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Smuts Finger Grass (*Digitaria Eriantha* Cv Irene) Root Growth Assessment and Some Physicochemical Characteristics on Coal Mined Land Compacted Soil

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ABSTRACT: The coal mine soil layers contained high values of bulk density of 1.80gcm^{-3} and 1.90gcm^{-3} at depths of 0-20 and 20-40 cm respectively, low contents of organic matter, soil pH and soil nutrients concentration. A field trial was conducted to investigate root growth responses of Smuts Finger grass (*Digitaria eriantha* cv Irene) to compacted mine soil layers. It was revealed that the greatest root masses were noted in the upper horizons with progressively significantly less in the deeper horizons. Roots of this species penetrated compacted soil layers and decreased soil bulk density. The highest soil pH values were found in the upper layers with greatest root biomass. Soil nutrients (P, Mg, Ca, Na and K) status was also better in the upper layers. Smuts Finger grass could be used as an alternative method for rehabilitation of compacted mine soil layers.

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Returning mined land to productivity through reclamation activities requires more time than other stages of site construction and mining (Adiansyah *et al.*, 2015). Process of restoring surface environment to acceptable pre-existing condition includes various approaches such as surface contouring and re-vegetation. Technical approaches of reclamation activities often aim to manage a mined area for specific natural value or agricultural activities or other human uses. Where other human uses are planned, mined area is shaped in a manner that it would allow future infrastructure development (Edraki *et al.*, 2014). Reclamation activities to return mined areas to a more natural state focus on soil, wildlife, water and vegetation management values. Agricultural activities target livestock, grassland and forestry production (Kavamura & Esposito, 2010). Reclamation activities that may cause environment impacts include heavy vehicle traffic during filling in the mine, removal of infrastructure and land re-contouring (Pan *et al.*, 2014). In coal mined areas, soil compaction is very important problem. Compaction increased the bulk density and strength of soil. Coal mine soil layers contain high values of bulk density of 1.80gcm^{-3} and 1.90gcm^{-3} at depths of 0-20 and 20-40 cm respectively. Compaction resulted to reduced circulation of air and water in soil leading to poor plant growth. Compaction has reduced ground coverage and enhanced erosion. Impacts of soil erosion include soil nutrient loss and reduced water quality in nearby surface water bodies (Shahgholi *et al*., 2015). Soil compaction can be maintained or improved through various management strategies. Using self-sustaining plant cover which includes grass species that vary in rooting depth and type help to minimize soil compaction impacts (Kaliyan, *et al*., 2013). Grass species with good root systems help in several ways. Plant roots grow through and break compacted soil aggregates. Plant cover improves soil structure, water infiltration by creating root channels and penetration into soil (Wick *et al*., 2017). Both roots and vegetative cover increase organic matter and recycle soil nutrients, which improve compacted soil particles. Grass species promote biological diversity by improving aggregate stability through root entanglement around soil particles and root secretion, which act as glues to hold soil particles together (Stumpf *et al.*, 2016).

Morphological characteristics of Smuts Finger grass (*Digitaria eriantha* cv Irene) makes it suitable to grow on extreme soils and climatic conditions. It is well reported that being vegetative it is environmental friendly and very effective in slowing and spreading runoff water, reducing soil erosion and conserving soil moisture (Homma *et al*., 2012). Some previous studies on Smuts Finger grass have elaborated the root morphological characteristics. Deep and massive thick root system of Smuts Finger grass binds soil. The root properties can help improve aggregate stability of disturbed soil. This very deep growing root system

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enhances slope stability when properly planted on soil slopes (Chen *et al*., 2014). Deep root system makes Smuts Finger grass extremely drought tolerant (Lindh *et al*., 2014). The root penetration is mainly vertical and grows up to 2 m deep depending on the soil conditions (Alcantara *et al*., 2015). Based on these characteristics Smuts Finger grass is being used in a range of disturbed areas. This study was conducted to assess root growth of Smuts Finger grass on compacted soil and to see their potential for improved bulk density in order to have a better understanding of soil compaction tolerance. In addition, investigate pH (H_2O) and nutrients concentration in the compacted soil.

MATERIALS AND METHODS

Site description: The field trial was located on a surface coal mine planted to Smuts Finger grass (5 years old) in Mpumalanga Province in South Africa in between Latitude 26º28'S and Longitude 28º75'E. The average annual temperature was 30.4 °C and annual rainfall was 750 mm. This site is at a altitude of 1570 m above sea level. The area of the field trial was 20 ha. The soil comprised a mixture of sandy clay A and a silty loam B horizons. The main characteristics of this cover soil were 11.5% clay, 12.9% silt and 67.8% sand. The Smuts Finger grass (*D. eriantha* cv Irene) was established on rehabilitated dryland, which had been identified as compacted mine land. The bulk density of cover mine soil varied from 1.80gcm^{-3} to 1.90gcm^{-3} at depths of 0-20 and 20-40 cm respectively.

