Manure from cattle as fertilizer for soil fertility and growth characteristics of Tall Fescue (*Festuca arundinacea*) and Smuts Finger grass (*Digitaria eriantha*)

P E Mosebi, W F Truter and I C Madakadze

Department of Plant Production and Soil Science, University of Pretoria, Pretoria, 0002
pe.mosebi@nul.ls

Abstract

Applying cattle manure to soil in optimum rates can enhance soil fertility and plant growth. The objectives of this study were to investigate the influence of different rates of cattle manure application on soil fertility and the growth and productivity of Tall Fescue (*Festuca arundinaceae*) and Smuts Finger grass (*Digitaria eriantha*), two popular pasture species in South Africa. These field trials were established on a uniform sandy clay loam (Hutton) soil on the Hatfield Experimental Farm, of the University of Pretoria in Pretoria. There were five treatments comprising five rates of cattle manure incorporation (0, 20, 40, 80 and 120 tonnes/ha). During the growing season, Tall Fescue plants from cattle manure-amended plots were significantly taller in the 80 tonnes/ha treatment, while Smuts Finger grass reached the maximum height in the 40 tonnes/ha treatment.

The cattle manure-treated plots also produced greater leaf areas than the untreated control of both grasses. Dry matter yields of Tall Fescue were greater with 80 tonnes/ha, while Smuts Finger grass responded best to 40 tonnes/ha. The stubble and root biomass of both grass species were once again higher on cattle manure-amended plots. The concentration of soil nutrients also increased significantly in response to applications of cattle manure.

Keywords: *cattle manure, dry matter yields, plant height, root biomass, soil nutrient concentrations*

Introduction

Grasses depend on an abundance of plant available nutrients for survival and good productivity. Cattle manure has been used as a soil amendment in agricultural systems for centuries. The addition of cattle manure to soil provides several potential benefits by improving soil structure, fertility and increasing soil organic matter (McAndrews et al 2006). Because manure has a high organic matter content, the application of cattle manure also often helps restore depleted organic matter in degraded areas, and a majority of nutrients added through manure applications are in organic form (Zhang et al 2006), which implies slow release over a longer period than is obtained from most inorganic fertilizers.

Deterioration of grasslands made it possible for livestock production to move into planted grass species. Poor soil fertility of most soils poses a major constraint to temperate and tropical grass species in Southern Africa. Grass species growth and development is adversely affected by limited access of nutrients in the soil. The initial overall symptom is slow, weak, and stunted growth. Pale green to light yellow colour is appearing first on older leaves usually starting at the tips, delayed maturity, poor stem and leaves development. Soils supplying limited amount of nutrients at critical time points in grass growth produce low disease resistance in plants and the quantity of their production is reduced.Consequently, major sources of energy, proteins, minerals and vitamins for animals required to maintain body weight for lactation, growth and reproduction are adversely affected, thereby reducing maximum productivity.

With low level of nutrients in the soils required to maintain grass species growth, soil amendment with cattle manure may result in increased crop growth through the addition of organic matter. Soil organic matter is critical for preventing nutrients from leaching or loss through nutrient runoff (Bellows 2001). Regular applications of organic materials to soils increase the humus content and enhance nutrient availability, nutrient holding capacity, and soil pore space (Zinati et al 2001). Rethman, (2006) also emphasized the addition of cattle manure to restore and maintain organic matter levels in grassland soils over the long term.

The improvement of soil fertility also largely depends on the addition of organic manure materials which increase nutritive value of pastures. Matsi et al (2003) have shown that the application of cattle manure can increase soil available macronutrients; nitrogen, phosphorus and potassium. Nitrogen is a primary plant nutrient (especially for grasses) and exists as plant available nitrogen in the form of ammonium or nitrate (Thomas 1992). Nitrogen applied to grasses before they begin flowering stimulates tillering, while nitrogen applied during or after flowering stimulates stem and leaves growth (Whitehead 2000). In photosynthesis and respiration, phosphorus plays a major role in energy storage and part of structures, which are the major components of genetic information (Whitehead 2000). Potassiumis important for improving the nutrient quality of grasses, extending stand life, enhancing their persistence and productivity (Lory and Roberts 2000).

In addition to the levels of plant-available nutrients in soils, the organic manure plays an important role in nutrient cycling which provides nutrients for plants growth, food for soil organisms and facilitates the formation of aggregates. Tripathi and Singh (2004) reported that the application of manure improved soil physical properties and nutrient capacity of the soil and increased plant growth. The increased cover, productivity and yields of plants growing on such soil, extends nutrient cycling in the ecosystem that maintain the pasture soil as a habitat favorable for soil organisms (Rethman 2006). Haynes & Naidu (1998) also reported that increased root growth and activity of grasses improves soil aggregation, decreases soil bulk density and large quantities of organic material are supplied to soils from roots and plant residues.

The objectives of this study were to investigate the impact of incorporating different levels of cattle manure into the soil on the growth and dry matter production of Tall Fescue (*Festuca arundinacea* cv Dovey) and Smuts Finger grass (*Digitaria eriantha* cv Irene), and determine the effects on root biomass and soil nutrient concentrations.

