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Full Length Research Paper

Organization of manure from Ruminant (cattle and goat) in Wedza smallholder farming area, Zimbabwe

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Cattle and goat manure are widely used as soil fertility amendments in the smallholder farming sector of Zimbabwe but their fertilizer value is often reduced due to poor handling and management. Management of goat and cattle manure in Wedza smallholder farming area in Zimbabwe was studied from 1996 to 1998. The survey showed that farmers removed manure from kraals between May and August and heaped or composted it for between 8 to 16 weeks and then applied it to fields in October just before the commencement of the rainy season. Goat and cattle manure collected from kraals and heaps outside kraals and finally, a few days after application to the field but before incorporation were monitored for total N, P, K and organic C. Goat manure sampled after application to the field had mean percentage (%) total N, P, K and organic C of 1.37 ± 0.097, 0.26 ± 0.028, 0.66 ± 0.048 and 18.51 ± 1.610, respectively. Cattle manure collected after application to the field had a mean % total N, P, K and organic C of 1.01 ± 0.043, 0.20 ± 0.009, 0.40 ± 0.019 and 18.12 ± 0.869, respectively. Goat manure managed in the same way as cattle manure was found to be of better quality when applied to the field than cattle manure for the macronutrient N, P and K (P<0.05).

Key words: Crop-livestock systems, manure, composting, C-to-N ratio, organic C, macro-nutrients.

INTRODUCTION

Cattle and goats are important components of sub-Saharan Africa mixed crop-livestock farming systems. In Zimbabwe, goats form an integral component of agriculture, with a population of 4.7 million and over 97% of these are owned by smallholder farmers (Kusina and Kusina, 2001). Goats, like cattle, play a significant role in the socio-economic livelihoods and food security of smallholder farmers through sale, slaughter, provision of milk, skins and manure for cropping and in various socio-cultural ceremonies (Kusina et al., 2000; Homann et al., 2007). Use of livestock manure as a soil fertility amendment is a common practice in smallholder farming systems in Zimbabwe and a lot of research has been done on the use of cattle manure (Mugwira, 1984, 1985; Mugwira and Murwira, 1997). There has been very little research on manure from small ruminants (especially, goats) in spite of being widely used in smallholder crop-livestock systems. In Matebeleland North province of Zimbabwe, goat manure is an important soil amendment and Ahmed et al. (1997) noted that goat manure is used by most farmers in Kezi. However, in other parts of Zimbabwe, goat manure is relegated to vegetable gardens. Cattle manure has received greater attention because it is more available in larger amounts and is widely used than manure from small ruminants. Most of the soils in smallholder farming areas are derived from granitic parent material and are sandy and inherently deficient in N, P and S (Nyamapfene, 1991). Grant (1970a) observed that continued cropping on granitic soils in smallholder farming areas can result in multiple nutrient deficiencies of N, P, S, Mg, K and some micronutrients. Use of manure can help supply some of these nutrients (Grant, 1981) increase pH, organic matter content and cation exchange capacity, and also improve soil physical characteristics like water holding capacity (Grant, 1967a, b, 1970b; Mathers and Stewart, 1984;

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Murwira et al., 1995). Though use of manure alone has been noted to generally produce less than optimum yields (Grant, 1970a, b, 1981), its use increases yields and can avoid total crop failure.

There has been a general decline in the amount of cattle manure available (Ahmed et al., 1997) as a result of reduced cattle number due to droughts. Shumba (1985) observed a significant reduction in cattle ownership in Mangwende communal area. It is likely that the droughts in the 1990's have further reduced cattle numbers in smallholder farming systems. The situation has been aggravated by the escalating costs of commercial inorganic fertilizers. There is therefore the need for resource poor farmers together with researchers to consider and investigate other affordable sources of soil amendments like goat and chicken manure.

Manure quality is important because it indicates the ability to supply nutrients and improve yields. Manure quality can be measured by its nutrient content, especially, the amount of nitrogen and the C-to-N ratio (Mugwira and Mukurumbira, 1986). Tanner and Mugwira (1984) reported that cattle manures used in fields in smallholder farming areas have N contents ranging from 0.5 to 1.4% of dry matter. The quality of manure depends on the quality of grazing, mode of manure storage and how the manure is handled (Mugwira and Murwira, 1997). There is limited information on management of manure from small ruminants. The objective of this study was to understand how smallholder farmers in Wedza manage both cattle and goat manure and to monitor any changes in quality of the manure from the kraal to the time when it is applied to the field.

