# INFLUENCE OF SOIL FERTILITY ON BOTANICAL COMPOSITION OF REHABILITATED PASTURES IN SOUTH AFRICA[1]

by

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**Abstract**. Soil conditions created during the rehabilitation process of strip-mined areas differ from the original in respect of depth, density, drainage, organic material content, fertility and microbial activity. This paper reports on the influence of soil fertility on the botanical composition of pasture established on such areas. The study was conducted on a site with grassland capability classification, making it suitable for utilization as reclaimed rangeland or as planted pasture. The ultimate land use would be determined by economic and ecological considerations. Over an experimental period of five years (1987-1992) it was found that of the seeded species the annual Eragrostis tef and weakly perennial Chloris gayana disappeared completely, irrespective of the level of fertility, whereas the perennial Digitaria eriantha persisted as the dominant species irrespective of soil acidity, phosphorus or potassium status. In contrast, Medicago sativa was extremely sensitive to low pH, phosphorus or potassium and was completely eliminated under such conditions. It was particularly noteworthy that volunteer species such as Cynodon dactylon and Eragrostis curvula increased under low phosphorus/low nitrogen treatments and low pH conditions respectively. These results hold important implications for policy decisions concerning sustained levels of fertilization, the composition of seeding mixtures and the consideration of pasture reinforcement at a later stage where the restoration of a greater diversity typical of a rangeland situation may be an objective.

Additional keywords: Liming, fertilization, Digitaria eriantha, Medicago sativa, Eragrostis curvula, cynodon dactylon.

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## Introduction

Although the coal mining industry in South Africa is over 100 years old, strip mining has only been used for the past two decades. During those 20 years rehabilitation policies and practices have developed continuously. Guidelines have been developed by the Chamber of Mines and mining companies are required to submit detailed impact studies and rehabilitation programs before approval for mining is granted. Subsequent monitoring of soil, water and vegetation facilities and auditing of standards and in many cases has resulted in refinements to both mining and rehabilitation practices.

One of the most basic principles in present rehabilitation practice is the restoration of land capability classes in approximately the same proportions as prior to mining. Areas considered suitable for arable purposes could be used for cropping with annual or perennial crops, whereas areas considered suitable for grassland could be used for perennial planted pastures or "restored range". The development of sustainable land use practices for rehabilitated areas with a grassland capability is an objective of current work. Sustainability implies both economic and ecological stability. Neither of these is, however, static and a deeper understanding of the dynamics of change in pastures in response to changes in fertility, which is one of the more easily manipulated environmental (and economic) variables, is needed.

The scenario reported in this paper is that of manipulating the fertility levels in a planted pasture to be utilized in semi-intensive livestock production systems. Such manipulations were originally seen as a reaction to economic constraints (prices of fertilizers and livestock products) but it is becoming increasingly obvious that these manipulations may have even greater implications for the ecological stability of different pasture components.

## Materials and Methods

### Experimental terrain

The investigation was conducted on a colliery situated 10 km SW or Witbank on the eastern Transvaal Highveld. Located 1550 m above sea level the area receives an average annual rainfall of 700 mm, concentrated in the October-March period. Maximum temperatures in summer are mild, averaging 27°C in the hottest month with an extreme of 36°C. The winters are dry and cold with frosts occurring from April to September, an average minimum temperature in the coldest month of -2°C and extreme minimum of -12°C.

The research was conducted on a site strip mined in 1985, regarded with a slope of less than one percent in 1986/87 and topsoiled with 250 mm of pre-stripped topsoil in the winter of 1987. After standard agricultural ripping, specified liming and fertilization treatments were incorporated into the topsoil and after ensuring a fine, firm and even seedbed the area was seeded to a mixture of Digitaria eriantha Chloris gayana, Medicago sativa and Eragrostis tef, in the ration of 5:5:5:3, at a seeding rate of 18 kg/ha.

