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Full Length Research Paper

Improvement on grass establishment at a quarry rehabilitation site influenced by poultry manure in the subtropical South Africa

Lule E. Nelson, Oliver R. Khama and Kaiser Cedric

Department of plant and crop science, Faculty of Science and Agriculture, University of Fort Hare, East London, Eastern Cape, South Africa.

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The rehabilitation of a quarry was conducted with selected grass species in northern KwaZulu-Natal, South Africa. The seed cocktail applied contained *Chloris gayana*, *Cynodon dactylon*, *Digitaria eriantha*, *Eragrostis curvula*, *Panicum maximum* and *Paspalum distichum*. Three treatments used were: No soil enhancement (control), poultry manure application, and commercial fertilizer application. Four months after sowing, the percentage grass cover per 1 m^2 of treatment was 33% for the control, 65% where manure was applied and 76% with fertilizer application. Both fertilizer and manure applications promoted the colonization of grass species. Fertilizer application significantly increased biomass of grass (P 0.05). Poultry manure resulted in higher biomass of approximately 5 g per m^2 more than the control; however the mean was not significantly different from the control (P 0.05). These results suggest that fertilizer application prior to seed sowing in a rehabilitated quarry provide the highest biomass after four months. The application of poultry manure proved to be a cheaper option to increase aboveground plant cover in a rehabilitated area, but it is less effective than fertilizer in terms of biomass production.

Key words: Quarry, vegetation, restoration, biomass, grassland.

INTRODUCTION

A quarry is a surface mining operation, which produces raw materials of gravel, limestone and other materials for agricultural, industrial and construction applications (Duan et al., 2008). Mining activities produce large amounts of wastes that create economic and environmental problems (Maboeta and van Rensburg, 2003). Most research to address this problem considers ecological restoration, which is generally focused on large mines where valuable materials have been extracted, and operators can therefore afford to set aside funds specifically for rehabilitation purposes (Duan et al., 2008). Little research had been afforded to quarries producing low-value materials (Duan et al., 2008).

South African legislation requires developers to ecologically rehabilitate damaged environments (Claassens et al., 2005). The ultimate goal in any remediation project is to return the site to its precontamination state, which often includes revegetation to stabilise the treated soil (Maboeta and van Rensburg, 2003). This is both difficult and expensive due to the unavailability of potential topsoil as well as a deficiency of organic matter (Maboeta and van Rensburg, 2003). These problems are currently being addressed by importing topsoil from other areas or periodic treatment with inorganic fertilizers. Both options are expensive and are not ecologically sustainable (Maboeta and van Rensburg, 2003).

An integral part of the mine rehabilitation process is the use of grass seed cocktails and fertilizers to promote rapid vegetation cover which prevents erosion, provides ecological habitat and diversity, accumulates high nutrient levels and accelerates nutrient cycling processes (Lubke et al., 1996). Grasses are most ideal and have

*Corresponding author. E-mail: nelson15@gmail.com

Table 1. Some chemical characteristics of poultry manure applied as an amendment.

Characteristics	Value
Total N (%)	2.39
P (%)	1.45
K (%)	1.8
S (%)	0.41
Mn (ppm`)	168
Cu (ppm)	21
Organic C (g kg^{-1})	194

favourable characteristics that include rapid growth, high biomass, strong resistance, and effective stabilization of soils and, therefore, usually results in efficient restoration (Xia, 2004). Research in South Africa had shown that indigenous species are preferred for restoration as alien species regularly escape from rehabilitation sites to invade and degrade natural vegetation (Lubke et al., 1996).

Forms of organic wastes, such as poultry manure, can be used for nutrient release and soil amendment of mine degraded soils (Wong, 2003). Compost manure is currently being used as an inexpensive and simple solution for a wide variety of environmental and socio-economic problems (Manungufala et al., 2008). According to Abbasi et al. (2010) poultry manure enhance pH and increases soil organic matter, total N, and available P and K. Application of animal manure also improves a number of soil properties including soil tilth, water holding capacity, oxygen content and soil fertility. It reduces soil erosion, restores eroded cropland, improves solar heat absorption, increases water infiltration rates, reduces nutrient leaching and increases crop yields (Araji et al., 2001). A problem with the use of compost manures is that it increases the level of potentially harmful trace metals and various organic toxic substances in the soil and plants (Manungufala et al., 2008). Much research (Lubke et al., 1996; van Rensburg et al., 2004) had demonstrated the possibilities of using indigenous grasses for rehabilitation, but there is little information on the use of manure for optimizing the success of quarry revegetation. The objective of this study was, therefore, to test the effect of poultry manure on the revegetation of a quarry with indigenous grass species.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Ninians Quarry (Empangeni) in Northern KwaZulu-Natal (KZN), South Africa, situated at (28°48'S, 31°52'E) (Figure 1). It is situated approximately 160 km north ofDurban, in the undulating countryside of Uthungulu District. The climate of Empangeni is humid subtropical, with a high rainfall (> 1000 mm/annum). The daily mean temperature is 28.4°C in summer and 14.5°C in winter.