MATERIALS AND METHODS

Study site

The study was carried out in Chigodora (S 18° 55' and E 31° 45') and Goneso (S 18° 55' and E 31° 50') wards in Wedza Smallholder farming area in Zimbabwe from 1996 to 1998. The area has 3 seasons, a hot dry summer season from August to October, a hot wet summer season (rainy season) from October/November to March/April and a cold dry winter season from May to July. The area has an average annual rainfall ranging from 700 to 850 mm. Average maximum and minimum temperatures are 27.5 and 12.7°C respectively. The areas are predominantly underlain by granitic parent rock. Portions of limited extent underlain by doleritic parent rock however, also occur in the areas. Granitic rock has given rise to sandy soils with dolerite giving rise to clayey soils.

Farmer selection and questionnaire survey

A hundred and fifty questionnaires were first administered so as to understand the crop-livestock system in the area and identify farmers to work with (Chikura, 1999). Sixty farmers were then randomly selected for the study of goat and cattle manure. Information on manure management by Wedza farmers was obtained through questionnaires, field observations, meetings and discussions with the selected farmers.

Sampling and chemical analysis of manure

Goat and cattle manure samples were collected for chemical analysis at 3 sampling times from kraals in February, from composts heaped outside kraals in August and September and finally, at between 1 to 3 weeks after application to the field in September and October. Each manure sample was a composite of five manure subsamples. For the manure heaped in the field, the five subsamples were taken randomly from different heaps. The manures were air dried, ground and passed through a 0.5 mm sieve before laboratory analysis. Samples were analyzed for organic carbon (C), total nitrogen (N), phosphorus (P) and potassium (K). Organic C was determined using the Walkley-Black method (Anderson and Ingram, 1993). Total N was determined using the micro-Kjeldahl method (Bremner, 1996). Total P was analyzed colorimetrically after ashing samples in a furnace at 450°C (Okalebo et al., 1993). Potassium was determined after ashing using a flame photometer. Data were subjected to analysis of variance (ANOVA) using GENSTAT statistical package (GENSTAT, 2003). The Fisher test was used to separate means of total N, P, K, organic C, and C-to-N ratio that were significantly different ($P<0.05$) for the different manure sampling times and manure type.

RESULTS

In Wedza smallholder farming area, farmers use manure from livestock, leaf litter, compost material from households refuse pits, and mineral fertilizers to improve soil fertility. Livestock manure mainly comes from cattle and goats.

Management of cattle and goat manure

Addition of bedding material in kraals is an important management practice which helps to keep kraals dry. The practice increases the amount of manure and prevents excessive loss of nutrients like nitrogen (Nzuma and Murwira, 2000). Table 1 shows material used as bedding in cattle and goat kraals. In cattle kraals, 59% of the farmers in the study area used maize stover and grass as bedding, while 41% used maize stover only as bedding material. In goat kraals, grass was the most widely used bedding material (59%) followed by groundnut stover mixed with grass (21%).

During the 1997/1998 season, cattle manure was taken from kraals and heaped/composted outside kraals between May and August (Figure 1) so as to allow as much time as possible for decomposition before applying to the field. The highest number of farmers (40%) heaped their manure in June. All the farmers pointed out that heaping manure helps decompose stover and grass and thus, improve manure quality. According to farmers in the study area, it is preferable to heap manure early, that is, in May/June so as to have better quality manure. However, this is not possible in some instances because of shortage of manpower to carry maize stover from the field to the kraals and also latter remove the manure from the kraals. According to 10% of the farmers, the rise in temperature during decomposition kills some weed

Table 1. Bedding material used in cattle and goat kraals in Wedza (n=60).

