

Effect of combined application of cattle manure and mineral fertilisers on the growth characteristics and quality of *Pennisetum purpureum* fodder

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Abstract

Smallholder urban and peri-urban dairy farmers use elephant grass (*Pennisetum purpureum*) fodder on top of crop wastes for feeding livestock. However, with limited application of soil fertility management techniques, there has been progressive deterioration of soil fertility. Consequently, fodder yields have declined leading to reduced milk output, and in turn, to unstable household incomes and food insecurity. This study investigated whether composted cattle manure alone, or in combination with mineral fertilizers could improve fodder production.

Application of cattle manure at low (ML), medium (MM) and high (MH) rates, or in combination with mineral fertilisers at medium (MFM) and high (MFH) rates significantly increased the leaf area indices (LAIs) and dry matter (DM) yields of *Pennisetum purpureum* fodder. The mean LAIs of treatments ML, MM, MH, MFM and MFH were 3.58, 3.69, 3.31, 3.28 and 3.56 respectively, and were significantly higher than 2.89 for the control which did not receive manure and fertilisers. Fodder yields from these treatments were 7.15, 6.99, 6.74, 6.80 and 7.01 ton ha⁻¹. Fodder obtained from ML, MM and MFH contained greater proportions of leaf than fodder from the control, indicating that there was greater vegetative growth in these treatments than in the control. Since the leaves of plants usually contain less fibre and thus are more easily digested than stems, higher leaf content was an indication of improvement in fodder quality. The *in vitro* organic matter digestibilities of fodder from all treatments were similar but greater than that of the control.

Key words: Dairy cows, fodder yields, leaf area index, smallholder dairy farmers

Introduction

The excreta of dairy cows can contribute to the improvement of soil fertility and productivity if well conserved and recycled. Although animal manure is of major importance in nutrient recycling on smallholder farms, it does not supply plants with sufficient amounts of nutrients (Giller et al 1997). Farmers can only achieve better crop yield responses when they apply large amounts of animal manure (Probert et al 1995), which indicates that animal manure

alone is ineffective as a source of nutrients for plants due to large losses of nutrients during storage. Other researchers, notably Makokha et al (2001) and Lekasi et al (2001) also reported that the quantities of manure available on the majority of smallholder farms are not enough to sustain soil fertility. Therefore, a strategic intervention like the application of cattle manure in combination with mineral fertilisers could be a better option.

Soil quality is a major factor determining the sustainability of the urban and peri-urban smallholder dairy production that provides livelihood in terms of nutrition, manure for crop production and generating income and employment. Through sampling and analysis of soils and observation of crops during extensive field tours, soil nutrient depletion was identified as the major constraint to obtaining optimum maize grain and fodder yields in the urban and peri-urban areas of Uganda (Katuromunda et al., 2001; Mugisa et al., 1999). These studies also showed that integration of forage legumes into maize and *Pennisetum purpureum* enhanced fodder and milk yields, with commensurate increase in profitability. It was envisaged that the productivity of smallholder farming could further be improved if farmers conserved the cattle manure produced on their farms and recycled it back into the soil.

Materials and methods

Production of composted cattle manure and soil preparation

Cattle manure was derived from faeces excreted by dairy cows offered *Pennisetum purpureum ad libitum* and supplemented with *Calliandra* meal. The manure contained 18.6, 7.30 and 0.000355 g kg⁻¹ of total N, P and NH₄-N respectively. The soil used was collected from a field at Makerere University Agricultural Research Institute Kabanyolo, and was a ferrallitic sandy-clay loam. The soil's total N and the available P concentrations were 1.98 and 0.027 g kg⁻¹ soil, respectively. Prior to the experiment, the soil was heat-sterilised and then analysed for its physical and chemical characteristics following methods described by Okalebo (1985).

Experimental design and measurements

The greenhouse experiment comprised twelve treatments arranged in a split plot design with three main plots, four sub-plots and replicated four times. The experimental unit was a 25 cm diameter plastic pot filled up to the height of 20 cm with 10 kg of sandy-clay loam soil (dry weight basis). The composted cattle manure and mineral fertilizers [urea (46% N) and SSP (18% P)] which were added to each pot were thoroughly mixed with 8 kg soil, placed in the pot and covered with additional 2 kg of soil to provide a manure-free layer that would minimize NH₃ volatilization. The main plots comprised three soil amendment treatments namely; sole composted cattle manure application, sole mineral fertiliser application and composted cattle manure + mineral fertiliser application. Each of the amendments was applied at four rates that supplied N and P as described in Table 1.