Materials and methods

Two field experiments with Tall Fescue (*Festuca arundinacea* cv Dovey) and Smuts Finger grass (*Digitaria eriantha* cv Irene) were established on a uniform sandy clay loam soil belonging to the Hutton soil form (Soil Classification Working Group) on the Hatfield Experimental Farm, of the University of Pretoria in Pretoria, South Africa (25º45'S, 28º16'E) situated 1327m above sea level. The experimental design was a complete randomized design with 5 treatments and 5 replications. Five rates of cattle manure incorporation (0, 20, 40, 80 and 120 tonnes/ha) were evaluated. Treatments were planted with seedlings of Tall Fescue and Smuts Finger grass at an espacement of 10 cm x 10 cm. These seedlings were produced in the seedling trays, eight weeks before being transplanted to the field trials. The gross plot dimensions for both Tall Fescue and Smuts Finger grass were 9 x 2 m with 25 plots in total.

The cattle manure used in the experiment was collected from a local dairy farm. The cattle manure had been analysed for the following nutrients: N, P, K, Mg, Na and Ca. The different rates of cattle manure incorporated at the beginning of the study provided the following amounts of nutrients as shown in Table 1. In both trials the cattle manure was surface applied and tilled in to a depth of 10 cm. The seedlings were irrigated once a week to ensure that soil moisture was not a limiting factor. Weeds were removed between rows by hand and no pesticides were applied after grass planting.

Table 1. Nutrients added to the soil by different levels of cattle manure.

Cattle manure	**Nutrients applied (mg/kg)**					
tonnes/ha	**N**	**P**	**K**	**Mg**	**Na**	**Ca**
20	34.9	11.7	156	21.9	28.5	10.8
40	69.9	23.4	313	43.8	57.0	21.7
80	139	46.9	626	87.6	114	43.5
120	209	70.4	939	131	171	65.2

Forage grass samples for growth were taken by measuring plant height of each treatment over the 210 days of the experimental period using a measuring tape. The leaf area index was measured using leaf area meter over the 180 days of the experimental period. Leaf area index is the component of plant growth analysis that accounts for the ability of the plant to capture light energy. Forage samples were harvested to determine forage yields over the 210 days. The grass seedlings were cut at stubble height of 7 cm above the ground and the harvested material collected as dried at 65ºC for 72 hours to constant mass. Stubble of the two grass species as cut at the soil surface after the last harvest was washed with tap water. The roots from core samples having a diameter of 20 cm, to depth of 0-30 cm were also washed free of soil using a 250µm sieve. The dry mass of stubble and roots was recorded after oven-drying at 65 ºC for 72 hours to constant mass. Soil samples were collected after 210 days and the concentrations of N, P, K, Mg, Na and Ca, and pH (H_2 0) values were determined using an ammonium acetate extraction.

The PROC GLM procedure of SAS (SAS Inst., 2004) was used for statistical analyses. Analysis of variance (ANOVA) was done for each species for growth, biomass yields and nutrient concentrations followed by mean comparison and LSD at a probability level of $\leq$5%.

Results and discussion

Plant height

Tall Fescue

Manuring only had a significant effect over 120 days to 210 days with no significant difference over 60 and 90 days and this significance only persisted at the higher levels over 180 and 210 days (Figure 1). Throughout the growing season, the tallest plants were observed on the 80 tonnes/ha plots, followed by 120 tonnes/ha, 40 tonnes/ha and 20 tonnes/ha plots with the shortest plants being on the control. These results indicate that heavy application of cattle manure still had positive residual effects after 210 days. The application of cattle manure has often been reported to increase plant growth and yields. This has been attributed to the macronutrients contained in manure (Sutton et al 1986; Motavalli et al 1989). On five of six measurement dates, McAndrews et al (2006) also found that the mean height of oats grass on manured plots was 6 to 12% taller than on the control plots.

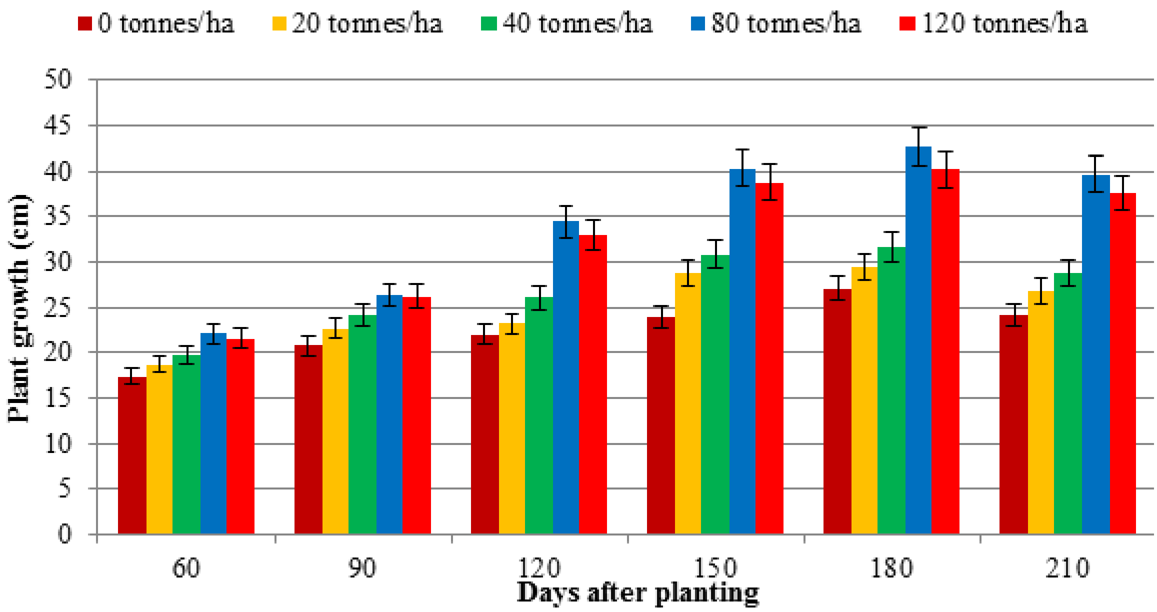

Figure 1. Plant height of Tall Fescue measured over 210 days after the initial incorporation of different levels of cattle manure. *Bars indicate standard error.*