Establishment of vegetation

The soil used as the experimental growth medium was taken from retained topsoil heaps at the quarry. The use of the topsoil was to promote vegetation growth and evapotranspiration, and act as protection against water and wind erosion (Vermaak et al., 2004). The topsoil was spread 10 cm deep over disturbed areas at the quarry.

A field plot trial was designed to test the growth of grasses under three different nutrient treatments, namely a control without nutrient enhancements, soil amended with poultry manure, and soil amended with fertiliser (N:P:K 1.2:1.3:0.8). The size of each treatment plot was approximately 10 × 10 m (n=9).

Poultry manure, a biofertiliser, could be compared with commercial fertilisers during the experiment as especially indigenous species do not always require a large nutrient input during revegetation (van Rensburg et al., 2004). The chemical characteristics of poultry manure are presented in Table 1. Poultry manure is rich in nutrients (Materechera and Mkhabela, 2002) and is regularly available from poultry farms, and hence was chosen as the manure for this study. Rate of application was not increased in this study, as dry matter gains decreases at an increasing rate of poultry manure application (Boateng et al., 2006).

Grass species were used for these initial field trials, as the dense root system network of grasses bind soil better than woody species with taproot systems (van den Berg and Zeng, 2006). The long-term rehabilitation trial involved a follow up planting with legumes and trees. Field data will only be analyzed after five years.

Prior to the experiment, a detailed survey was conducted on grass species that occur naturally at the quarry (Table 2). Indigenous grass species for ecological rehabilitation at Ninians quarry were selected from this list. Seeds were purchased from Coastal farmers Co-operation in Durban, South Africa. A seed cocktail (approximately 7.5 gm^{-2}) was then prepared consisting of *Chloris gayana, Cynodon dactylon, Digitaria eriantha, Eragrostis curvula, Panicum maximum* and *Paspalum distichum*, and was sewn into each of the treatment plots. Seeds were broadcasted by hand at 2 gm^{-2} and lightly raked in. Fertilizer and manure was also spread by hand in the specific treatments both at 15 gm^{-2}.

Field plots were not irrigated but subjected to natural rainfall. The grass seed germinated within a week in all the treatments. Aboveground biomass (g) was harvested in December (four months after planting). Three 1 m^2 quadrants were placed at random in each of three plots per treatment and all aboveground biomass was harvested down to 50 mm (ground level). Most biomass data is generally represented by above ground plant matter (Barbour et al., 1987), therefore belowground biomass was excluded. In this study, the use of the term biomass refers to aboveground biomass only. The fresh plant material was oven dried at 70°C and weighed.

Before the harvesting of aboveground biomass, the mean height was measured and percentage of grass cover was estimated per 1 m^2 quadrants. Mean grass cover was estimated using cover abundance classes (Braun-Blanquent cover abundance scale) and converted to percentage cover (Jury et al., 2007).

Statistical analysis

The data for height, biomass and cover under different treatments were analyzed using the SPSS statistical package by one-way analysis of variance (ANOVA) to compare the means of different treatments (Xia, 2004). Analysis of variance was done at 95% confidence limit.

Table 2. Twenty-six naturally occurring grass species recorded from Ninians quarry. Species marked with an asterisk (*) are not indigenous, but are naturalised alien species.

Species
Andropogon eucomus Nees
Aristida junciformis Trin. and Rupr. subsp.
junciformis Brachiaria humidicola (Rendle) Schweik.
Chloris gayana Kunth
Cymbopogon nardus (L.) Rendle
Cynodon dactylon (L.) Pers.
Dactyloctenium geminatum
Hack. *Digitaria debilis* (Desf.)
Willd. *Digitaria eriantha* Steud.
Digitaria natalensis Stent
Eleusine coracana (L.) Gaertn subsp., *africana* (K-O'Byrne) Hilu and de Wet
Eragrostis capensis (Thunb.) Trin.
Eragrostis curvula (Schrad.) Nees
Eragrostis heteromera Stapf
Eragrostis plana Nees
**Eragrostis tef* (Zucc.) Trotter
Imperata cylindrica (L.) Beauv.
Melinis repens (Willd.) Zizka subsp.
repens Panicum maximum Jacq.
Panicum subalbidum Kunth
Panicum distichum L.
**Paspalum urvillei* Steud.
**Pennisetum setaceum* (Forssk.) Chiov.
Sorghum bicolor (L.) Moench. subsp. *arundinaceum* (Desv.) De Wet and Harlan
Sporobolus pyramidalis Beauv.
Stenotaphrum secundatum (Walt.) Kuntze

