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Full Length Research Paper

Productivity of soil fertilised with faecal manure of cattle fed Calliandra, Gliricidia and Luecaena browse/maize silages

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The use of farmyard manure to improve soil productivity is a key element in mixed crop/livestock farming systems. Browse/maize silage mixtures (20% browse DM basis) of Calliandra, Gliricidia, and Leucaena and maize silage alone and their corresponding cattle faecal manure were applied to the soil to determine their effect on soil productivity. Hopi Red Dye Amaranthus (*Amaranthus cruentus*) was used as the test crop. Its dry matter (DM) yield, and crude protein and fiber content were determined. The browse/maize silages had higher total N and narrower C:N ratio than that of maize silage alone. Calliandra/maize silage mixture had higher levels of ADFN and lignin. Cattle faecal manure derived from the browse/maize silages had higher total N and ADFN content and narrower C:N ratios compared to the faecal manure from maize silage alone. Application of the browse/maize silages and the corresponding cattle faecal manures raised C, N and C:N of the soil compared to the control soil. The treated soils maintained higher levels of C and N up to the third crop but the C:N ratios were similar with the control soil. Amaranthus DM yield was highest with faecal manure treatments. Treatments with silages had no DM yield advantage over the control soil. Addition of faecal manure from maize silage alone gave highest DM yield followed by feacal manure from Gliricidia/maize and Leucaena/maize silages. Faecal manure from Calliandra/maize silage gave lower yields in spite of having similar levels of N. Much of its N was fiber bound, thus limiting availability of the N for plant growth.

Key words: Calliandra, Gliricidia, Leucaena, Amaranthus, browse.

INTRODUCTION

The use of manure to improve soil productivity is a key element in mixed agro-pastoral farming systems (Fernandez-Rivera et al., 1993; Karl et al., 1994; Twinamasiko, 2001; Kajura, 2001). Farmyard manure has greater positive effects on soil than resting periods, with crop response to farmyard manure increasing linearly with rate of application and total number of applications (Ssali, 2001). The beneficial effects of farmyard manure on the soil is due to the presence of hormones, vitamins, antibiotics and growth regulating substances such as biotin, whose stimulating effect on root growth and on the growth of micro organisms (yeast cultures) has been demonstrated (Karl et al., 1994). The nutrient release from farmyard manure is dependent on how fine it is spread, the proportion of soluble N, the C:N ratio and storage methods (Karl et al., 1994; Katuromunda et al., 2010). Also, the type of feed and passage of the feed through the ruminants` digestive tract affects the availability of nutrients in the manure. The total amount and proportion of nutrients excreted in faeces and urine vary with the lignin:neutral-detergent fiber (NDF), lignin:N and polyhenol:N ratios of the diets (Powell et al., 1994). The browses, Calliandra and Leucaena have substantial levels of tannins and lignin

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(Bareeba and Aluma, 2000) which bind protein and protect it from degradation in the rumen (Fahey et al., 1980; Navas-Camancho et al., 1993). Tannins have a binding effect and interfere with adequate utilization of browse protein by grazing animals and shift N excretion from urine to faeces and from faecal microbial to undigested feed N (Topps, 1992). The binding of protein could also subsequently affect the availability of manure N in the soil when animals are fed browse diets. In Uganda, zero-grazing farmers are encouraged to preserve forage which is usually elephant grass (*Penisetum purpureum*) by ensiling. The crude protein (CP) content of the silage could be improved to 12% DM by ensiling the elephant grass with browses such as Calliandra, Leucaena or Gliricidia (Kato et al., 2004). These browses have been identified and recommended as the most suitable species for supplementation of indigenous goats under tethering or free range grazing conditions in the sub-humid zones of Uganda (NARO, 1999; Sabiiti, 2001). The purpose of this study was to investigate the effect of applying faecal manure from cattle fed Calliandra, Gliricidia and Leucaena browse/maize silages on soil C and N and DM yield and chemical composition of Amaranthus grown on the soil.

MATERIALS AND METHODS

Experiment

The study investigated Amarathus growth response to application to the soil of Calliandra, Gliricidia and Leucaena browse/maize silages (20% browse DM basis), maize silage alone and the corresponding faecal manure from cattle fed the silages.