Bedding material	Frequency in cattle kraals	Frequency in goat kraals (%)
No material	Nil	7
Maize stover	41%	3
Grass stover	Nil	59
Groundnut stover	Nil	7
Maize stover and grass	59%	3
Groundnut stover and grass	Nil	21

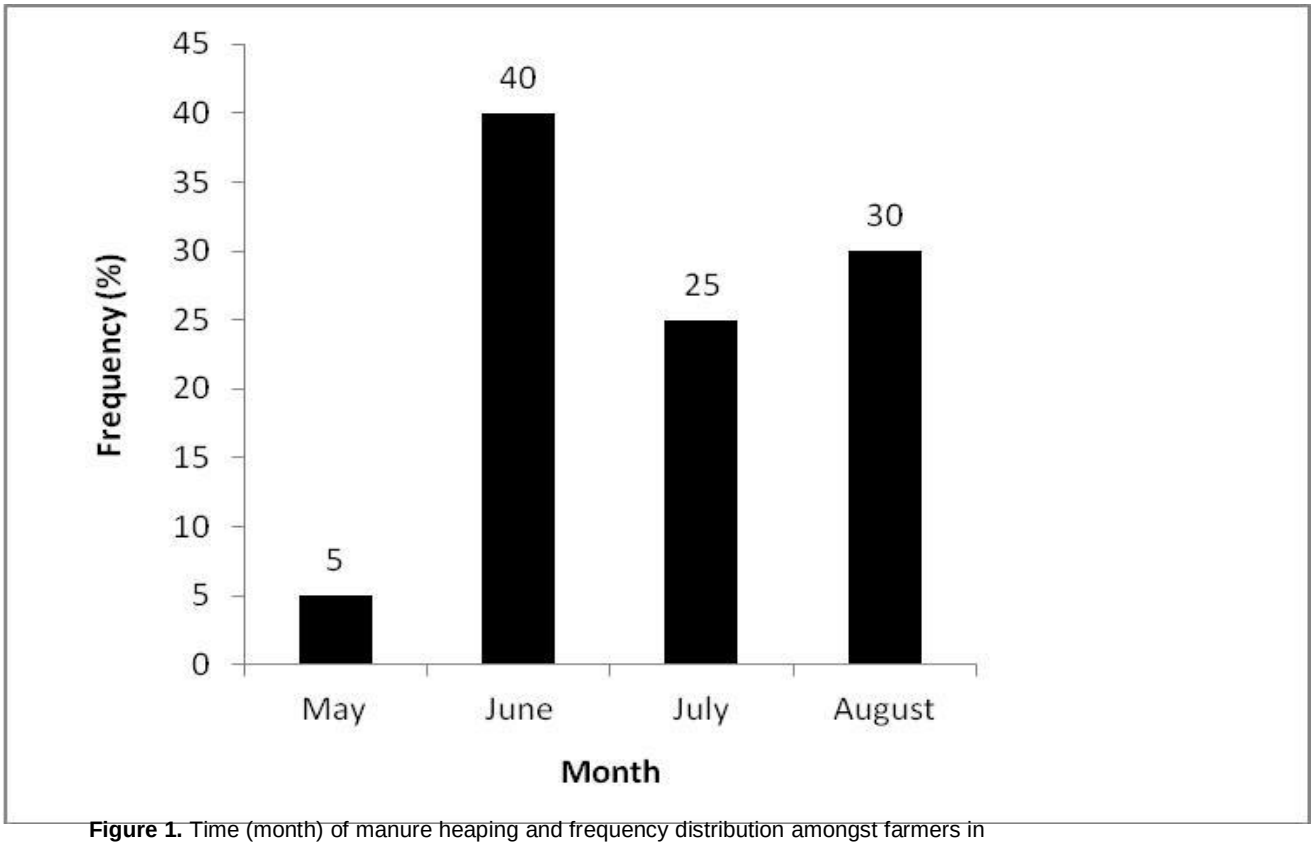

Figure 1. Time (month) of manure heaping and frequency distribution amongst farmers in Chigodora and Goneso wards in Wedza smallholder farming area (n=60).

seeds and therefore, reduces weed infestation and this is corroborated by Rupende et al. (1998).

Goat manure is generally removed from kraals and applied directly in vegetable gardens. From interviews with farmers and field observations, it was found that most farmers in Wedza do not compost goat manure. Where a farmer has many goats (≥ 10 goats), the surplus manure after applying to vegetable gardens is also composted outside the kraal like cattle manure. Only 25% of the farmers composted goat manure and used the manure in their vegetable gardens and fields.