Smuts Finger grass

The incorporation of cattle manure into soil also increased the height of Smuts Finger grass significantly ($P \leq 0.05$) relative to control treatment in three of the six growth periods (Figure 2). The tallest plants were observed from both 40 and 80 tonnes/ha treatments, followed by 120 and 20 tonnes/ha plots and then the control. Increases in plant height might be attributed to enhanced soil fertility and improved soil physical condition. Hati et al (2006) reported that the application of animal manures improved physical properties of the soil, which promoted higher nutrient and water uptake by plant roots and increased plant growth. During the first year after application of manure, Hati et al (2007) also found that the average plant height of barley grass on the farmyard manure treatments was 16% higher than on the control.

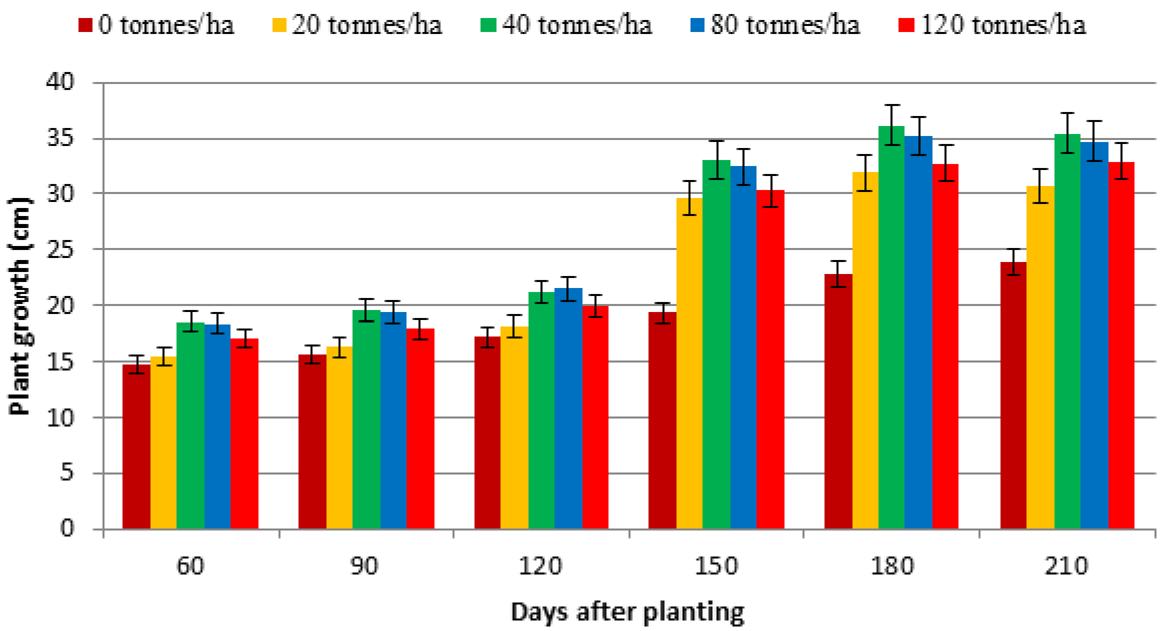

Figure 2. Plant height of Smuts Finger grass measured over 210 days after the initial incorporation of different levels of cattle manure. *Bars indicate standard error*

Leaf area index

Tall Fescue

In the later half of the experimental period Tall Fescue pasture, which received manure produced significantly greater leaf areas compared with the control plots (Table 2). In the first measurement at 120 days after planting (DAP), the leaf area on both 80 and 120 tonnes/ha plots was statistically similar but significantly greater ($P \leq 0.05$) than the other treatments. A similar trend was observed on both 40 and 20 tonnes/ha treatments which were, in turn, greater ($P \leq 0.05$) than on the control. At 150 DAP, the highest Tall Fescue leaf area was produced in both 80 and 120 tonnes/ha cattle manure followed by 40 tonnes/ha, 20 tonnes/ha and 0 tonnes/ha respectively. At the last measurement (180 DAP) the highest leaf area was found in 80 tonnes/ha cattle manure amended-plots followed by 120 tonnes/ha, 40 tonnes/ha and 20 tonnes/ha respectively and the least was on the control. McAndrews et al (2006) also reported that lucerne plants in plots receiving fresh and composted swine manure produced a significantly greater leaf area (39%) than did the control.

