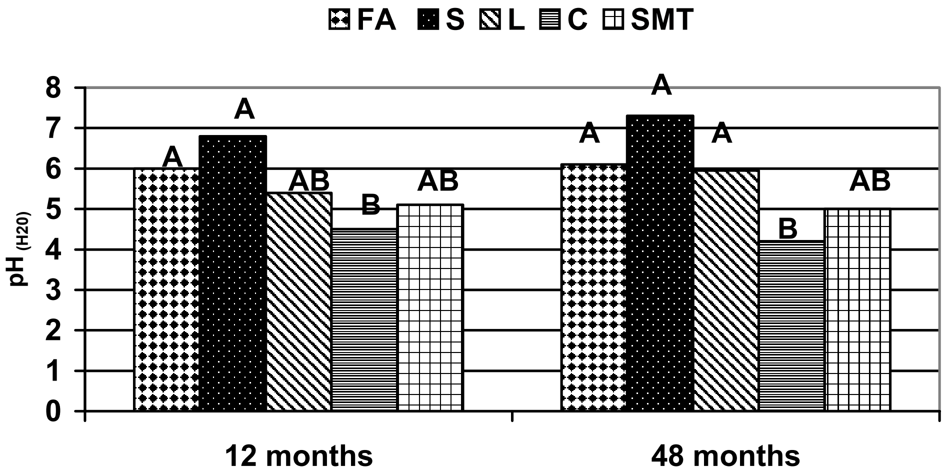

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Figure 14: The influence of treatments on the soil pH levels at 12 months and 48 months

CONCLUSIONS

Results indicate that alternative ameliorants (fly ash and organic wastes) can have a marked beneficial effect, which is still evident in the 4th year after establishment, despite no fertilizer having been applied since the 1st season. This would appear to indicate that such ameliorants produce more sustainable vegetation than current practice.

Excellent cover and yields are obtained when planted pastures on reclaimed soils are fertilized. The challenge, therefore, is to establish a sustainable system, when fertilization is either reduced or stopped. Industrial and urban by-products have unique properties and provide both micro and macro nutrients slowly over time, to sustain biodiversity, and to effectively reclaim degraded soils. On the basis of these preliminary results, investigations of using alternative materials as ameliorants to reclaim degraded mine soils are being expanded.

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