Farmers heap their manure for between 8 to 16 weeks (Figure 2). The highest numbers of farmers (28%) were found to heap their manure for 11 weeks. After heaping, cattle manure is applied to ploughed fields immediately before the onset of the rain season. Farmers apply manure from August to October, with 72% applying manure during the month of October (Figure 3). Manure is placed in small heaps all over the field and then uniformly spread.

Changes in chemical characteristics of manure

Nitrogen and organic carbon

The mean total N in cattle manure changed from 1.68 in kraals to 1.05% in heaps respectively (Table 2). After

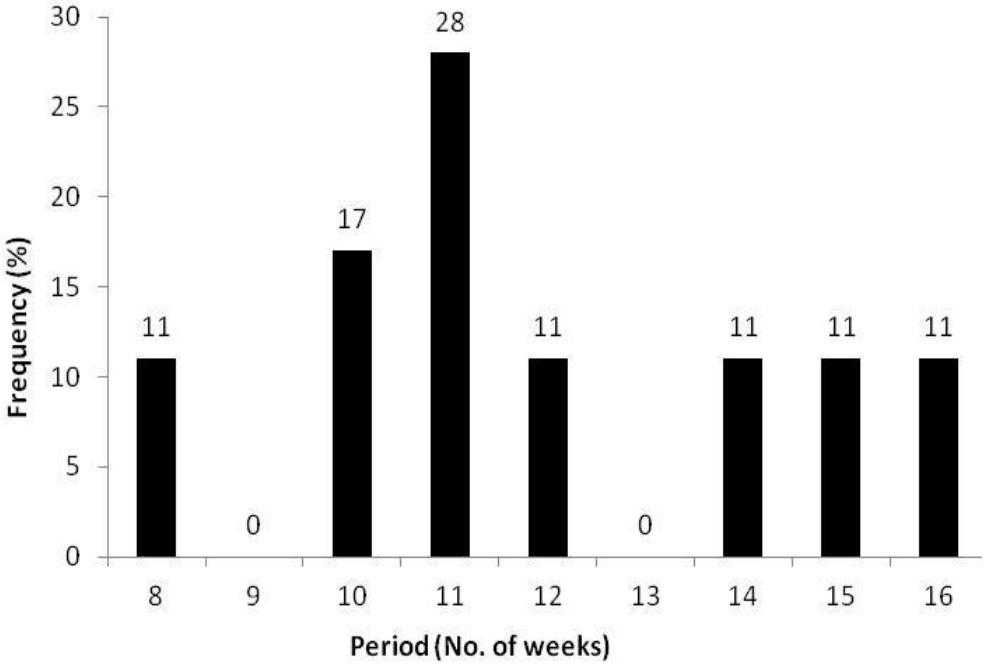

Figure 2. Duration of heaping/composting manure and frequency distribution amongst farmers in Chigodora and Goneso wards in Wedza smallholder farming area (n=60).