The rates of manure application in treatments that received manure alone were zero, 2.7, 5.4 and 10.8 tons ha⁻¹ for the control, ML, MM and MH, respectively. These rates of manure application supplied P at rates of zero, 19.6, 39.1 and 78.2 kg P ha⁻¹, respectively (Table 1).

For the case of treatments which received mineral fertilisers only, they were applied at rates that supplied same amounts of N and P as cattle manure. Treatments where combinations of cattle manure and mineral fertilisers were applied, the two sources of N and P were combined in a way that each contributed half the amount of N and P that would lead to the application rates of zero (control), 50 (MFL), 100 (MFM) and 200 (MFH) kg N ha⁻¹ and zero, 19.6, 39.1 and 78.2 kg P ha⁻¹.

One *Pennisetum purpureum* cutting with two nodes was planted by laying it horizontally at a depth of 3 cm below the soil surface in each plastic pot. The pots were irrigated every the other day with two litres of tap water to ensure that they are maintained at the same moisture content of 80% field capacity. Counting of leaves and measuring leaf sizes to determine the leaf area index (LAI) commenced at the end of third week from planting date, and was repeated fortnightly up to week 11. The area of each leaf was calculated using the formula 0.71 (length x width), where 0.71 is a constant for grasses. The LAI was then calculated by dividing the total leaf area at a particular time of measurement, with the area of soil surface in the plastic pot.

Table 1. Description of the experimental treatments

Treatment	N	P	Nutrient sources
	(kg ha ⁻¹)		
Control	0	0	Zero manure and fertilizers added
ML	50	19.6	Composted cattle manure only
MM	100	39.2	Composted cattle manure only
MH	200	78.4	Composted cattle manure only
FL	50	19.6	Urea and Single superphosphate
FM	100	39.2	Urea and Single superphosphate
FH	200	78.4	Urea and Single superphosphate
MFL	25	9.8	Composted cattle manure
	25	9.8	Urea and Single superphosphate
MFM	50	19.6	Composted cattle manure
	50	19.6	Urea and Single superphosphate
MFH	100	39.2	Composted cattle manure
	100	39.2	Urea and Single superphosphate

ML, MM and MH = Low, medium and high rates of manure-only application, respectively;

FL, FM and FH = Low, medium and high rates of fertiliser-only application, respectively;

MFL, MFM and MFH = Low, medium and high rates of cattle manure + mineral fertiliser combinations, respectively.

Harvesting of the above ground biomass in each pot was done at the end of week 11. Fodder was chopped into pieces of about 5 cm length, placed in a polythene bag and weighed immediately. After weighing, chopped fodder was dried in the oven at 60 °C for 72 hours and then weighed to determine fodder DM yield per pot. Fodder from each pot was then separated into leaf and stem, and each portion weighed again. After harvesting fodder, the pots were watered and left undisturbed so that *Pennisetum purpureum* sprouts again. The above procedure was repeated for four consecutive rounds.

Chemical analysis of samples and data analysis

The leaf and stem portions from each pot were recombined and ground to pass through a 1mm sieve. Ground samples were then analysed to determine their OM contents by loss on ignition in a muffle furnace at 550°C; total N, P, K and Ca (Okalebo 1985) and *in vitro* organic matter digestibility (IVOMD) (Tilley and Terry 1963). The fibre (NDF, ADF and ADL) contents were determined using the Van Soest and Robertson (1985) method. Statistical analyses of data were carried out using Factorial ANOVA of the Statistical Analyses Systems (SAS 2002). Mean comparisons were made using the least significant difference (LSD) and differences were considered significant at the 5% level.

Results

Leaf area index

The LAIs for all treatments increased gradually as the period of growth advanced up to the eleventh week (Figures 1 to 3). The *Pennisetum purpureum* plants were able to regenerate after every round of harvesting. At the age of three weeks, the LAIs of all the treatments were similar, except those of FH, ML and MFM which were higher than that of the control. At the fifth and seventh weeks of growth, no significant differences were observed between the LAIs of all treatments, apart from those of MM and ML which were greater than that of the control. At the ninth week of growth, the LAIs of MM and ML were persistently greater than that of the control. However, no differences were observed among the composted cattle manure-only, as well as those of fertiliser-only treatments. For the case of composted cattle manure + fertiliser treatments, the LAI of MFH was similar to that of MFM but higher than that of MFL.

