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Managing Manures Throughout their Production Cycle Enhances their Usefulness as Fertilisers: A Review

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Abstract

Per capital food production lags behind population growth in most parts of sub-Saharan Africa. One of the reasons for this situation is the decline in soil fertility, arising from continuous cultivation where the levels of soil replenishment, by whatever means, are too low to redress the process of nutrient mining. One of the ways to address the problem of the low and declining soil fertility is by using inorganic fertilisers, but use of these inputs in most of sub-Saharan Africa is currently low. High costs, unavailability, marketing problems, poor infrastructure, and the absence of enabling policy environment are major reasons for the low use of inorganic fertilisers. The use of other resources available on farm is therefore increasingly gaining importance. These include green manures, farmyard manure, crop residues and composts. Of these resources, farmyard manure is by far the most important. However, a major limitation in the effectiveness of organic resources is the quality and quantity of these materials. This review paper attempts to define cattle manure quality and discusses some management factors that influence its quality. The paper also suggests some way forward in better use of cattle manures for enhanced crop production.

Introduction

Per capital food production lags behind population growth in most parts of sub-Saharan Africa. One of the reasons for this situation is the decline in soil fertility. The low and declining soil fertility arises from continuous cultivation where the levels of soil replenishment, by whatever means, are too low to mitigate the process of soil mining, whereby the soil fertility is not replaced by new inputs. One of the effective ways to address this problem is by using inorganic fertilisers. This is, however, beset by several problems. Africa's average annual fertiliser use is only 20 kg ha^{-1} against a world average of 96 kg ha^{-1} (Heisey and Mwangi, 1996). In central highlands of Kenya, farmers who use inorganic nitrogen (N) fertilisers do so at rates between 15-25 kg N ha^{-1}, which is far below recommended rates at 40 kg N ha^{-1} and above (Kimani *et al*, 2001). High costs, marketing problems, and poor infrastructure are major reasons for the low use of inorganic fertilisers. The use of other resources available on farm is therefore increasingly gaining importance. These resources include green manures, farmyard manure, crop residues and composts.

Of these resources, farmyard manure is by far the most important. In most farms in central Kenya the manure used is mainly cattle (65%) with the rest comprising sources such as shoats (6%) and poultry (4%) (Kimani *et al.*, 2000). Most of the manures are from own sources (83%) with a very small proportion of farmers (2%) purchasing manure (Kimani *et al.*, 2000). Manures, or other organic inputs applied to the soil control the rate, pattern and extent of growth and activity of soil organisms and provide the source of carbon, energy and nutrients for the synthesis of soil organic matter. Manure can increase the humus content of soils by 15-50%, depending on soil type, in addition to increasing soil aggregate stability and root permeability (Klapp, 1967). In the longer term, as shown in an ongoing experiment (20 years by 1996) in Kabete, Kenya

(Swift *et al*., 1994; Kapkiyai *et al*., 1996), manuring restocks the particulate organic matter fraction better than fresh crop residues. Manure also acts as a buffer, thus improving nutrient uptake for crops grown in acid soils. Using manures alleviates aluminium toxicity and improves the availability of nutrients such as P, particularly in soils with a high P fixation, and sulphur (S) (Simpson, 1986). Manure also supplies essential elements such as Mg, and trace elements which may not be available in commonly used inorganic fertilisers (Simpson, 1986).

However, the use of manure has several drawbacks. Firstly, the farmers cite quantity as a problem, that the manure is usually not enough. Secondly, the quality of manure with regard to nutrient release and crop uptake is poor. In some instances manure has alternative uses such as fuel and house construction material. Despite these drawbacks, manure continues to be an important source of nutrients.

This paper attempts, firstly, to define manure quality. This is followed by a discussion on the improvement of manure quality through better management of animal feed, coupled with improved collection and storage methods. The paper also provides a brief discussion on the effects of combining manures with inorganic fertilisers.

What is manure quality?