### Experimental design

The trial was laid out in a randomized blocks design with 13 treatments and 3 replicates. Treatments were aimed at creating a range of soil fertility conditions, which were maintained by regular monitoring of soil nutrient status and adapting levels of fertilization. The only fixed treatments were the levels of nitrogen fertilization. Treatments applied to plots measuring 10m X 7m were as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | - | Zero | $N_1$, $N_2$, $N_3$ are the equivalent of 100, 200 and 300 kg | | | |
| 2 | - | $N_1P_2K_2L_2$ | N/ha/annum respectively | | | |
| 3 | - | $N_2P_2K_2L_2$ | $P_o$ represented a range of 2-8 mg/kg P (Bray 1) | | | |
| 4 | - | $N_3P_2K_2L_2$ | $P_1$ | " | " " | 10-20 " |
| 5 | - | $N_2P_oK_2L_2$ | $P_2$ | " | " " | 30-60 " |
| 6 | - | $N_2P_1K_2L_2$ | $P_3$ | " | " " | 70-120 " |
| 7 | - | $N_2P_3K_2L_2$ | $K_o$ | " | " " | 0-40 mg/kg K |
| 8 | - | $N_2P_2K_0L_2$ | $K_1$ | " | " " | 40-80 " |
| 9 | - | $N_2P_2K_1L_2$ | $K_2$ | " | " " | 80-120 " |
| 10 | - | $N_2P_2K_3L_2$ | $K_3$ | " | " " | 120-160 " |
| 11 | - | $N_2P_2K_2L_o$ | $L_o$ | " | " " | pH(KCl) of 3.8-4.2 |
| 12 | - | $N_2P_2K_2L_1$ | $L_1$ | " | " " | " 4.3-4.7 |
| 13 | - | $N_2P_2K_2L_3$ | $L_2$ | " | " " | " 5.0-5.4 |
| | | | $L_3$ | " | " " | " " 5.5-6.0 |

Phosphorus was applied in the form of single superphosphate (10.5% P), potassium in the form of potassium chloride (50% K), nitrogen in the form of limestone ammonium nitrate (28% N) and lime in the form of calcitic lime ($CaCO_3$), in the establishment season (1987-88) no differential nitrogen treatments were applied, all treatments receiving 199 kg N/ha.

### Observations

The first assessment of the influence of fertility status on botanical composition and basal cover was conducted in January 1990, 27 months after planting. The technique used was to register presence or absence of each species in each of 30 quadrats (250mm X 250mm) in each plot. The basal cover was calculated from a count of tufts multiplied by mean tuft size.

In October 1992, 60 months after planting, a further assessment using 100 sharp points per plot was conducted. The botanical composition was based on the identification of the nearest plant to each point. Assessments of basal cover were made, firstly, on the basis of a strike on living rooted material at ground level and, secondly, on the basis of bare areas (no living plant within 150mm radius of a point).

Soil fertility was monitored annually by analyzing a representative core sample taken to a depth of 100 mm at the end of each growing season. The soil phosphorus status was determined using the Bray 1 technique, while exchangeable potassium was determined using molar ammonium acetate extraction and the pH in 1:5 potassium chloride (molar) (Non-affiliated soil analysis comm., 1990).

## Results

### Botanical composition

The annual E. tef and weakly perennial C. gayana had already served their purpose of being nurse crops and had disappeared by January 1990. It was, therefore, decided to concentrate attention on the remaining seeded species (Digitaria and Medicago) and the most prominent volunteer species (Eragrostis curvula and Cynodon dactylon).

The date for Digitaria, presented in Table 1, would seem to indicate that, whilst the level of respective nutrients had very little effect on this species in a young pasture, three years later the evidence was very much more indicative of a sensitivity to phosphorus deficiency and high acidity. Morality rates of this species from 1990 to 1992 on unlimed/unfertilized zero treatments were most significant.

Medicago was originally incorporated in the seeding mixture, in the absence of seed of indigenous legumes, with the objective of improving forage quality and providing more nitrogen in the ecosystem. From the data presented in Table 2 it must be clear that this objective has not been realized.

Table 1 Percentage occurrence of Digitaria eriantha in January 1990 and October 1992 as influenced by fertility level.

| Fertility level as in Jan 1990 | % Occurrence | |
|---|---|---|
| | Jan 1990 | Oct 1992 |
| 100 kg N/ha | 93 | 90 |
| 200 " | 93 | 90 |
| 300 " | 97 | 92 |
| 9 mg/kg P | 93 | 76 |
| 12 " | 94 | 89 |
| 52 " | 93 | 91 |
| 143 " | 96 | 94 |
| 17 mg/kg K | 96 | 94 |
| 51 " | 92 | 95 |
| 67 " | 93 | 91 |
| 77 " | 78 | 89 |
| pH(KCl) 4.1 | 92 | 82 |
| " 4.2 | 90 | 89 |
| " 5.1 | 93 | 91 |
| " 5.4 | 97 | 93 |
| Zero | 81 | 55 |
| Mean | 91.9 | 87.6 |

There was already strong evidence in 1990 that alfalfa was very sensitive to acidity, potassium and phosphorus deficiencies. Subsequently this species has virtually disappeared from the pasture and was so infrequent in the 1992 survey as to be virtually meaningless.