Preparation of the treatment materials

The silages and manure were obtained from a feeding trial of 12 weeks. The silages and manure samples were air dried, aggregated and ground in a laboratory mill to pass through a 2 mm sieve before application to the soil. The soil used in the experiment was collected from a crop field. The soil was spread out in a screen house to dry after which it was ground to pass through a 2 mm sieve and mixed thoroughly. A sample of the soil was taken for laboratory analysis.

Setting up the experiment and sampling procedures

The experiment was a pot experiment in a screen house set out in a completely randomized design (CRD) with treatments replicated four times. Four kilograms of soil were used per pot. The ground silages and manures applied at the rate of 5 g/kg of soil was equivalent to the rate of manure application of 10 t/ha for 3 years for Uganda, each hectare being equivalent to a plough share of 2,000,000 kg of soil (Anderson and Ingram, 1993; Ssali, 2001). Four successive plantings were made without changing the soil or treatments in the pots. Each planting cycle lasted four weeks. Planting done by seed broadcast in the pots and the seeds covered thinly with soil. Adequate moisture for crop growth was maintained by watering with tap water. The pot soils were sampled at the beginning and after the first, second and third harvests for chemical analysis. Five plants from each pot were harvested at flower bud stage by cutting the plants at collar level, weighed and fresh weights recorded. Whole plant materials for the five plants from each pot were packed in paper bags and dried in the oven at 60°C for 72 h to determine dry matter (DM) content (%) and yield (kg). The dried plant materials were ground in a laboratory mill to pass through a 2 mm sieve and preserved for chemical analysis.

Chemical analyses of the soil, browse/maize silages, faecal manures and the harvested plant material

The soil samples were analyzed for soil OM and C according to Walkley and Black (1993) and N by the Kjeldal method (AOAC, 1990). Samples of the silages, faecal manures and the harvested plant material were analyzed for total N, crude fiber (CF), and ash by the AOAC (1990) procedures, non protein nitrogen (NPN) by the trichloro acetic acid method (Gaines, 1977), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) by the Van Soest and Robertson (1985) procedures; neutral detergent fiber nitrogen (NDFN) and acid detergent fiber nitrogen (ADFN) were obtained by determining N in the NDF and ADF residues respectively.

Data analysis

The data obtained was subjected to statistical analysis by Genstat Release 12.2 and differences between the means were separated using the least significant difference (LSD) method at probability level of 5%.

RESULTS AND DISCUSSION

Composition of the browse/maize silages

The chemical composition of the browse/maize silages applied to the soils is shown in Table 1. The browse/maize silage mixtures had higher levels of N than maize silage alone and maize silage had a much higher C:N ratio. The browse/maize silage mixtures had much less soluble N (NPN), particularly Calliandra mixture compared to maize silage alone. Also, Calliandra mixture had higher levels of insoluble fiber (ADF), fiber bound N (ADFN) and lignin. Therefore, while application of the browse/maize silage materials would introduce more N in the soil than maize silage alone, their low levels of soluble N would limit their decomposition in the soil and availability of their nutrients for plant growth. Maize silage had less N and a wider C:N ratio, but much more soluble N, which would make it more decomposable in the soil and make its nutrients available for plant growth.

Chemical composition of the faecal manures

The chemical composition of faecal manure from feeding cattle the browse/maize silages and applied to the soil is shown in Table 2. Compared to the feed silages (Table 1), all the faecal manures had less C, higher levels of total N and narrower C:N ratio. Digestion in the animals'

Table 1. Chemical composition (% DM) of the browse/maize silages (20% browse) applied to the soil as compost.

	Browse/maize silages			
Composition	**Calliandra**	**Gliricidia**	**Leuceana**	**Maize**
Carbon	46.47	46.23	45.82	46.32
Nitrogen	1.70	1.90	1.87	1.28
C:N ratio	27.34	24.33	24.50	36.19
NPN (% Total N)	21.95	34.71	27.02	41.28
NDF	67.07	61.70	64.90	70.60
ADF	42.40	37.33	35.58	38.27
NDFN (%Total N)	34.49	25.40	31.72	21.52
ADFN (%Total N)	24.82	11.58	14.42	16.14
ADL	19.58	11.85	13.75	6.40

Table 2. Chemical composition (%DM) of the fecal from feeding cattle the browse/maize silages.