Manure quality may simply be defined as the value of manure in improving soil properties and enhancing crop yields. Scientists have used laboratory analysis for nutrient contents as a measure of quality. The perception has been that the higher the nutrient levels, the better the manure quality. More recently the use of nutrient release patterns, using laboratory incubations of manures, and how the nutrient release can be synchronised with crop uptake has been considered a better measure of manure quality. On the other hand farmers have traditionally used their own yardsticks to determine what quality manure is. The challenge is therefore to match the scientist and farmer perceptions to come up with simple decision making tools for defining quality manure without expensive laboratory analysis. An example of laboratory analysis for manure quality determination is given in Table 13.1. While the values given are means, the range is quite variable and wide. For instance, N contents for cattle manures from Kenya range from 0.20-2.2%N, whilst P contents range from 0.08-0.95%.

The farmers of central Kenya use texture, longevity of composting, homogeneity, presence of fungi spores/hyphae, as some of the quality characteristics (Lekasi *et al.*, 1998; Wanjekeche *et al.*, 1999). In Ethiopia, Tigray region farmers distinguish between two types of manure, the ‘husse’ and ‘aleba’, based on the degree of decomposition. The ‘husse’ is well-decomposed and rich in plant nutrients while 'aleba' is less decomposed and has less nutrients (Kihanda and Gichuru, 1999). Table 13.2 shows indicators of manure quality as determined by farmers in West Pokot district, northern Kenya.

Table 13.1: Nutrient contents of farmyard manure samples collected from different countries.

	Nutrient content (%)				
Country	N	P	K	Ca	Mg
UK	1.76	0.24	1.29	0.74	0.34
Kenya	1.62	0.50	1.34	0.26	0.26
Zimbabwe	0.80	0.20	0.85	0.25	0.15
Madagascar	1.10	0.80	0.86	0.85	0.40

Source: Manure management for soil fertility improvement (Kihanda and Gichuru, 1999)

Table 13.2: Indicators of good quality manures used by farmers in Cheptuya village, West Pokot district, northern Kenya.

Indicator	Frequency of farmers
Fine soil-like texture	10
Black-grey colour	12
Longer time of composting	3
Appearance of white caterpillars	5
Lack of heat in the manure	2

Source: Wanjekeche *et al*., 1999

Management factors influence manure quality: Effects of animal feed

Animals fed on high quality supplements produce high quality manures. The high quality supplement would range from feeds concentrates (Lekasi, 2000; Odongo, 1999), to high N content legumes (Delve *et al.*, 1999). Tables 13.3 and 13.4 show the effects of diet supplementation on manure quality, with regard to P and N. The practicality of these findings at the smallholder farm level is doubtful. This is because in most situations farmers feed their livestock opportunistically. This is the feeding situation where a farmer feeds the livestock with whatever feed may be available at a particular time. In general, feeds fluctuate with the rain patterns, where large quantities of high quality are available during wet periods, and low quantities of poor quality dominating during the dry periods. The improved quality associated with improved diets is therefore more practical in the more intensive systems for instance under Zero-grazing units, which are generally associated with farmers with medium to high income.

Table 13.3: Effect of feeding different P supplements on manure P contents.

Diet	% P of the collected manure
Basal diet (Napier grass)	0.24
Busumbu Rock Phosphate	0.70
Mijingu Rock Phosphate	0.45
Bone meal	0.50
Unga commercial feed	0.95

Source: Odongo, 1999, (unpublished)

Table 13.4: Total N content and C:N ratio of faeces obtained from feeding supplemented diets. Percentages indicate supplementation in relation to the total dry matter offered as feed

Faecal sample	Nitrogen (%)	C:N ratio
Barley straw basal diet	0.9	27
15% C. calothyrsus diet	1.4	23
30% C. calothyrsus diet	1.7	22
15% M. axillare diet	1.1	20
30% M. axillare diet	1.2	23
15% poultry manure diet	1.2	27
30% poultry manure diet	1.3	23

Source: Delve *et al*., 1999.

Collection and Storage methods

In the extensive systems, where animals graze freely manuring is done in-situ as the animals graze. Where they are confined overnight at the 'Kraal', the manure collected usually comprises faeces only. The dung is heaped besides the kraal as a continuous process throughout the year. This system is common in pastoral areas of Kenya, such as Maasai land and West Pokot (Wanjekeche *et al., 1999).* Similar methods of manure collection have been reported for the communal grazing areas of Zimbabwe *(Nzuma et al*., 1998). A limitation in this method of manure collection is that most of the urinary N is leached down the soil profile.