Experimental layout: The root biomass, bulk density, pH (H_2O) and soil nutrients concentration were collected from compacted soil depth. The treatments were composed of 0-10, 10-20, 20-30 and 30-40 cm on two sites Upland and Lowland. At each site, observations were replicated five times over a representative 0.5 ha. The total area of the field was 20 ha. The Upland site was identified as the area with a higher elevation and the Lowland site was the area with a lower elevation.

Root sampling and analysis: Root samples of Smuts Finger grass were collected in the first and second growing seasons (February to April and October to December). The soil coring method used to sample the roots was implemented by inserting a root augur having a diameter of 20 cm, to depths of 0-10, 10-20, 20-30 and 30-40 cm. The root mass at each depth was determined by dispersing the soil sample in water and subsequently retrieving the floating roots on a 250µm sieve. The root dry mass was measured using a Sartorius scale after samples had been dried in an oven at 65 ºC for 72 hours.

Bulk Density: Penetrometer cone was inserted into the soil at 0-10, 10-20, 20-30 and 30-40 cm depth. At each depth measurements were taken and used for calibration. The calibration data were fitted to wave software that was used to show calibration curve, which allows determination of density values.

Soil sampling and analysis: Soil samples were collected from the same location as the root samples. Soil samples at 0-20 and 20-40 cm were collected during each growing season to analyse for pH (H_2O) and nutrient concentrations (P, Ca, K, Mg and Na mgkg^{-1}) using an ammonium acetate extraction method.

Statistical analysis: Data were analysed statistically and the significant differences between different treatments were determined using SAS (SAS Inst., 2004). Least significant difference (LSD) mean separation test at $P \leq 0.05$ was used where significant differences occurred.

RESULTS AND DISCUSSION

Root biomass: The root biomass of Smuts Finger grass in four soil layers, at both Lowland and Upland sites in the first and second growing seasons is illustrated in Table 1. In the first season, the highest root biomass was in the 0-10 cm soil layer followed by the 10-20 cm soil layer, then the 20-30 and 30-40 cm soil layers. By the second season, the root biomass in all layers had increased markedly. The greatest root masses were noted in the 0-10 cm horizon with progressively significantly less in the deeper horizons. This might have been due to differences in rainfall between the two seasons. In a good rainfall season (second season) roots penetrated much deeper, while in a bad season (first season) the roots were restricted, being concentrated mainly in the topsoil. Plant species differ considerably in their ability to distribute their roots (Tow *et al.*, 1997).

Table 1: Smuts Finger grass root biomass at different sites over two growing seasons

Seasons	Soil depth cm	Upland	Lowland kgha^{-1}
1st Season	0-10	3534.04^{A}	3344.91^{A}
	10-20	1556.53^{B}	1565.49^{B}
	20-30	406.05^{C}	49.84^{C}
	30-40	243.83^{C}	46.82^{C}
	SE±	1.02	1.07
2nd Season	0-10	5464.77^{A}	7093.95^{A}
	10-20	4064.49^{B}	4923.37^{B}
	20-30	3913.22^{B}	3854.5^{BC}
	30-40	3604.70^{B}	3427.55^{C}
	SE±	1.34	1.42

*^{ABC} superscript values in the same season column followed by a different letter are significantly different according to Duncan's test at the P value ≤ 0.05. S.E. is the standard error.

A study in Vetiver suggested that higher density of roots in the soil layers may be associated with an increased rainfall (Le Bot *et al.*, 2010).

Soil bulk density: Bulk density of mine soil planted to Smuts Finger grass increased with soil depth on both Upland and Lowland sites (Figure 1). At these sites, the lowest bulk density was recorded in 0-10 cm soil depth, followed by 10-20 cm, 20-30 cm and it was highest in the 30-40 cm soil depth. This lower bulk density in the upper layers might be due to the increased root growth of Smuts Finger grass. It has been reported that increased root growth and activity improves soil aggregation, decreases soil bulk density when large quantities of organic material are supplied to soils from roots (Haynes & Naidu, 1998). Fitter (1996) also reported that living roots, through normal growth and senescence of root segments and root hairs, may exert great forces on soil and might then have the ability to penetrate compacted soil.