Table 2. Leaf area index of Tall Fescue as influenced by different levels of cattle manure

Cattle manure	**Leaf area index days after planting (m^2)**		
tonnes/ha	**90-120**	**120-150**	**150-180**
0	14.9^{C}	17.6^{D}	16.2^{E}
20	19.7^{B}	27^{C}	25.7^{D}
40	24.0^{B}	39.1^{B}	37.6^{C}
80	33.3^{A}	50.8^{A}	49^{A}
120	31.5^{A}	47.5^{A}	45.2^{B}
S.E	**±1.04**	**±0.85**	**±0.74**

^{*ABCDE} superscript values in the same 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

Smuts Finger grass

The leaf area responses to increasing manure rates were significantly different during the growing season (Table 3). At the first measurement at 120 DAP, this grass produced the highest leaf area from 40 tonnes/ha when compared to 80 tonnes/ha, 120 tonnes/ha, 20 tonnes/ha cattle manure-amended pots and unamended control. A similar trend was observed at 150, and 180 DAP, with the leaf area from both 40 and 80 tonnes/ha being statistically similar ($P \leq 0.05$) but greater than 120 tonnes/ha, 20 tonnes/ha and the unamended control respectively. A considerable increase in the leaf area on both 40 and 80 tonnes/ha plots were most notable. Liebman et al (2004) also reported that the leaf area was increased over a two year period, in response to increasing rates of manure application, but that the leaf area of the control was significantly lower in both years.

Table 3. Leaf area index of Smuts Finger grass as influenced by different levels of cattle manure

Cattle manure tonnes/ha	Leaf area index days after planting m^2		
	90-120	**120-150**	**150-180**
0	12.9^{B}	17.4^{C}	19.5^{C}
20	13.5^{AB}	27.1^{B}	29.5^{B}
40	15.3^{A}	46.5^{A}	49.4^{A}
80	14^{AB}	44.3^{A}	48.3^{A}
120	13.4^{AB}	29.3^{B}	30.8^{B}
S.E.	**±0.42**	**±0.77**	**±0.63**

*^{ABC} *superscript values in the same 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*

Forage Yields

Tall Fescue

The dry matter yields were significantly increased with increasing rates of manure over the 180 day experimental period (Figure 3). In the first harvest, over 60 days, the average dry matter yields from 120 tonnes/ha, 80 tonnes/ha and 40 tonnes/ha cattle manure amended plots were statistically similar ($P \leq 0.05$) but were significantly greater than 20 tonnes/ha and control. Over 90 days, the 120 tonnes/ha plots produced significantly higher yields than 20 tonnes/ha or 0 tonnes/ha treatments. Dry matter yields from 120 to 210 days were the highest on the 80 tonnes/ha with varying degrees of significance between levels of manure. Tall Fescue as temperate species is characterised by high nutrient use efficiency and high nutrient requirement. These results suggest that the use of cattle manure improved the nutrient status of the soil, which increased the forage yields. Lund et al (1975) found that the continuous application of dairy cattle manure at a rate of 65 $tha^{-1}year^{-1}$ for three years produced excellent yields of coastal Bermudagrass (*Cynodon dactylon* L.) as compared to control treatments.

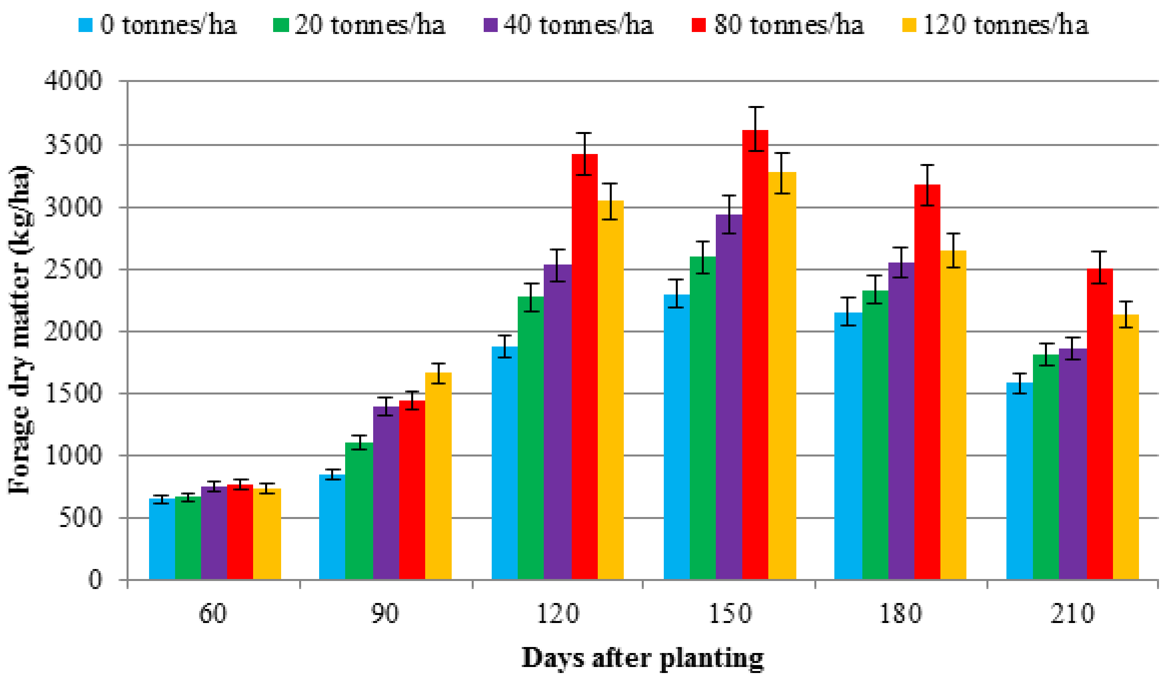

Figure 3. Influence of different treatment levels of cattle manure on the forage dry matter yields of Tall Fescue over six harvests. *Bars indicate standard error.*