It is also suffices to say that a considerable amount of N is lost via volatilization. During the wet season, the soggy anaerobic conditions may result in denitrification. Where possible, there is therefore need to improve on composting methods, for instance in areas characterised by intensive farming.

Methods of Composting

The purpose of composting is to allow further microbial decomposition. Methods of composting include surface heaps, pitting and deep litter systems. In Zimbabwe, Nzuma *et al.*, (1998) compared pit and heap composting, with or without straw additions. They showed that manures composted for three months using pit method was of higher quality (N content) than the surface heap. These differences of N contents in the manure could be related to the pH of the manures during the composting process. In the heaps, where conditions are aerobic, the manure pH is normally high (8-9). This tends to stimulate N losses via volatilization. On the other hand, manure stored under anaerobic conditions tends to produce organic acids that lead to a lower pH (<7), and therefore fewer losses of N via volatilization (Kihanda and Gichuru, 1999). A threshold moisture content of 40-60% is recommended for composting with a view to enhancing fertiliser value. Table 13.5 shows different composting methods and the effects on quality. Farmer cattle manure from a traditional system of central Kenya has manures with a lower N concentration compared with improved composting systems, other than the Maasai manure. The stable system is where the animal is confined throughout. Feed is provided on the stable floor, and the animal feeds on what is necessary and tramples on the rest, mixing it with the urine and faeces. In faeces, urine and feed refusals (F+U+FR), the animal is fed from a trough and the refusals are collected on a daily basis and put in the zero-grazing unit, where they are mixed by the animal through trampling. F+FR refers to the system where animals are fed from a trough. The feed refusals and faeces are collected daily and heaped in a covered storage area, outside the stable, where they are mixed manually. F+U refer to the system where the faeces and urine only are mixed by the animal in the stable. Faeces alone (F) is the system where only the faeces are composted, in a heap outside the stable, with no urine. Other than the farmer practice and the Maasai, the other composting systems were done at a research station, where composting period was 90 days. Details of the procedures of all these systems are provided by Lekasi (2000).

Table 13.5: N and C:N ratios of manures under different composting systems

Type of manure/composting	N%	C:N ratio
Farmer cattle manure	1.1	31
Stable	1.6	23
F+U+FR	1.7	21
F+FR	1.9	19
F+U	1.5	24
F	1.6	25
Maasai cattle manure	0.8	32

Source: Lekasi, 2000. Faeces (F), Urine (U) and Feed Refusals (FR)

The results show that composting process affects C:N ratios. Subsequent work in the field showed that manures with high N contents resulted in higher N mineralisation and a better crop performance, with the exception of Maasai kraal manure (Lekasi, 2000).

Composting in Zero-grazing Systems

In zero grazing units, it is important to manage manures to enhance fertiliser quality. Where animals are confined this way, the land sizes are generally small, for some of them as small as 0.01 ha, for instance in Kiambu and Muranga districts of central Kenya. In the high potential areas, manures combined with feed refusals are of superior quality compared with faeces alone (Table 13.5). The added feed refusals help to conserve urinary N, by minimising leaching losses, apart from providing a conducive environment for aerobic decomposition. This composting method thus reduces environmental problems associated with leaching of nutrients.

According to studies by Lekasi (2000), a small scale farm can produce cattle manures that are able to supply 100 kg N within a period of six months, and this supply may be in excess of the farm requirement for a 0.01 ha small farm in densely populated Kiambu district of central Kenya. This raises a question as to why farmers in the central Kenya highlands continue to indicate that they do not have enough manures (Makokha *et al.*, 2001). It is probable that manures produced may be of low quality, rather than quantity, and therefore not effective in raising crop yields, to the satisfaction of farmers. The finding thus highlight the possibility that what may be required in the high potential areas of central Kenya may be a better focus on manure quality and management. Such results also indicate the possibility of selling the excess manures elsewhere, thus providing a source of income to those farmers with surplus manure.