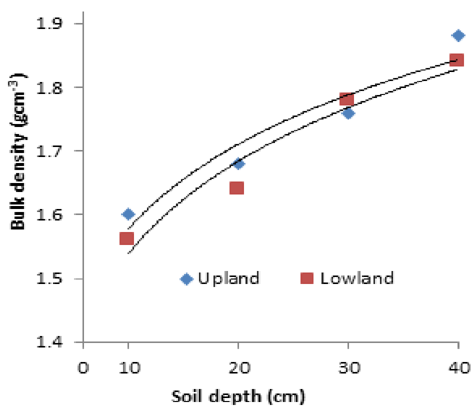

Fig. 1: Soil bulk density at different soil depths on Upland and Lowland sites planted to Smuts Finger grass. *Equations provided are logarithmic regressions.*

Soil pH (H_20): The soil pH (H_20) at different depths from Upland and Lowland site is presented in Figure 2. In Upland site, the soil pH(H_20) ranged between 4.15 and 5.62. The soil pH(H_20) of Lowland site ranged between 4.96 and 5.74. At these sites the highest soil pH values were found at 0-10, followed by 10-20 cm, 20-30 cm and the lowest at 30-40 cm. This might be the available root biomass in upper layers than lower layers. In other studies it was reported that roots have the buffering effect for changing soil pH (Maiti & Ghose, 2005; Li 2006). Plant roots raised soil pH by absorbing mobile heavy metals (Lone *et al.*, 2008). As plant roots add organic matter in soil textural class, soil pH increases significantly (Moreno-de las *et al*., 2008).

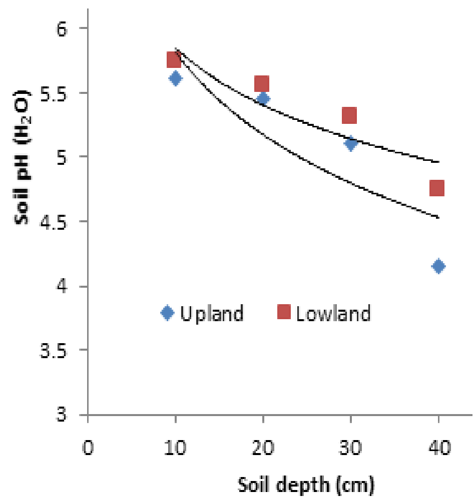

Fig. 2: Soil pH (H_2O) at different soil depths on Upland and Lowland sites planted to Smuts Finger grass. *Equations provided are logarithmic regressions.*

Table 2: Nutrient concentrations in the compacted mine soil planted to Smuts Finger grass on the Upland and Lowland site.

Site	Soil depth cm	P	N	K mgkg^{-1}	Mg	Ca
Upland	0-20	74.54^A	96.01^A	107.8^A	274.8^A	698^A
	20-40	61.84^A	85.06^A	99.04^A	259.1^A	636^A
	SE±	1.55	0.89	1.25	1.42	0.57
Lowland	0-20	93.02^A	198.8^A	255^A	352.6^A	1142^A
	20-40	73.28^A	180.8^A	208^A	299.4^A	1081^A
	SE±	1.34	0.75	1.82	1.19	1.71

The columns for each individual element with same letters denote no significant ($P \leq 0.05$) difference between soil nutrients by Duncan's multiple range test. S.E. indicates standard error.

Soil nutrients concentration: Soil nutrients (P, Mg, Ca, Na and K) concentration were statistically similar in both at 0-20 and 20-40 cm soil depths on both Upland and Lowland site (Table 2), although, there was a tendency that the nutrient status was better in the upper layers. This might be ascribed to accumulation of organic matter and highly developed roots of Smuts Finger grass into upper layers as compared to lower layers. In another study, investigating the influence of the level of soil fertility on the botanical composition of pastures established on rehabilitated strip-mined land in South Africa, high soil nutrients concentration was found around Smuts Finger grass rooting depth (Rethman and Tanner, 1993). Metalliferous soils in the Bo Ngam lead mine area planted to grass species had the highest soil nutrients at 0-20cm soil depths (Rotkittikhun *et al.*, 2006).

*Conclusion***:** Smuts Finger grass showed the best growth in compacted soil layers. The greatest root masses were noted in the upper horizons with progressively significantly less in the deeper horizons. Smuts Finger grass was good choice for improving of compacted mine soils. Smuts Finger grass showed very high tolerance to high bulk density and increased root growth to penetrate compacted soil layers. In addition, the use of Smuts Finger grass also resulted in improved soil pH and increased soil nutrient concentrations. This species was considered more suitable for improving mine soil condition and the danger of compacted soil layers became minimal.

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