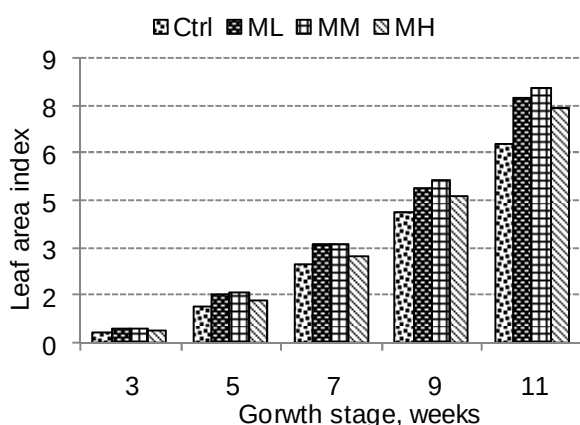


Figure 1. Effect of level of composted cattle manure on LAI of *Pennisetum purpureum* during growth to week 11 from planting

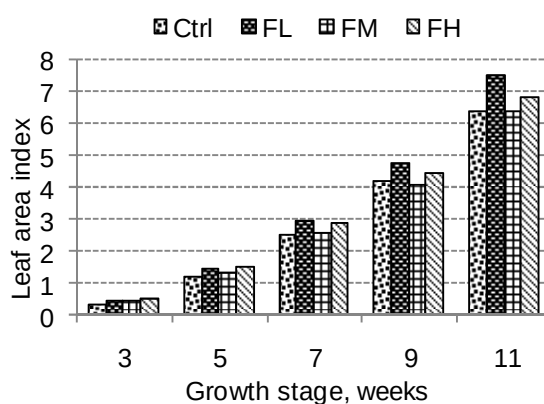


Figure 2. Effect of level of mineral fertilizers on LAI of *Pennisetum purpureum* during growth to week 11 from planting

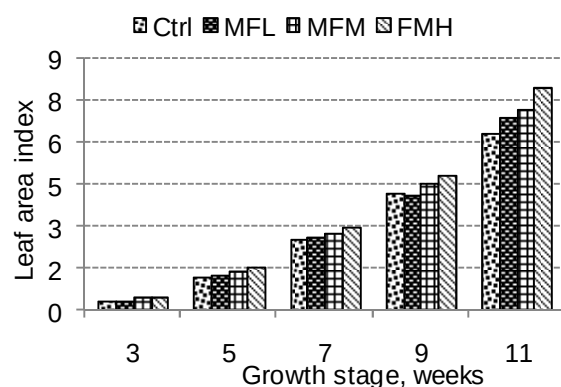


Figure 3. Effect of level of cattle manure + mineral fertilisers on LAI of *Pennisetum purpureum* during growth to week 11 from planting

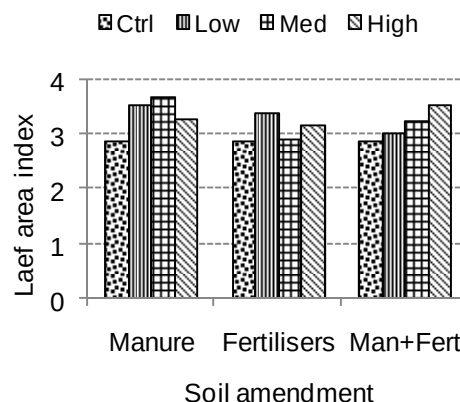


Figure 4. Effect of level of cattle manure, fertilizers and manure + fertilizers on LAI of *Pennisetum purpureum* during growth to week 11 from planting

At the eleventh week of growth, the LAIs of ML, MM, MH, MFH and FL were superior to that of the control. No differences were observed among the composted cattle manure-only treatments. For the case of fertiliser-only treatments, the LAI of FL was similar to that of FH but higher than that of FM. For the case of composted cattle manure + fertiliser treatments, the LAI of MFH did not differ from that of MFM but was higher than that of MFL. The LAI increased with the increase in the level of cattle manure up to MM, but further increase of manure to MH led to a decline in the LAI (Figure 4). Whereas there was no clear response pattern of LAI to the level of mineral fertiliser application, the LAI increased linearly with the level of cattle manure + fertiliser application. Comparisons between the composted cattle manure-only and fertiliser-only treatments revealed that the LAIs of composted cattle manure-only treatments were higher than those of fertiliser-only treatments, except that of FL. When averaged across main treatments, the LAIs were in the order $2.89 < 3.18 < 3.29 < 3.53$ for the control, fertiliser-only, composted cattle manure + fertiliser and the composted cattle manure-only, respectively and highly differed ($P < 0.0001$) from each other.