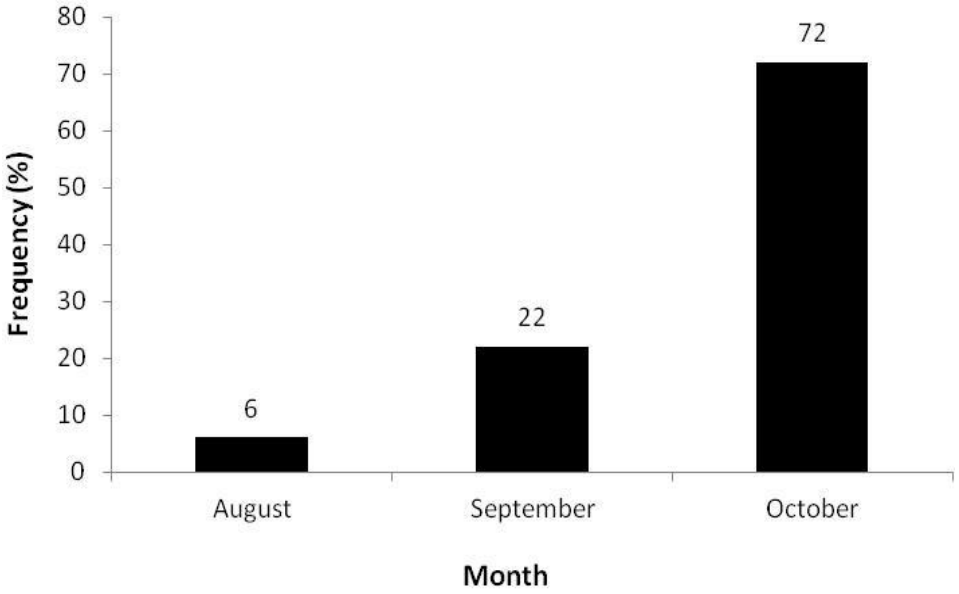

Figure 3. Time of application of heaped/composted manure to the field and frequency distribution amongst farmers in Chigodora and Goneso wards in Wedza smallholder farming area (n=60).

application to the field, total N had decreased to 1.01%. Total N in goat manure however, was 2.57% in kraals, 1.69% in heaps and 1.37% after field application (Table 2). Goat manure in kraals had significantly higher total N content ($P<0.05$) compared to cattle manure also collected from kraals. Total N in goat manure heaped was also significantly higher ($P<0.05$) than in heaped cattle manure. After application to fields, total N in goat manure was still higher ($P<0.05$) than in cattle manure. Mean % organic carbon in cattle manure collected from the kraals, from heaps, and after field application was 28.0, 18.7 and 18.12, respectively (Table 2). Mean %

Table 2. Nutrient concentration of cattle and goat manure from kraals, compost heap and just after application to fields. Values in the same row with different letters are significantly different (P<0.05).

Nutrient*	Manure from kraal		Manure from compost heap		Manure from field	
	Cattle	Goat	Cattle	Goat	Cattle	Goat
% N	1.68±0.082^{a}	2.57±0.182^{b}	1.05±0.043^{c}	1.69±0.063^{a}	1.01±0.043^{c}	1.37±0.097^{d}
% P	0.28±0.012^{a}	0.36±0.029^{b}	0.26±0.011^{a}	0.34±0.036^{b}	0.20±0.009^{c}	0.26±0.028^{a}
% K	0.54±0.064^{a}	0.77±0.042^{b}	0.42±0.015^{c}	0.73±0.057^{bd}	0.40±0.019^{c}	0.66±0.048^{d}
% OC	28.0±0.82^{a}	26.2±1.15^{a}	18.7±0.95^{b}	19.1±1.54^{b}	18.1±0.87^{b}	18.5±1.61^{b}

*Nutrient values are means ±SE.

total organic carbon in goat manure collected from the kraals, from heaps, and after field application was 26.3, 19.1 and 18.5, respectively (Table 2). The % organic C in cattle and goat manure collected at the same sampling times, that is, from kraals, from heaps and after application were not significantly different (P<0.05).

The C-to-N ratio was used to compare the quality of goat and cattle manures. Cattle manure in kraals, in heaps outside kraals and after application to fields had mean C-to-N ratios of 20, 18 and 14, respectively. Goat manure had mean C-to-N ratios of 12, 11 and 14 in kraals, in heaps outside kraals and after field application, respectively. Goat manure from kraals was of significantly higher quality (P<0.05) than cattle manure collected from kraals. Goat manure from heaps was also of significantly higher quality (P<0.05) than cattle manure also collected from heaps. After application to the field, goat manure was not significantly of higher quality (P<0.05) compared to cattle manure.

Phosphorus

Mean % total P in cattle manure from kraals, heaps and fields was 0.28, 0.26 and 0.20 respectively (Table 2). This was lower than goat manure which was also collected from kraals, heaps and fields which had mean % total P of 0.36, 0.34 and 0.26, respectively (Table 2). Comparison of manure from kraals showed that goat manure had higher total P (P<0.05) than cattle manure. Goat manure from heaps had significantly higher (P<0.05) total P than cattle manure from heaps. This significant difference was maintained after application of manure to fields.