RESULTS AND DISCUSSION

Germination rates were not tested in this study, but personal field observations suggested that the germination rate was slightly higher in the treatments than the control, which is in accordance with the work of others (Ye et al., 2000; van Rensburg et al., 2004).

The growth of grasses was stimulated, as expected, by application of appropriate fertilisers and manure (biofertilisers) (Aydin and Uzun, 2005; Rivera-Cruz et al., 2008). The percentage grass cover per treatment was 33% (control), 65% (manure) and 76% (fertilizer) (Table 3). The percentage grass cover of control plants was significantly lower (P 0.05) than that of manure and fertilizer treatments (Table 3), indicating that soil amended with fertilizer and manure stimulated plant growth. However, there were no significant differences between manure and fertilizer treatments in grass cover per m^2 (Table 3). There were also no significant differences (P 0.05) between manure and fertilizer treatments in terms of plant height (Table 3). Once again, the plant height of fertilizer and manure treatments were significantly higher (P 0.05) than that of the control (Table 3). This confirms that soil amendments form an integral part in re-vegetation of degraded soils. It also indicates that biofertilisers (in this case poultry manure) had potential compared to commercial inorganic fertilisers. Biofertilisers based on rhizospheric beneficial microorganisms have emerged as an alternative to chemical fertilizers to increase soil fertility (River-Cruz et al., 2008). Poultry manure therefore enhanced the growth of indigenous grasses.

However, the success of a rehabilitation programme is not measured as plant growth, but in terms of biomass production (O'Dell et al., 2007; Rosenschein et al., 1999). The biomass of fertilizer treatment was significantly higher (P 0.05) than that of both the manure and control treatments (Table 3). However, the biomass of the poultry manure treatment was significantly higher (P 0.05) than that of the control. Therefore, significant increases in percentage cover and height does translate into significantly higher biomass. The present study agrees with findings of other workers whereby fertilizer applications significantly increased biomass of grasses