Smuts Finger grass

The forage yields were also significantly influenced by different levels of cattle manure treatments (0, 20, 40, 80 and 120 tonnes/ha) (Figure 4). Forage yields for the first and second cuttings from 60 to 90 days were significantly greater for the 40 and 80 tonnes/ha plots than on 120, 20 and 0 tonnes/ha plots. For the fourth harvest over 120 days and the last cutting over 210 days, the grass biomass from both 40 and 80 tonnes/ha plots was statistically similar, but greater ($P \leq 0.05$) than that from 120 tonnes/ha, 20 tonnes/ha and unamended control. With respect to nutrient use and requirement, Smuts Finger grass as tropical species is characterised by low nutrient requirement and low nutrient use efficiency. These results indicated that incorporation of cattle manure into soil does have beneficial effects on plant yields by improving fertility of the soil. Ladha et al (2002) also reported that wheat yields were consistently higher in the farmyard manure treatments than on the control.

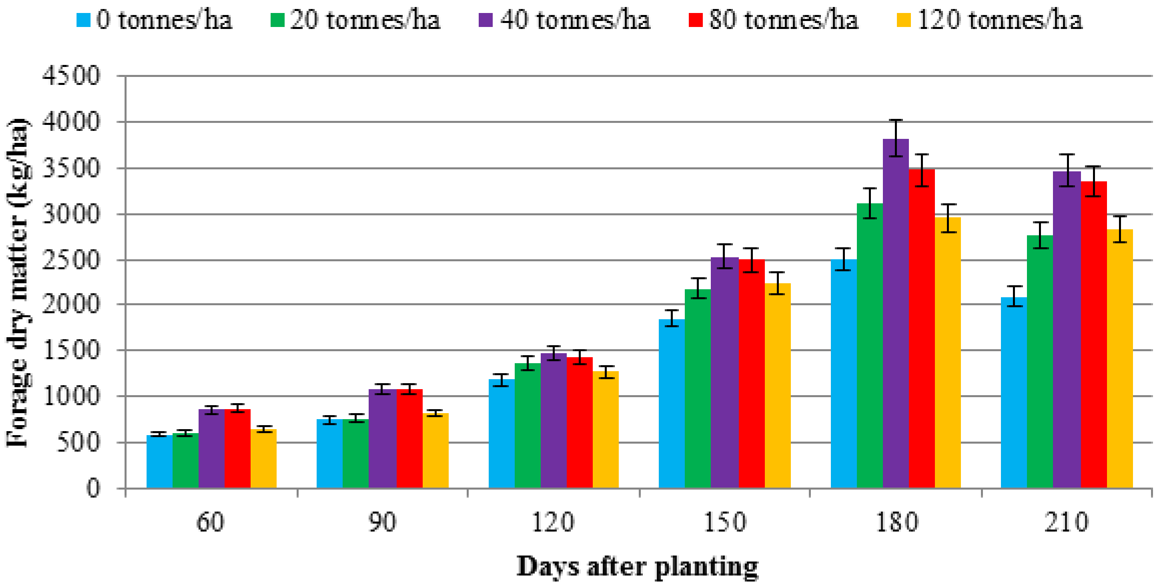

Figure 4. Influence of different treatment levels of cattle manure on the forage dry matter yields of Smuts Finger grass over six harvests. *Bars indicate standard error*.

Stubble biomass (Tiller Development)

Tall Fescue

Significant differences in stubble biomass were detected on plots treated with different rates of cattle manure (Table 4). The highest stubble biomass was achieved on 80 tonnes/ha plots. The stubble biomass from 40 and 120 tonnes/ha cattle manure-amended plots although significantly less, were statistically similar but significantly greater ($P \leq 0.05$) than both the 20 tonnes/ha and the unamended control (0 tonnes/ha) respectively. The beneficial effects of incorporation of cattle manure were very clear in the differences between amended plots and unamended plots. Hati et al (2008) reported that the addition of organic matter, either through animal manure or through crop residues, enhanced soil physical properties which, in turn, promoted higher nutrient and water uptake by the crops. Saha et al (2008) also reported that the shoot dry weight of barley was significantly increased by the incorporation of animal manure compared to the control treatment.

Table 4. Stubble biomass (kg/ha) of Tall Fescue grown on a soil amended with different levels of cattle manure.

Treatment tonnes/ha	R1	R2	R3 kg/ha	R4	R5	Mean
0	3354	4558	3570	5376	2793	3330^{D}
20	6784	5140	6268	6929	6487	6322^{C}
40	7454	8661	8267	7673	8415	8094^{B}
80	8180	9748	9145	8580	9324	8995^{A}
120	7539	7328	8177	7669	8054	7753^{B}
S.E.						**±4.22**

$*^{ABCD}$ superscript values in the same 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

Smuts Finger grass

The stubble biomass was increased significantly by the application of cattle manure (Table 5). The average stubble biomass was highest on the 40 tonnes/ha plots, followed by that on

80 tonnes/ha, 120 tonnes/ha and 20 tonnes/ha treatments respectively, while the lowest was on the unamended control (0 tonnes/ha). Yang et al (2004) reported that the application of dairy cattle manure significantly increased the yield of maize and facilitated the allocation and transfer of nutrient elements to the maize ears and grains. Reddy et al (2000) also found that the application of cattle manure, at rates of 4, 8 and 16 tonnes/ha increased the Kentucky bluegrass (*Poa pratensis*) yields by 42%, 57% and 75%, respectively, and Wild rye (*Elymus canadensis*) yields by 67%, 116% and 143%, respectively over the control.