Potassium

Cattle manure from kraals, heaps and fields had mean % total K of 0.54, 0.42 and 0.40, respectively (Table 2). Total K in goat manure was 0.77% in kraals, 0.73 in heaps and 0.66% after application to the field (Table 2). Goat manure from kraals had higher total K (P<0.05) than cattle manure from kraals. Goat manure from heaps also had more K (P<0.05) than cattle manure also collected from heaps. After application to the field, there was still a significant difference (P<0.05) in total K between goat manure and cattle manure.

DISCUSSION

In the study area, like in most smallholder farming areas in Zimbabwe, cattle manure is used to improve yields of field crops like maize (Trounce et al., 1985; Mugwira and Shumba, 1986). Goat manure is mainly used in vegetable gardens. Where a farmer has many goats, usually 10 or more, the excess manure produced is used also in crop fields. Few farmers have many goats and in this study only 25% were found to be using their goat manure in vegetable gardens and fields. This figure obtained from a sample of farmers in Chigodora and Goneso Wards may actually be higher than other Wards in Wedza because farmers in these areas were being encouraged to keep small ruminants especially, goats under the European Union funded Small Ruminants Project.

The nutrient levels in goat and cattle manure decreased from the kraal to the time after application to fields. The study showed that from time of sampling in kraals to time of sampling of manure in heaps, 38 and 34% N was lost from cattle and goat manure respectively. Nitrogen was the nutrient with the highest losses from both cattle and goat manure. Markewich et al. (2010) in his study noted that manure storage time is an important factor that determines N concentration in manure. Therefore, the longer the time manure is kept in kraals and in compost heaps, the greater the N losses. From time after sampling from compost heaps to the time after application of manure to fields, cattle manure lost 3% N whilst goat manure lost 12% N. Cattle and goat manure lost 22 and 16% K respectively from the time of sampling in kraals to time of sampling of manure in heaps. Only 1 and 2% K was lost from cattle and goat manure, respectively from the time when samples were collected from heaps to the sampling time after application of manure to fields. A relatively small amount of P was lost when manure was moved from kraals to

compost heaps. Cattle manure lost 8% P whereas goat manure lost 6% P.

Goat manure managed in the same way as cattle manure was found to be of better quality when applied to the field than cattle manure for macronutrients N, P and K (Table 2). Organic C loss from kraal to heap was significantly different in both manures. The difference were mainly due to decomposition and loss of labile C. Comparing the C-to-N ratio of goat and cattle manure collected at the same sampling times showed that goat manure from kraals and compost heaps is superior to cattle manure. This was attributed to the type of bedding material used in kraals and the nature of the food eaten by the animals. Where farmers do not have enough maize stover they supplement with grass. Mugwira and Mukurumbira (1984) found that the quality of manure depends on the quality of the feed.

Goat manure was mainly used in vegetable gardens because farmers believe that it is better than cattle manure. Goat manure is generally taken directly from the kraal to the gardens. In a few cases, the manure is heaped for on average for a week in transit to the gardens. Goat manure used in vegetable gardens is therefore exposed to the weather elements, like gaseous losses and leaching by rain for a shorter time than cattle manure. This could explain the view by some of the farmers that goat manure is better than cattle manure. Cattle manure is heaped or composted outside kraals for between 2 to 4 months (Figure 2) before applying to the field just before rains in October. Only 25% of the farmers manage goat manure in the same way as cattle manure. These farmers have on average, 15 goats and therefore, have more than enough goat manure for their gardens. It is therefore, clear that increased goat production will result in an increase in goat manure which is of higher quality. However, goat production is affected by poorly developed markets and farmers rely on informal market channels with the main buyers being traders and neighboring farmers (Homann et al., 2007). During the heaping period, a lot of nutrients are lost through erosion and leaching by rainfall and for N also through volatilization (Murwira, 1995). The goat manure managed in the same way as cattle manure showed no significant difference in C-to-N ratios compared to cattle manure at field application stage.