Fodder dry matter yields and *in vitro* organic matter digestibility

Composted cattle manure significantly increased fodder yields (Table 2). Sole application of fertilisers at different rates did not cause significant increase in fodder yields. The medium (MFM) and higher (MFH) rates of composted cattle manure + fertiliser treatment combinations produced fodder yields which were similar to those of the composted cattle manure-only treatments, and were also greater than that of the control. Comparisons revealed that the lowest rate of composted cattle manure-only (ML) treatment yielded more fodder than the medium rate of fertiliser-only (FM) treatment.

Statistical analysis of pooled data indicated that fodder DM yields across the four rounds of harvesting increased in the order $5.61 < 6.25 < 6.58 < 6.96 \text{ ton ha}^{-1}$ for the control, fertiliser-only, composted cattle manure + fertiliser combinations and composted cattle manure-only

treatments, respectively. Thus, the overall fodder DM yield for the composted cattle manure-only treatments did not differ from that of the composted cattle manure + fertiliser treatment combinations, but was superior to those for the fertiliser-only treatments and the control. The fodder DM yield for the composted cattle manure + fertiliser combinations was similar to that of the fertiliser-only treatments, but was greater than that of the control.

Table 2. Effect of composted cattle manure and mineral fertiliser application on dry matter yields, morphological fractions and IVOMD of *Pennisetum purpureum* fodder

Treatments	Dry matter yields, morphological fractions and IVOMD of fodder			
	Total fodder yield (ton ha ⁻¹)	Leaf yield (ton ha ⁻¹)	Stem yield (ton ha ⁻¹)	IVOMD (kg ha ⁻¹)
ML	7.15 ^a	5.45 ^{ab}	1.71 ^{abc}	561 ^b
MM	6.99 ^{ab}	5.58 ^a	1.43 ^{abcd}	628 ^a
MH	6.74 ^{abc}	5.03 ^{abcd}	1.72 ^{abc}	615 ^a
FL	6.29 ^{abcd}	4.90 ^{abcd}	1.40 ^{bcd}	624 ^a
FM	5.98 ^{bcd}	4.67 ^{bcd}	1.32 ^{cd}	597 ^{ab}
FH	6.48 ^{abcd}	4.60 ^{cd}	1.90 ^{ab}	598 ^{ab}
MFL	5.91 ^{cd}	4.84 ^{abcd}	1.17 ^d	613 ^a
MFM	6.80 ^{abc}	4.90 ^{abcd}	1.91 ^a	590 ^{ab}
MFH	7.01 ^{ab}	5.30 ^{abc}	1.72 ^{abc}	606 ^a
Control	5.61 ^d	4.47 ^d	1.18 ^d	514 ^c
LSD _(0.05)	1.06	0.81	0.50	39.2

^{abcd} Means within the same column followed by different superscripts differ ($P < 0.05$)

ML, MM and MH = Low, medium and high rates of manure-only application, respectively;

FL, FM and FH = Low, medium and high rates of fertiliser-only application, respectively;

MFL, MFM and MFH = Low, medium and high rates of cattle manure + mineral fertiliser combinations, respectively.

Yields of *Pennisetum purpureum* leaves and stems varied ($P < 0.05$) between treatments (Table 2). Leaf yields of the low (ML) and medium (MM) rates of composted cattle manure application were significantly higher than that of the control. However, leaf yields of the fertiliser-only treatments were similar across all the rates of application as well as the control. The leaf yields of the composted cattle manure + fertiliser treatment combinations did not differ from that of the control, except MFH whose leaf yield was superior. With the exception of MM, FL, FM and MFL the proportions of stem in fodder from all treatments were higher than that of the control.

The application of composted cattle manure, mineral fertilisers and composted cattle manure + fertiliser combinations led to the production of *Pennisetum purpureum* fodder with better IVOMD as compared with the control (Table 2). Among the composted cattle manure-only treatments, the IVOMD levels of MM and MH were similar, but were higher than that of ML which indicated an improvement in the digestibility of fodder as the quantity of cattle manure applied increased. No differences were observed among IVOMD levels of fodder from the fertiliser-only as well as the cattle manure + fertiliser treatments. Chemical analyses of fodder from all the treatments did not show remarkable differences in the concentrations of N, P, K, NDF, ADF and ADL (Table 3).