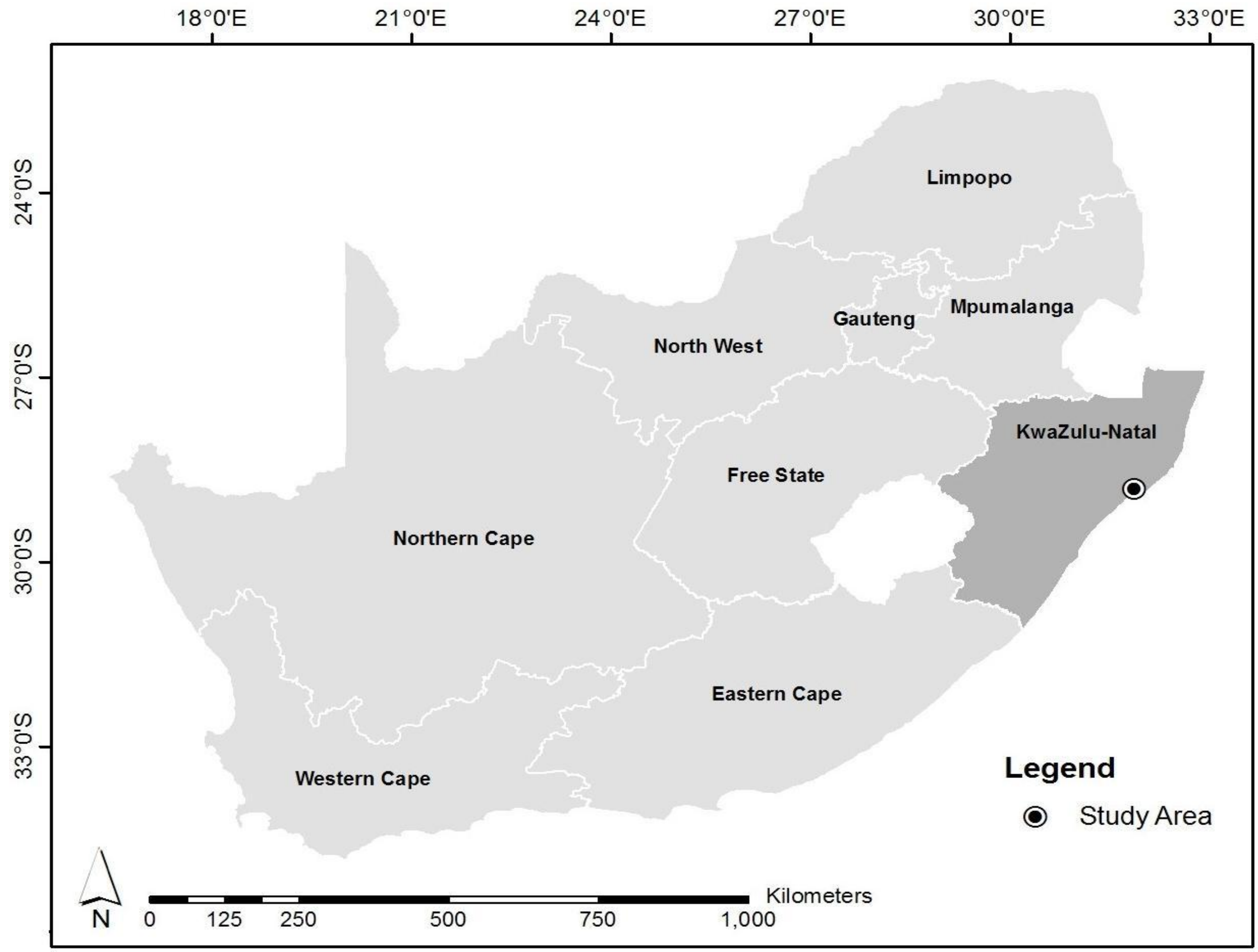

Figure 1 . Locality of the study area in South Africa.

Table 3. Grass cover (%/m^2), mean plant height (cm/m^2) and biomass (g/m^2) of grass species cultivated under different treatments. Mean values are presented ± standard error (N= 3).

	Treatment		
Growth parameter	**Control**	**Manure (15 g/ m^2)**	**Fertilizer(15 g/ m^2)**
Grass cover (%/m^2)	33.33 ± 4.485a[1]	65.33 ± 5.488b	76.00 ± 1.000b
Mean plant height (cm/m^2)	14.73 ± 1.157a	30.60 ± 3.700b	32.67 ± 1.312b
Biomass (g/m^2)	0.71 ± 0.183a	4.98 ± 1.685b	20.10 ± 2.866c

[1]Within rows, values followed by the same letter are not significantly different from each other. Values with different letters in the same row indicate a significant difference at 5% or ($P < 0.05$) level based on the least significant difference (LSD) test.

(Xia, 2004), and plant height in *Sorghum* (Agbede et al., 2008) and *Zea mays* (Obi and Ebo, 1995; Materechera and Morutse, 2009). This indicates that fertilizer application is more effective than poultry manure, albeit poultry manure showing potential in the enhancement of soils which improves grass establishment. A greenhouse study by Villar et al. (2004) showed that organic wastes rich in lignocellulosic materials (e.g. poultry manure) can improve soil structure of degraded soils, and therefore the application of poultry manure could improve soil structure and in this way enhance establishment of indigenous grasses at the same time.

CONCLUSION AND RECOMMENDATIONS

Application of poultry manure and fertiliser resulted in increased growth of grass species. Fertiliser was a better amendment for grass cover establishment, as it enhanced plant cover and biomass rapidly. Poultry manure showed potential to improve the establishment of grasses during revegetation. The efficiency of poultry manure is ascribed to high pH, low organic carbon, high organic nitrogen, and low carbon/nitrogen ratio compared to other types of manure (Araji et al., 2001).

Poultry manure is environmentally sustainable, cheap and easily accessible (Kang et al., 2008; Bhatta and Doppler, 2010). The availability thereof could empower local communities to conduct ecological restoration with manure. The South African government are encouraging compost making and recycling as community projects (Manungufala et al., 2008). The production of poultry manure for rehabilitation purposes could form part of such endeavours. Poultry manure is a biofertiliser that is currently available in large quantities in KZN (Materechera and Mkhabela, 2002) and future research should determine which application concentrations would be most cost-effective and suitable for revegetation, especially the enhancement of grass biomass. In the northern part of KZN, sugarcane manure is the most cost effective for small rural farmers (Zobolo et al., 2008) and its application with poultry manure should be further investigated for both rehabilitation and agricultural applications.

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