	Browse/maize silages			
Composition	**Calliandra**	**Gliricidia**	**Leuceana**	**Maize**
Carbon	41.99	40.10	40.84	41.09
Nitrogen	2.27	2.05	2.28	1.80
C:N ratio	18.50	19.56	17.91	22.83
NPN (% Total N)	19.13	18.43	14.58	12.84
ADF	46.96	46.13	46.50	46.22
ADFN (% Total N)	25.42	19.97	26.11	15.64

gut could have reduced the C content in the undigested material. The N retained in the undigested material depends on the lignin content of the feed material. The browses, Calliandra and Leucaena for example, have substantial levels of tannins and lignin (Bareeba and Aluma, 2000) which bind protein and protect it from degradation. Thus, much of the N in the browse/maize silage diets was retained compared to the non-browse maize silage diet (Fahey et al., 1980; Navas-Camancho et al., 1993). The faecal manures also had less soluble N (NPN) and higher levels of fiber-bound N (ADFN). Faecal manure from maize silage had the lowest level of total and soluble N although the maize silage feed had the highest level of soluble N compared to the browse/maize silages (Table 2). Since maize silage had a high proportion of soluble N much of its N could have been metabolized into microbial protein in the rumen and subsequently utilized by the host animal (Fahey et al., 1980; Navas-Camancho et al., 1993). Faecal manure from maize silage had the lowest level of fiber bound N compared to faecal manure from browse/maize silages. Therefore, although faecal manure from maize silage had a lower level of total N, its N would be readily available for plant growth. Faecal manure from browse/maize silages particularly Calliandra/maize silage had higher levels of fiber bound N, which would limit its OM decomposition and release of their nutrients in the soil for plant growth. The high level of fiber bound N of the browse/maize silages, particularly Calliandra/maize silage mixture persisted in their corresponding faecal manures. This means that the faecal manure from Calliandra silage mixture would decompose slowly and its beneficial effects could last longer in the soil.

Effect of treatments on C, N and C:N in the soil

The levels of C, N and C:N ratios in the soils after the third harvest are shown in Table 3. The results at the initial stage indicated that the treated soils attained higher levels of C, N and a wider C:N ratio as a result of the materials added compared to the control soil. There were variations between treatments which could have arisen because the treatments were based on the manure kg rate of 10 t/ha rather than on the basis of N/ha to be supplied by each treatment. The values after the third harvest indicated that the treated soils maintained higher levels of C and N than the control soil. However, the C:N ratio was similar for all treatments. The fact that the treated soils maintained higher levels of C and N indicated that the treatments were effective in having the expected effects on the soil.

The C:N ratio was similar for all treatments therefore, it is possible that irrespective of rate of decomposition of

Table 3. Mean levels (%) of carbon, nitrogen and C:N ratio of soils fertilized with the browse/maize silages and corresponding fecal manure.

	Soil treatments									
Composition	**Control**	**CS**	**CF**	**GS**	**GF**	**LS**	**LF**	**MS**	**MF**	**LSD**
Initial										
Carbon	0.97	1.39	1.31	1.39	1.22	1.38	1.31	1.31	1.39	0.12
Nitrogen	0.12	0.150	0.130	0.130	0.120	0.140	0.130	0.130	0.14	0.01
C:N ratio	8.08	9.27	10.08	10.69	10.17	10.57	10.08	10.08	9.92	0.87
Mean values after three planting cycles										
Carbon	1.01	1.36	1.41	1.53	1.27	1.41	1.53	1.49	1.31	0.12
Nitrogen	0.12	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.01
C:N	10.58	8.50	9.40	10.20	8.47	9.40	10.20	10.64	9.36	0.87

LSD is at P<0.05; CS, Calliandra/maize silage; CF, fecal manure from Calliandra/maize silage; GS, Gliricidia/maize silage; GF, fecal manure from Gliricidia/Maize silage; LS, Leucaena/maize silage; LF, fecal manure from Leucaena/maize silage; MS, maize silage; MF, fecal manure from maize silage.