Table 3. Effects of composted cattle manure and mineral fertilisers on chemical composition of *Pennisetum purpureum* fodder

Treatments	Chemical components (g kg ⁻¹ DM) of fodder								
	OM	Ash	N	P	K	Ca	NDF	ADF	ADL
ML	875 ^a	125 ^c	15.8 ^b	2.60 ^{ab}	25.2 ^{bc}	2.89 ^{ab}	584	375 ^{ab}	70.0 ^{bc}
MM	868 ^{ab}	132 ^{bc}	16.5 ^{ab}	2.89 ^a	25.8 ^{bc}	2.64 ^b	568	365 ^b	91.3 ^{ab}
MH	864 ^b	136 ^b	16.5 ^{ab}	2.48 ^{bc}	27.9 ^{abc}	2.68 ^{ab}	590	403 ^{ab}	73.8 ^{bc}
FL	862 ^b	138 ^b	17.5 ^a	2.27 ^c	26.6 ^{bc}	3.00 ^{ab}	586	491 ^a	104 ^a
FM	866 ^{ab}	134 ^{bc}	16.9 ^{ab}	2.27 ^c	28.7 ^{ab}	3.02 ^a	588	378 ^{ab}	82.5 ^{abc}
FH	868 ^{ab}	132 ^{bc}	16.8 ^{ab}	2.33 ^{bc}	24.6 ^c	2.91 ^{ab}	599	416 ^{ab}	86.3 ^{ab}
MFL	849 ^c	151 ^a	17.2 ^a	2.22 ^c	27.9 ^{abc}	2.69 ^{ab}	565	378 ^{ab}	73.8 ^{bc}
MFM	866 ^{ab}	134 ^{bc}	16.3 ^{ab}	2.28 ^c	24.8 ^c	2.67 ^{ab}	581	369 ^b	72.5 ^{bc}
MFH	865 ^{ab}	135 ^{bc}	17.3 ^a	2.30 ^{bc}	24.4 ^c	3.01 ^{ab}	558	366 ^b	58.8 ^c
Control	860 ^b	141 ^b	16.8 ^{ab}	2.54 ^{bc}	30.4 ^a	2.84 ^{ab}	560	404 ^{ab}	76.3 ^{bc}
Treatment means	864	136	16.8	2.4	26.6	2.8	578	395	78.9
LSD _(0.05)	10.3	10.3	1.3	0.32	3.8	0.36	42.2	121	25.3

^{abc}Means within a column followed by different superscripts differ ($P < 0.05$)

Discussion

Leaf area index

Results showed that the application of composted cattle manure, mineral fertilisers and composted cattle manure + fertiliser combinations improved the LAI of *Pennisetum purpureum* plants as compared to the control, which received no mineral fertilisers and/or composted cattle manure. Comparisons also revealed that LAIs of composted cattle manure-only treatments were consistently higher than those of the fertiliser-only treatments. This was attributed to the fact that in addition to N and P, composted cattle manure supplied other nutrients, all of which had an influence on the growth of *Pennisetum purpureum* plants (Chadwick et al 2000). In addition to supplying nutrients, manures affect plant growth indirectly by improving the physical, chemical and biological properties of soil, such as water retention, pH, cation exchange capacity and microbial activity and diversity (Harris et al 1997). Reddy et al (2000) observed that because of its buffer action on pH, manure increases the levels of P in the soil available to crops than when inorganic fertiliser P is applied at the same rate.

The decline in the LAI when a high level of cattle manure (10.8 ton ha⁻¹) was applied could be due to nutrient imbalances which were brought about by the high pH. The pH of cattle manure used in this study was 7.80. Applying a high level of this manure could have raised the pH of soil, resulting in reduced availability of some nutrients like P and Fe, which in turn affected the growth of the plants. Increasing the levels of mineral fertilisers when applied alone did not cause significant changes in the LAIs because, irrespective of the amounts of fertilisers applied, their effect on soil is short-lived. Fertilisers released the nutrients readily

at the onset, and were exhausted from the soil following the first and second rounds of fodder harvests. For the case of manure + fertiliser combinations, linear increases in LAI suggest that there was a synergy between cattle manure and mineral fertilisers. Kimani et al (2004) observed that when cattle manure and mineral fertilisers are applied together in the field, they complement each other and the resultant improvement in crop yields is greater than when they are applied separately.