Table 5. Stubble biomass (kg/ha) of Smuts Finger grass grown on a soil amended with different levels of cattle manure.

Treatment tonnes/ha	R1	R2	R3 kg/ha	R4	R5	Mean
0	4122	4485	5231	4326	4919	4617^{B}
20	4768	5436	4500	4199	5641	4909^{AB}
40	5210	5940	5768	5610	6364	5778^{A}
80	4423	6078	6587	6335	5097	5704^{AB}
120.	5295	4852	5869	5544	5001	5312^{AB}
S.E						**±1.16**

*^{AB} *superscript values in the same 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.*

Root Biomass

Tall Fescue

The root biomass was significantly influenced by increasing rates of cattle manure (Table 6). The highest root biomass was recorded in 80 tonnes/ha plots, followed by 40 tonnes/ha, 120 tonnes/ha and 20 tonnes/ha cattle manure-amended plots respectively, while the lowest root biomass was on the control plots. This indicated that the application of cattle manure to soil provided definite benefits for root development but it must be noted that 120 tonnes/ha had a negative effect. This implies that excessive application rates can have adverse effects on plant root development. Zhang et al (2006) found the highest root biomass in the soil treated with animal manure compared to control sites.

Table 6. Root biomass (kg/ha) of Tall Fescue grown on a soil amended with different levels of cattle manure.

Treatment tonnes/ha	R1	R2	R3 Ton/ha	R4	R5	Mean
0	1277	1600	1462	1940	1520	1560^{C}
20	1346	1930	1800	1817	2030	1785^{BC}
40	2227	2341	2295	2151	1995	2202^{B}
80	2871	2306	2676	3131	3363	2870^{A}
120	1689	1438	1823	2199	2117	1853^{BC}
S.E.						**±1.77**

*^{ABC} *superscript values in the same 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.*

Smuts Finger grass

The root biomass of this species was only increased significantly with increasing rates of cattle manure to a level of 40 tonnes/ha (Table 7). The average root biomass was highest in 40 and 80 tonnes/ha plots, followed by 120 and 20 tonnes/ha cattle manure-amended plots, but was significantly lower in the unmended control (0 tonnes/ha). The addition of animal manure has been demonstrated to improve the soil physical environment by increasing the above ground and root biomass due to valuable supply of plant nutrients in sufficient quantities (Rasool et al 2008). Yang et al 2004 also found that root biomass for the animal manure treatment increased significantly as compared to the control plots.

Table 7. Root biomass (kg/ha) of Smuts Finger grass grown on a soil amended with different levels of cattle manure.

Treatment tonnes/ha	R1	R2	R3 Kg/ha	R4	R5	Mean
0	1099	899	1113	793	1049	991[C]
20	1162	1268	1357	1131	1074	1198[B]
40	1403	1616	1566	1354	1470	1482[A]
80	1353	1701	1461	1289	1366	1434[A]
120	1253	1319	1312	1231	1523	1328[AB]
S.E.						**±0.8**

*[ABC] *superscript values in the same 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.*

Soil nutrient concentrations

Tall Fescue

The application of cattle manure resulted in marked increases in the concentration of nutrients in the soil planted to Tall Fescue (Figure 5 and 6). These concentrations increased significantly with the rate of cattle manure. This indicated that the incorporation of organic manure into soil improved soil fertility and was probably the major factor affecting the growth of Tall Fescue. Kundu et al (2002) reported that the incorporation of animal manure enhanced the soil organic matter and has direct and indirect effects on soil properties and processes, which promoted higher nutrient uptake by plants. Tripathi and Singh, (2004) also reported that application of manure improved soil physical properties and nutrient status of the soil and increased plant growth.

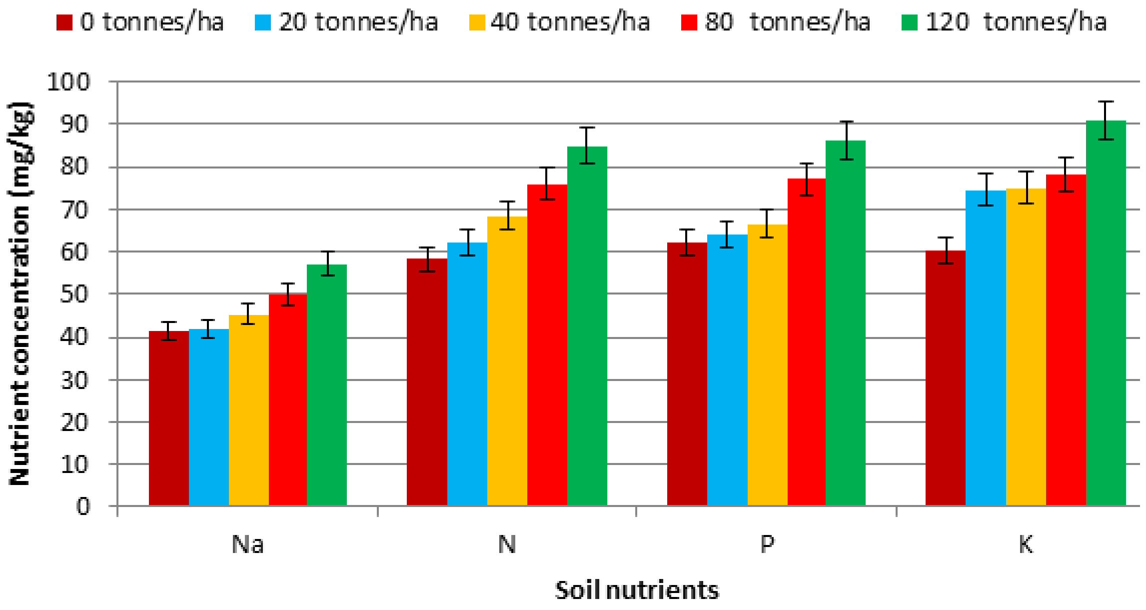

Figure 5. Concentrations of Na, N, P & K in a soil, planted to Tall Fescue, amended with different levels of cattle manure after 210 days growing period. *Bars indicate standard error.*