The material added to manure whilst in the kraals also influences quality. In the case of cattle manure, maize stover and grass is added whereas in the case of goat manure grass and ground-nut stover is used by many farmers. If the farmer does not grow ground-nuts, grass becomes the only material added to goat manure in kraals. The groundnut stover used improves the nutrient content especially, N of goat manure. Mugwira and Murwira (1997) pointed out that the amount of nutrients in manure depends on quality of feed, storage and handling conditions in the kraal, ambient temperature and moisture levels and the length of exposure to the environment. During the time when manure is in kraals to the time when it is applied to fields, a lot of the nutrients are lost through leaching by rainfall especially, N. Nitrogen and K losses mainly occur during the period from kraals to heaping. Esse et al. (2001) also reported high nutrient loss from manure as a result of heavy rainfall. Nitrogen is also lost through volatilization (Murwira, 1995) and these losses also largely occur in kraals and during heaping. It is likely that most of the K lost may have been in urine and therefore, in soluble and readily mobile form. The conditions under which manure is handled and stored can result in aerobically decomposed and dried manure which increases ammonia losses (Mugwira and Murwira, 1997). In both cattle and goat manure, P was found to be mainly lost during the period between heaping to the time after application to fields.

Interviews with farmers revealed that the main reason why they heap or compost their manure is to enable decomposition of added stover so as to improve quality. Ten percent of the farmers also pointed out that the heat generated during the composting period destroyed weed seeds. Rupende et al. (1998) found that weed seed viability is affected by heat generated during composting.

Conclusion

Results obtained from Wedza showed that goat manure is superior to cattle manure in terms of total nutrient content (N, P and K) when finally applied to the field. It is however, important to note that bedding material used in kraals and quality of feed eaten by animals also determines the quality of manure. For both, goat and cattle manure, handling results in high losses of nutrients, hence, lowering in quality. Manure handling from kraals to compost heaps, before application to the field is therefore, a critical stage of management of manure.

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REFERENCES

Ahmed MM, Rohrbach DD, Gono LT, Mazhangara EP, Mugwira L,

Masendeke DD, Alibaba S (1997). Soil fertility management in communal areas of Zimbabwe: current practices, constraints, and opportunities for change – results of a diagnostic survey. Southern and Eastern Africa Region Working Paper no. 6. ICRISAT

Anderson JM and Ingram JSI (1993). Tropical Soil Biology and Fertility: A handbook of methods. C.A.B. International. Wallingford, UK.

Bremner JM (1996). Nitrogen -Total. In: Sparks, D.L. (ed). Methods of Soil Analysis: Chemical Methods. Part 3. Soil Sci. Soc. Am. Book Series No. 5. ASA-SSSA, Madison, WI.

Chikura S (1999). Assessment of the role of goats in a smallholder crop-livestock production system of Zimbabwe: A case study of Wedza communal area. MPhil Thesis, University of Zimbabwe, Harare.

Esse PC, Buerkert A, Hiernaux P, Assa A (2001). Decomposition of and nutrient release from ruminant manure on acid sandy soils in the Sahelian zone of Niger, West Africa. Agriculture, Ecosyst. Environ., 83: 55-63.

GENSTAT (2003). GESTAT statistical package, 8th edn. VSN International, Oxford.

Grant PM (1967a). The fertility of sandveld soil under continuous cultivation. Part III. The effect of manure and nitrogen on the base status of the soil. Rhodesia Zambia Malawi J. Agric. Res., 5: 117-128.

Grant PM (1967b). The fertility of sandveld soil under continuous cultivation. Part I. The effect of manure and nitrogen on fertilizers on the nitrogen status of the soil. Rhodesia Zambia Malawi J. Agric. Res., 5: 71-79.

Grant PM (1970a). Changes in the fertility of para-ferralitic sands under continuous cropping. Soil Science Conference, April 1970. Soc. Soil Sci. South Africa.

Grant PM (1970b). Restoration of productivity of depleted sands. Rhodesia Agric. J., 67: 131-137.

Grant PM (1981). The fertility of sandy soil in peasant agriculture. Zimbabwe Agric. J., 78: 169-175.

Homann S, van Rooyen A, Moyo T and Nengomasha Z (2007). Goat production and marketing: Baseline information for semi-arid Zimbabwe. International Crops Research Institute for the Semi-Arid Tropics. Bulawayo, Zimbabwe, 84 pp.