Of the volunteer species weeping lovegrass can be seen to be playing an important role (Table 3). Whilst in 1990 this role appeared to be correlated with high acidity and a better potassium status, in 1992 it was only the unlimed soils (zero and $N_2P_2K_2L_o$) that illustrated a markedly higher incidence of Eragrostis.

The occurence of Bermuda grass (Cynodon dactylon) is illustrated in Table 4. The distribution of this species appeared to be entirely fortuitous but it appeared to do particularly well on low phosphorus soils (zero and $N_2P_0K_2L_2$)

It is of interest to note that whereas all indicator species (Tables 1-4) had declined in frequency of occurrence the incidence of other species and bare areas had increased, creating greater diversity.

## Basal cover

With respect to the basal cover the data presented in Table 5 is not comparable from year to year because of the different techniques used.

There are, however, no clear trends evident in these data. Most notable are the poor cover and high incidence of bare areas on plots with the most acidic substrate and the high incidence of bare areas on plots with a low phosphorus status. It is also most interesting to note that with respect to potassium status there is an apparent tendency for the poorest plots to have the best cover and the lowest occurrence of bare areas, when compared with plots receiving regular topdressings of potassium chloride.

Table 2 Percentage of Medicago sativa in January 1990 and October 1992 as influenced by fertility level.

| Fertility level | % Occurrence | |
|---|---|---|
| | Jan 1990 | Oct 1992 |
| 100 kg N/ha | 3 | 2 |
| 200 " | 6 | 1 |
| 300 " | 2 | 1 |
| 9 mg/kg P | 0 | 0 |
| 12 " | 3 | 0 |
| 52 " | 3 | 1 |
| 143 " | 4 | 1 |
| 17 mg/kg K | 1 | 0 |
| 51 " | 3 | 0 |
| 67 " | 6 | 1 |
| 77 " | 9 | 0 |
| pH(KC) 4.1 | 0 | 0 |
| " 4.2 | 1 | 2 |
| " 5.1 | 3 | 1 |
| " 5.4 | 9 | 2 |
| Zero | 0 | 0 |
| Mean | 3.3 | 0.8 |

Table 3 Percentage occurrence of Eragrostis curvula in January 1990 and October 1992 as influenced by fertility level.

| Fertility level | % Occurrence | |
|---|---|---|
| | Jan 1990 | Oct 1992 |
| 100kg N/ha | 7 | 2 |
| 200 " | 4 | 3 |
| 300 " | 4 | 3 |
| 9 mg/kg " | 7 | 3 |
| 12 " | 6 | 4 |
| 52 " | 7 | 3 |
| 143 " | 6 | 4 |
| 17 mg/kg K | 6 | 4 |
| 51 " | 7 | 1 |
| 67 " | 7 | 3 |
| 77 " | 18 | 4 |
| pH(KCl) 4.1 | 20 | 10 |
| " 4.2 | 11 | 3 |
| " 5.1 | 7 | 3 |
| " 5.4 | 3 | 1 |
| Zero | 36 | 29 |
| Mean | 39.8 | 5.0 |

Table 4 Percentage of Cynodon dactylon in January 1990 and October 1992 as influenced by fertility level.

| Fertility level | % Occurrence | |
|---|---|---|
| | Jan 1990 | Oct 1992 |
| 100 kg N/ha | 8 | 4 |
| 200 " | 8 | 6 |
| 300 " | 0 | 0 |
| 9 mg/kg P | 6 | 16 |
| 12 " | 3 | 5 |
| 52 " | 8 | 3 |
| 143 " | 8 | 0 |
| 17 mg/kg K | 4 | 1 |
| 51 " | 2 | 3 |
| 67 " | 8 | 3 |
| 77 " | 1 | 1 |
| pH(KCl) 4.1 | 3 | 4 |
| " 4.2 | 11 | 4 |
| " 5.1 | 8 | 3 |
| " 5.4 | 3 | 3 |
| Zero | 13 | 11 |
| Mean | 5.9 | 4.2 |

## Discussion and Conclusions

Where the stability of pasture species, which could be considered for use in rehabilitation work, is being evaluated it is particularly worthy of note that while D. eriantha appears to be well adapted to climatic conditions on the eastern Transvaal Highveld, it does appear that soil pH and phosphorus status will require regular monitoring and corrective fertilization to maintain the vigor and productivity of this species, even at relatively high levels of nitrogen fertilization. These ongoing high input requirements of Digitaria might count against its use in long term pastures for intensive livestock production systems, when economic sustainability is very uncertain.