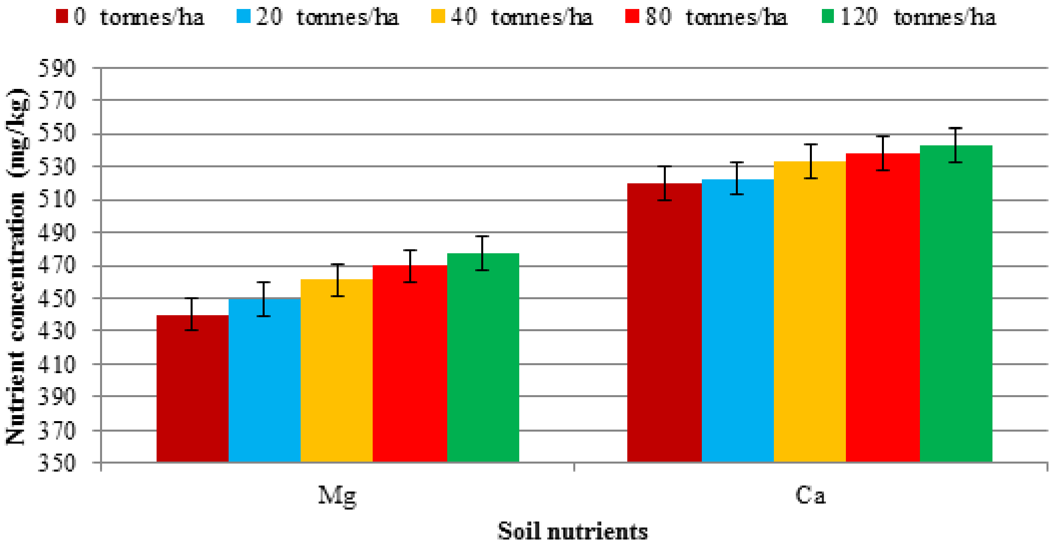

Figure 6. Concentrations of Mg & Ca in a soil, planted to Tall Fescue, amended with different levels of cattle manure after 210 days growing period. *Bars indicate standard error.*

Smuts Finger grass

Different levels of cattle manure also significantly improved the concentrations of nutrients in soil planted to Smuts Finger grass (Figure 7 and 8). The nutrient concentrations increased in the soil with each increase in the rate of manuring. This indicates that the application of cattle manure supplied valuable quantities of soil nutrients and improved soil fertility which contributed to the increased Smuts Finger grass growth. Whalen and Chang, (2002) have shown that the application of animal manure to agricultural land has been viewed as an excellent way to recycle nutrients and organic matter that can support crop production and maintain, or improve, soil fertility. One year after manure application, Sun et al (1995) found a significantly higher proportion of nutrients in soils treated with cattle manure, compared with unamended soils.

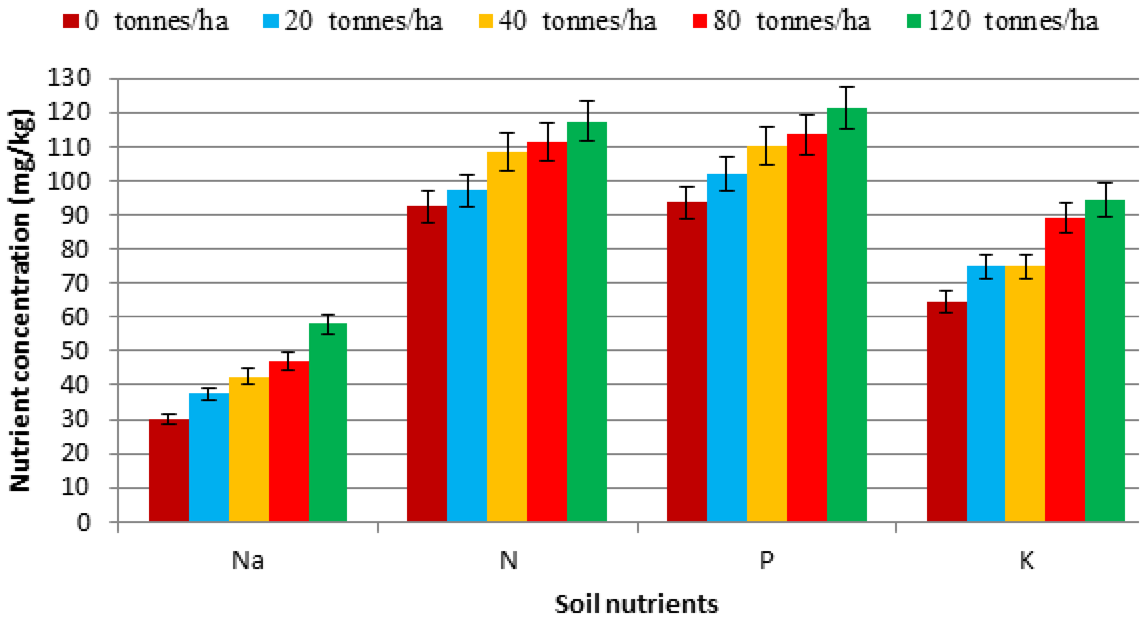

Figure 7. Concentrations of Na, N, P & K in a soil, planted to Smuts Finger grass, amended with different levels of cattle manure after 210 days growing period. *Bars indicate standard error.*