Kusina, NT, Chikura S and Sibanda, S (2000). Mortality and diseases of goats in Wedza communal area of Zimbabwe. Zimbabwe Veter. J., 31: 11-20.

Kusina NT and Kusina J (2001). Goat marketing model for enhanced revenue generation by smallholder farmers in Zimbabwe. TSAP Proceedings, 28. http://www.google.co.zw/#q=kusina+and+kusina+1999&hl=en&prmd=imvns&ei=jQGAT6q_EYLDhAfLq6GmBw&start=10&sa=N&bav=on.2,or.r_gc.r_pw.,cf.osb&fp=188cbbf0dee69c25&biw=1024&bih=457, Accessed on 7/04/2012.

Markewich HA, Pell AN, Mbugua DM, Cherney DJR, van Es HM, Lehmann J, Robertson JB (2010). Effects of storage methods on chemical composition of manure and manure decomposition in soil in small-scale Kenyan systems. Agric. Ecosyst. Environ., 139: 134-141.

Mathers AC, Stewart BA (1984). Manure effects on crop yields and soil properties. Trans. ASAE, Vol. 27(4): 1022-1026.

Mugwira LM (1984). Relative effectiveness of fertilizer and communal area manures as plant nutrient sources. Zimbabwe Agric. J., 81: 81-89.

Mugwira LM (1985). Effects of supplementing communal area manure with lime and fertilizer on plant growth and nutrient uptake. Zimbabwe Agric. J., 82:153-159.

Mugwira LM, Mukurumbira LM (1984). Comparative effectiveness of manures from the communal areas and commercial feedlots as plant nutrient sources. Zimbabwe Agric. J., 81: 241-250.

Mugwira LM, Mukurumbira LM (1986). Nutrient supplying power of different groups of manure from communal areas and commercial feedlots. Zimbabwe Agric. J., 83: 25-29.

Mugwira LM, Murwira HK (1997). Use of cattle manure to improve soil fertility in Zimbabwe: past and current research and future research needs. Network Research Results Working Paper, Number 2. CIMMYT Maize Programme and Natural Resources Group.

Mugwira LM, Shumba EM (1986). Rates of manure applied in some communal areas and their effect on plant growth and maize grain yield. Zimbabwean Agric. J., 83: 99-104.

Murwira HK (1995). Ammonia volatilization from Zimbabwean cattle manures before and after application to soil. Trop. Agric. (Trinidad), 72: 269-274.

Murwira HK, Swift MJ, Frost PGH (1995). Manure as a key resource in sustainable agriculture: a case study of communal area farming systems in Zimbabwe. A keynote address. In: Powel JM, Fernandez-Rivera S, Williams TO, Renard C (eds) Livestock and Sustainable Nutrient Cycling in Farming Systems of Sub-Saharan Africa, Volume II. ILCA proceedings, Addis Ababa, Ethiopia, 22-26 Nov. 1993, pp. 131-148.

Nyamapfene KW (1991). Soils of Zimbabwe. Nehanda Publishers, Harare, Zimbabwe.

Nzuma JK, Murwira HK (2000). Improving the management of manure in Zimbabwe. Managing Africa's Soils No. 15. Russel Press, Nottingham, pp. 1-20.

Okalebo JR, Gathua KW and Woomer PL (1993). Laboratory methods of soil and plant analysis: a working manual. Tropical Soil Biology and Fertility Programme. Soil Society of East Africa Technical Publication No. 1. Marvel EPZ (Kenya) Nairobi.

Rupende E, Chivinge OA, Mariga I K (1998). Effect of storing time on weed seedling emergence and nutrient release in cattle manure. Exp. Agric., 34: 277-285.

Shumba EM (1985). On-farm research priorities resulting from a diagnosis of the farming systems in Mangwende, a high potential area in Zimbabwe. Zimbabwe Agric. J. Special report No. 5.

Tanner PD, Mugwira LM (1984). Effectiveness of communal area manure as sources of nutrients for young maize plants. Zimbabwe Agric. J., 81:31-35.

Trounce JM, Tanner PD, Mandiringana OT (1985). The effect of compound fertilizer, manure and nitrogen topdressing on maize grown on communal area vlei soils. Zimbabwe Agric. J., 82: 199-203.