High costs of fertilization have been one of the major limitations of planted pastures for intensive livestock production systems in South Africa (Du Pisani, 1991). For this reason the inclusion of a perennial legume component in such pastures has been a major research objective for many years. To date the most successful pasture legume on the Transvaal Highveld has been alfalfa (Rethman, Odendaal and De Witt, 1986). The results obtained in this trial have, however, made it very clear that this legume may not be regarded as a low input solution to high costs of nitrogen fertilization. It should, therefore, be an urgent objective to identify forage legumes which do not have the sensitivities to soil fertility parameters exhibited by alfalfa. Such legumes, be they indigenous or exotic, could play a positive role in both planted pasture and "restored range" on rehabilitated areas.

In contrast to the findings with D. eriantha the reaction of volunteer species is particularly significant. E. curvula played a most significant role on plots with a low pH, while C. dactylon was notable on plots with a low phosphorus status. This does not

Table 5 The basal cover and percentage frequency of bare areas in January 1990 and October 1992 as influenced by fertility level.

| Fertility level | January 1990 | October 1992 | |
|---|---|---|---|
| | % basal cover | % basal cover | % bare areas |
| 100 kg N/ha | 10.8 | 31.7 | 2.3 |
| 200 " | 12.9 | 22.0 | 1.0 |
| 300 " | 10.5 | 25.0 | 4.0 |
| 9 mg/kg P | 9.2 | 29.7 | 4.3 |
| 12 " | 7.5 | 22.3 | 2.0 |
| 52 " | 11.4 | 26.2 | 1.0 |
| 143 " | 11.5 | 23.7 | 1.3 |
| 17 mg/kg K | 13.4 | 32.3 | 0.3 |
| 51 " | 10.0 | 25.7 | 2.3 |
| 67 " | 11.4 | 26.2 | 2.4 |
| 77 " | 7.5 | 24.3 | 5.3 |
| pH(KCl) 4.1 | 9.6 | 18.3 | 3.7 |
| " 4.2 | 11.5 | 29.0 | 2.0 |
| " 5.1 | 11.4 | 26.2 | 2.4 |
| " 5.4 | 13.6 | 24.3 | 0.0 |
| Zero | 14.4 | 25.7 | 2.5 |

necessarily imply that these species do not respond to soil amelioration by liming and phosphorus fertilization - in fact numerous reports list these species as being relatively tolerant of acid soils while the response to phosphorus was very good in the presence of nitrogen (Rethman, 1990). The influence of fertility levels on the relative success of these two species can probably be ascribed to the sensitivity of the dominant species (D. eriantha) to soil acidity and low phosphorus. This results in reduced competition for the hardy Eragrostis and Cynodon, which are typical pioneer species in degraded rangeland of the Highveld. In contrast Rethman and Beukes (1973) found that the establishment of overseeded E. curvula in rangeland was promoted by high levels of both nitrogen and phosphorous, which had reduced the competitive effect of climax grass species.

These findings hold profound implications for strategies aimed at increasing the diversity of species composition by providing seed of adapted species. Such strategies can only succeed if they take cognizance of such basic successional processes as ecesis and competition. Management manipulations may, however, advantage or disadvantage certain species.

In conclusion, it must be stated clearly that, while such small plot clipping trials may be very useful in identifying possible fertilization and seeding strategies, such strategies must also be evaluated under practical management conditions where factors such as selective grazing, circulation of nutrients, hoof action, and even burning may interact to improve or negate the effects reported in this investigation.

## Literature Cited

Du Pisani, L.G. and Skinner, T.E. 1991. The complemental role of dryland cultivated pastures in market-related beef production from semi-arid rangeland. J. Grassl. Soc. South Afr. 8(4):123-125. http://dx.doi.org/10.1080/02566702.1991.9648278

Non-affiliated Soil Analysis Committee. 1990. Handbook of standard soil testing methods for advisory purposes. Soil Sci. Soc. S. Afr., Pretoria, South Africa.

Rethman, N.F.G. 1990. The use of Eragrostis curvula in livestock production systems in the South-Eastern Transvaal. Ph.D. thesis, University of Netal, Pietermaritzburg, S. Africa.

Rethman, N.F.G. and Beukes, B.H. 1973. Overseeding of Eragrostis curvula on N-E Sandy Highveld. Proc. Grassl. Soc. South. Afr. 8:57-59. http://dx.doi.org/10.1080/00725560.1973.9648695

Rethman, N.F.G., Odendaal, J.J. and de Witt, C.C. 1986. Potential of dryland lucerne (Medicago sativa) in the mixed farming areas of the eastern Highveld. J. Grassl. Soc. South. Afr. 3(4):122-127. http://dx.doi.org/10.1080/02566702.1986.9648049