The studies by Lekasi (2000) also bring another dimension to manure quality. For instance, Maasai cattle manure with a low N concentration 0.8% was more superior to increasing maize yields when compared to feedlot Zero-grazing manure produced under experimental conditions (N = 1.6%) . The Maasai manure is usually collected from a kraal, where animals stay overnight after grazing. It is usually dry and dusty and of a finer tilth compared with the manure collected from zero-grazing units which is wet (usually 70% moisture), and aggregated into clods. It is possible that the fine tilth of the Maasai cattle manure provides a high surface area of application (when the manure is broadcast). The higher microbial activity releases nutrients readily for crop uptake in these Maasai manures compared to the feedlot ones , which comprise of moist clods and are more difficult to distribute in the soil. This raises questions as to whether farmers need to dry and grind manure for enhanced effectiveness.

Improving manure effectiveness by placement methods

The placement method also influences the effectiveness of manures. In a trial conducted at Thika, central Kenya, placing manure in a planting hole, as farmers commonly do, resulted in higher maize yields compared with broadcast manures. The yields were 3.5 t ha^{-1} and 1.3 t ha^{-1} for hole and broadcast treatments respectively (Kimani, 1999); Lekasi, 2000), where manures had been applied at an iso-N level of 75 kg ha^{-1}.

Improving manure effectiveness by combining with mineral fertilisers

The interaction between manures and inorganic fertilisers is increasingly becoming an important subject of research. A combination of organic-inorganic nutrient sources is thought to improve the synchronization of nutrient release and subsequent uptake by the crop. For example, the synchrony between N release and uptake is thought to be best achieved under a combined application of manures and inorganic fertilisers. This is particularly so when the manures are available on-farm, where only modest application of inorganic fertiliser are applied. The concept of organic-inorganic combinations (Table 13.6) has been demonstrated in central Kenya by Kimani *et al.*, (2001), where the combinations resulted in higher maize grain yields. The increased maize yields above an unfertilised control were 60%, 50% and 40% for mineral fertiliser alone, fertiliser-manure combination, and manure alone, respectively, in a single season (Table 13.6). Manure 1 and 2 had N contents of 1.8% and

1.6% respectively, and differed in composting methods whereby manure 1 consisted of faeces (F) alone plus feed refusals (FR) and was manually turned in a heap. On the other hand manure 2 consisted of faeces and feed refusals and was mixed by the animal via trampling in the animal housing. Both manures were composted over a period of four months and were applied at the rate of 75 kg N ha^{-1}. The small differences in N contents may therefore not result in significant differences in grain yields associated with the two manures, though both differed significantly compared with the control.

Table 13.6: Effects of manures when applied singly or in combination with mineral fertilisers on maize yields in Kariti, central Kenya long rains 1998. Manures were applied to supply 80 kg N ha^{-1}

Treatment	Grain yields t ha^{-1}
Control (no soil amendments)	2.53
100 kg N ha^{-1}	7.51
40 kg N ha^{-1}	5.36
20 kg N ha^{-1}	5.09
Manure 1 (F+FR manual mix)	4.82
Manure 2 (F+FR animal mix)	5.08
Manure 1 + 20 kg N ha^{-1}	5.64
Manure 1 + 40 kg N ha^{-1}	6.01
Manure 2 + 20 kg N ha^{-1}	5.75
Manure 2 + 40 kg N ha^{-1}	6.33
Lsd 0.05	1.03

Source: Kimani *et al.*, 2001. F, faeces alone; FR, feed refusals, either manually mixed or mixed by the animal in the stable, and composted for 4 months

Conclusions

This review shows that managing manures, through animal feed sources, or by composting can enhance fertiliser value. Quality parameters, based on laboratory measurements are available, although there is dire need to relate them to on-farm management systems. This would lead to production of simple extension manuals that relate management factors with quality, on-farm. Manure placement method will influence its effectiveness as a fertiliser. Hill placement produces a higher yield, at least during the first season of application. Recent studies indicate that in small farms (less than 1 ha), there is possibly excess manure, which is an opportunity to increase the financial situation of farmers through off-farm sales for the better-managed manures. There is need to monitor effects of excess nutrients with regard to environmental conservation.

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