Leaves of forage plants are usually better in nutritive quality, particularly in terms of crude protein content and digestibility, than stems from the same plant. Therefore, the higher the leaf component in fodder, the better the nutritive quality. Collins and Fritz (2003) noted that forage quality is a function of voluntary intake. When given the opportunity, ruminants usually select leafy forages over those with higher proportions of stem material. It is also important to note that while the nutritive quality of leaves changes little as shoots mature, the fibre content in maturing stems increases rapidly and as a result their digestibility declines (Collins and Fritz 2003).

The overall mean LAI for the composted cattle manure-only treatments was superior to that of the composted cattle manure + fertiliser treatments. Manure application rates in the composted cattle manure-only treatments were twice that in the manure + fertiliser treatments. Therefore, the superiority of the LAI for composted cattle manure-only treatments confirms the report by Probert (1995) that better crop responses are achieved when cattle manure is applied in large amounts. Manures mineralize and release nutrients slowly, and therefore, their nutrient supplying capacity lasts a little longer than that of mineral fertilisers. This was the reason why LAIs of composted cattle manure-only treatments were greater than those of the fertiliser-only treatments.

Fodder dry matter yields and *in vitro* organic matter digestibility

Results indicated that fodder DM yields for the composted cattle manure-only and the medium (MFM) and high (MFH) rates of composted cattle manure + fertiliser treatments were greater than that of the control. This was attributed to the ability of composted cattle manure to supply a variety of nutrients other than N and P, and by improving the physical, chemical and biological properties of soil. The fodder DM yield advantage in response to manure and manure + fertiliser application was also attributed to the slow release of organic nutrients in the manure, which could have benefited the plants over the growing period. Whereas nutrients in fertilisers are in readily soluble form, and therefore, become available to crops immediately following application, nutrients in manure must mineralize, and thus stay longer in the soil for the benefit of the growing plants over the growing seasons (Eghball and Power 1999, Williams et al 1995). Paul et al (1998) observed that although the soil inorganic N concentrations decreased with successive corn harvests, the decrease was not as great with the manure treatments compared to the fertiliser treatments. A study conducted by Kabirizi (2006) in Masaka District, Uganda revealed that *Pennisetum purpureum* fodder DM yields were quite low (4.17 ton ha⁻¹ year⁻¹) in urban areas as compared to fodder yields in the peri-urban and rural areas (4.95 and 5.72 ton ha⁻¹ year⁻¹, respectively). Therefore, utilization of cattle manure either alone or in combination with

mineral fertilizers as reported in this study, especially in the urban areas where cultivation is intensive would alleviate the problem of low fodder yields.

Fodder obtained from ML, MM and MFH contained greater proportions of leaf than fodder from the control. This suggests that there was greater vegetative growth in these treatments as compared to the control. In addition to having higher crude protein than stem, leaves of plants usually contain less fibre and thus are easily digested than stems. Because of these two reasons, higher leaf content is an indication of improvement in the quality of fodder. Thus, fodder from treatments ML, MM and MFH was regarded to be of better quality than that from the control.

The IVOMD levels of fodder from all treatments were similar but greater than that of the control. This implies that sole application of cattle manure or supplementing it with mineral fertilisers would lead to production of fodder with the digestibility similar to that of fodder produced using mineral fertilisers. Highly digestible forages increase animal production largely by increasing energy intake. Therefore, by conserving and utilizing cattle manure produced on farm, dairy farmers would benefit by minimizing the expenditure on quantities of fertilisers to be purchased.

Conclusions

- Sole application of composted cattle manure at low (ML), medium (MM) and high (MH) rates, or in combination with mineral fertilisers (urea and SSP) at medium (MFM) and high (MFH) rates, improved the growth of *Pennisetum purpureum* fodder in terms of LAIs and DM yields.
- Fodder obtained from ML, MM and MFH contained greater proportions of leaf and had higher IVOMD than fodder from the control, and therefore, was regarded to be of better quality.
- Sole application of composted cattle manure or in combination with urea and SSP at rates indicated herein has the potential of improving the yields and quality of *Pennisetum purpureum* fodder.
- There was no advantage in applying cattle manure in combination with mineral fertilisers over sole cattle manure application, since both treatments produced similar quantities of fodder with similar digestibilities.
- Composted cattle manure should only be supplemented with mineral fertilisers in case its supply is inadequate.
- Applying a combination of composted cattle manure, urea and SSP has a further advantage of lowering the farmer's expenditure on the purchase of fertilisers, since the quantities to be bought would be lower.

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