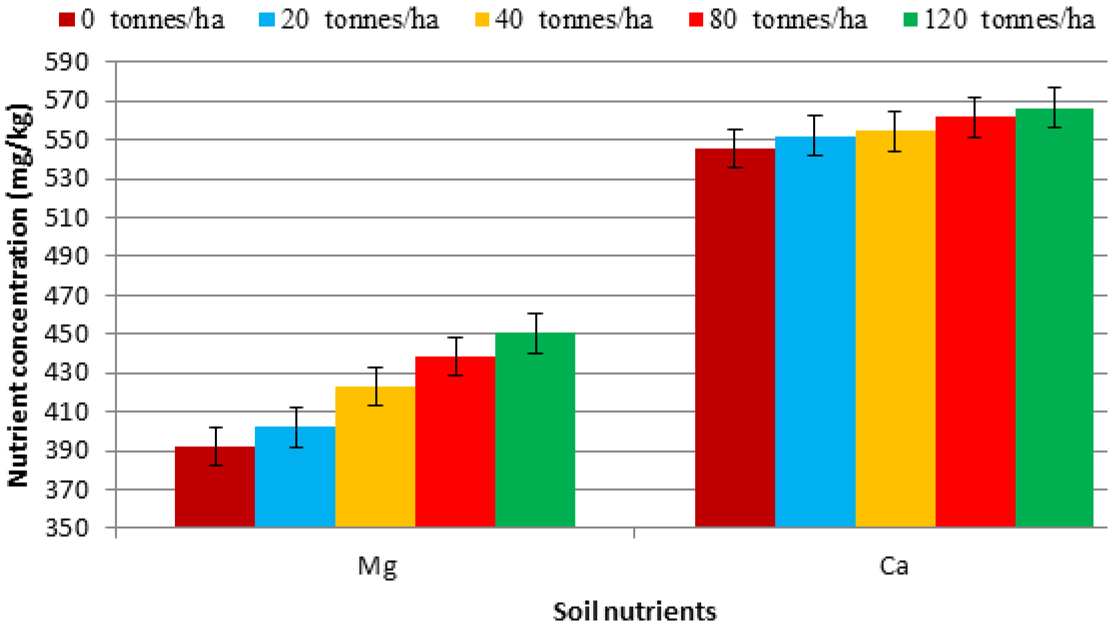

Figure 8. Concentrations of Mg & Ca in a soil, planted to Smuts Finger grass, amended with different levels of cattle manure after 210 days growing period. *Bars indicate standard error.*

Soil pH (H_2O)

The application of cattle manure increased pH (H_2O) in soils planted to Tall Fescue and Smuts Finger grass (Table 8) although these increases were not significant. The highest pH (H_2O) values of both grasses were observed in the 120 tonnes/ha cattle manure treatment, followed by 80, 40 and 20 tonnes/ha cattle manure levels, while the lowest was on the unmended control (0 tonnes/ha). Eghball (1999) also reported an increase in soil pH in plots receiving feedlot manure or compost. In the study of forage yields, nutrient uptake, soil chemical changes and nitrogen volatilization from Bermudagrass treated with dairy manure, Sanderson and Jones (1997) also reported that the soil pH from plots treated with manure was greater than the soil pH of the control sites. It is unlikely, however, that this effect had any implications for growth of grasses, therefore, pH of site was already in optimum range for these species.

Table 8. pH (H_2O) of a soil, planted to Tall Fescue and Smuts Finger grass amended with different levels of cattle manure.

Cattle manure tonnes/ha	**Soil pH (H_2O)**	
	Tall Fescue	**Smuts Finger grass**
0	7.22^{A}	7.22^{A}
20	7.31^{A}	7.28^{A}
40	7.44^{A}	7.31^{A}
80	7.52^{A}	7.34^{A}
120	7.56^{A}	7.38^{A}
S.E.	**±0.43**	**±0.39**

*^{A} *superscript values in the same column followed by a same letter are not significantly different according to Duncan's test at the P value ≤ 0.05. S.E. is the standard error.*

Conclusions

- This study has demonstrated that plant height, leaf area index, forage yields, stubble biomass and root biomass were all beneficially influenced by the incorporation of different levels of cattle manure.

- The growth of Tall Fescue was best with 80 tonnes/ha cattle manure and Smuts Finger grass was best at 40 tonnes/ha. Tall Fescue is temperate species with high nutrient use efficiency and Smuts Finger grass is tropical species identified with low nutrient use efficiency.

- All plant parameters were significantly lower in the control treatment (0 tonnes/ha).

- The application of cattle manure also resulted in improved nutrient concentration and pH (H_2O) in the soil. In addition to the above parameters cattle manure can also improve soil structure and cation exchange capacity of the soil, which might also associated with increased plant yields.

- The application of cattle manure has a potentially very important role to play as an amendment to improve nutrient cycling.

- The addition of cattle manure to soil provides several potential benefits by improving physical properties and fertility of the soil and promoting better rooting.

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