Table 4. Fiber and protein composition (% DM) of *Amaranthus cruentus* grown on soils fertilized with browse/maize silages and corresponding cattle fecal manure.

	Soil treatments									
Composition	**Control**	**CS**	**CF**	**GS**	**GF**	**LS**	**LF**	**MS**	**MF**	**LSD**
DM(kg)	0.23	0.26	0.36	0.20	0.40	0.23	0.43	0.22	0.46	0.08
C P	25.08	28.37	27.85	28.03	28.35	27.27	26.98	23.71	28.20	4.04
C F	9.68	10.50	10.31	9.41	11.24	11.32	12.03	9.84	10.75	2.16
NDF	32.02	32.75	25.04	32.63	34.57	34.65	36.28	33.55	42.44	7.78
ADF	14.81	14.82	13.63	15.04	17.77	15.51	18.17	13.59	17.63	2.79

LSD is at P<0.05; CS, Calliandra/maize silage; CF, fecal manure from Calliandra/maize silage; GS, Gliricidia/Maize silage; GF, fecal manure from Gliricidia/maize silage; LS, Leucaena/maize silage; LF, fecal manure from Leucaena/maize silage; MS, maize silage; MF, fecal manure from Maize silage.

the added organic matter to the soil, the C:N ratio subsequently settled to the constant soil ratio of about 10:1 (Russell, 1961; Brady, 1974).

Effect of treatments on DM yield

The mean DM yield (kg) of Amaranthus after treatment of soil with selected manure is as shown in Table 4. *Amaranthus cruentus* grown on soils treated with faecal manure had significantly higher DM yield than that grown on soils treated with silages and the control soil. Soil treatment with silages had no yield advantage over the control soil. Treatment of soils with the faecal manures could have given higher yields because the manures had more N, and narrower C:N ratios, which could have made more N available for plant growth. Of the manure treatments, the soil treated with fecal manure from maize silage alone gave the highest yield in spite of having lower N content and a wider C:N ratio. However, it had less fiber-bound N (Table 2) and therefore, more of its N could have been available for plant growth (Delve et al., 2001). Of the browses, treatment with fecal manure from Gliricidia and Leucaena silage mixtures gave higher yields than treatment with fecal manure from Calliandra silage mixture. The manure from Calliandra/maize silage in spite of having a similar level of N, more of its N was fiber bound (Table 2) and therefore, may not have released as much N in the soil to support as much or higher DM yield.

Effect of treatments on the composition of the plant material

The protein and fiber composition of the Amaranthus is shown in Table 4. Treatment with either silage or manure tended to increase CP and fiber content compared to the control. Amaranthus grown on soils treated with faecal manure had significantly higher DM yield or growth. Hence, the higher fiber content of the Amaranthus. Also, the faecal manures had more N and narrower C:N ratios that could have made more N available that could have resulted into higher CP content of the Amaranthus. Also, the faecal manures had more N and narrower C:N ratios that could have made more N available which could have resulted into higher CP content of the Amaranthus. Lubis and Kumagai (2007) observed that manure application had no effect on chemical composition of maize and sorghum except for crude protein (CP) and that manure application higher than 8 ton/ha might cause greater DM yield of sorghum and maize without any increase in fiber fraction. Mpairwe et al. (2002) observed that intercropping forage legumes with cereals generally resulted in fodder with higher fodder CP concentration, lower NDF and higher DM degradability than fodder from sole cereals.

Conclusion

The results showed that faecal manure from browse/maize silage mixtures would improve soil productivity. Faecal manure from maize silage alone or forages alone would be more effective than faecal manure from browse/maize silage mixtures in improving soil productivity. Also, the faecal manure from Gliricidia/maize and Leucaena/maize silage mixtures would be more effective than the faecal manure from Calliandra/maize silage mixture. In spite of faecal manure having the ability to improve soil productivity it would not have direct bearing on crude protein and fiber content of forage DM.

RECOMMENDATIONS

The results obtained in this study are indicative results that need to be tested further under field conditions.

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