African Journal of Agricultural Research Vol. 7(31), pp. 4362-4367, 14 August, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.673
ISSN 1991-637X

Full Length Research Paper

The nutrient status of organic soil amendments from selected wards of Chivi district, Zimbabwe

S. Mavengahama[1]* and F. Mapanda[2]

[1]Department of Agriculture, Faculty of Science and Agriculture, University of Zululand, Private Bag X1001, KwaDlangezwa, 3886, South Africa.
[2]Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P. O. Box MP 167, Mount Pleasant, Harare, Zimbabwe.

Accepted 26 March, 2012

The potential of animal manure, leaf litter, anthill soil, ash, and compost to supply nutrients was investigated in samples collected from 16 villages from four wards in Chivi district, Zimbabwe. The objective of the study was to generate a biophysical knowledge base on the nutrient status of soil amendments. A total of 134 samples of amendments were collected from homesteads and analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), Zinc (Zn), iron (Fe), manganese (Mn), and boron (B). With the exception of Cu, no significant differences ($P > 0.05$) in selected nutrients were found among the different types of soil amendments. Most of the amendments sampled had medium to low levels of nutrients. It was concluded that most of the soil amendments in the selected villages are of poor nutrient status. It is recommended to find management practices that minimize nutrient losses as well as to supplement the nutrients with inorganic fertilisers.

Key words: Soil amendments, nutrients, villages, communal areas.

INTRODUCTION

The use of organic and inorganic soil amendments, such as animal manure, leaf litter, anthill soil, and mineral fertilizer is a common practice aimed at improving soil productivity in the communal areas of Zimbabwe. Manure from cattle, goats, sheep, and poultry have been widely applied on sandy soils of low inherent fertility in crop production in Zimbabwe (Grant, 1981; Tanner and Mugwira, 1984; Shumba et al., 1989). Kraals are cleared every year or after two years and the manure are spread onto fields before the planting period by broadcasting and ploughing under or dribbling in planting furrows (Mombeshora and Mudhara, 1994; FSRU, 1993; Mavedzenge et al., 1996). Tanner and Mugwira (1984), Mugwira and Mukurumbira (1984), and Murwira and Kirchmann (1993) indicated that proper handling and management of soil amendments, particularly animal manure, can improve crop growth and yield. Their studies also show that improper handling of manure can produce poor quality manure with high sand content (up to 90%) and low N content.

It is thus essential to improve the nutrient supply potential of soil amendments in order to enhance soil fertility and subsequently crop production. Although, a lot of research has been done on the use cattle manure in Zimbabwe, the differences in the nutrient supply potential of other types of animal manure and among various types of soil amendments that include anthill soil and leaf litter, have not been fully investigated. These differences would affect the optimum amounts of each type of amendment that may be needed to achieve a targeted crop yield. The objective of this study was to determine the levels of crop nutrients in organic soil amendments used by farmers to improve soil productivity in Chivi communal areas.

*Corresponding author. E-mail: sydmavengahama@yahoo.co.uk.

MATERIALS AND METHODS

Location and description of study area

Chivi district is located in Masvingo province, Southern Zimbabwe and extends from 20°14' S to 20°14' S and lies bet ween 30°13' E and 30°57' E. It is located in natural regions IV (39 %) and V (61%) with low and unreliable rainfall. Average annual rainfall is about 530 mm.

Site selection

This participatory study was conducted in four purposively selected wards (that is, Wards 14, 15, 17, and 19) which had been identified as the worst in terms of the biophysical variables, such as crop yields, soil productivity, food security, and ecological status according to the perceptions of villagers and extension workers using their prior knowledge of the wards. Four villages were then selected from each of the wards to make a total of 16 villages, with over 155 participating farmers whose fields were also sampled for soil analyses reported elsewhere (Mapanda and Mavengahama, 2011).

In each selected ward, two villages identified as the 'worst' and the other two as the 'best' in relative terms using the same criteria employed in the selection of the wards were selected. From ward 14, Vafana and Tagarira villages were selected as 'best' and Gwandomba and Chigava were selected as 'worst'. In ward 15, Mhosva and Ruzive villages were selected as 'best' while Madya and Mafidhi were selected as 'worst'. In ward 17, Manyumbu and Zengwe were selected as 'best', while Chikamba and Zihwa were selected as 'worst'. In ward 19, Chimhamhiwa and Choga were selected as 'best' while Chiponda and Machona were selected as 'worst'.

Livestock kept in the four wards were cattle, goats, donkeys, and poultry (mainly chickens). Some few farmers kept sheep. Livestock manure were an important source of the amendments applied onto the fields and gardens for crop production. Major sources of income included crop production and livestock rearing, beer brewing, and gold panning. The opportunities identified in the wards included a large number of wetlands (particularly in wards 14 and 15); abundant groundwater resources; and a good road network. The major threats identified in the wards included poor soil fertility; siltation of dams, rivers, and wetlands; inadequate draught power; deforestation; overpopulation; and grazing land shortage.

Sampling of soil amendments

The soil amendments, namely cattle, goat, donkey and poultry manure, leaf litter, compost, ash, and anthill soil (termitaria), were collected from the homesteads in the 16 selected villages. The samples (weighing at least 1 kg each) were composite samples made up of at least five sub-samples at each heap mixed together. The samples were also collected from the kraals, compost heaps, and pits at the homesteads. A total of 134 composite samples of soil organic amendments were collected between July and August, 2004 before the fields were prepared for the 2004/2005 cropping season. This study was part of a bigger participatory programme which used questionnaires and focus group discussion to interact with villagers (farmers) and obtain data. The soil amendments were jointly collected by researchers and farmers. Each sample (total 134) represented a respondent, although it was possible that the same respondent would have more than one type of a soil organic amendment (which was collected separately). However, in total, over 155 farmers participated in the survey.

Chemical analysis

Animal manure, leaf litter, compost, ash, and anthill soil samples were air dried and ground to pass through a 2 mm sieve. The samples were analyzed for total nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), Zinc (Zn), iron (Fe), manganese (Mn), and boron (B) contents using methods comparable to those described by Anderson and Ingram (1993). Total N was determined using the semi-micro Kjeldahl method. For the determination of trace elements (Mn, Zn, Cu, and Fe) and bases (Ca, Mg, and K), the samples were ashed at 500°C for 16 h and the ashes were dissolved in concentrated hydrochloric acid (HCl) before filtering, adding strontium chloride and was diluted with distilled water. The amount of K was determined using the flame emission photometer, while the amounts of trace elements and other bases were determined using the atomic absorption spectrophotometer. Total P was determined by the vanado-molybdate method (Okalebo et al., 1993).

Data analysis

The data from the analyses of nutrient levels in soil amendments were subjected to a normality test to determine whether they came from a population that is normally distributed. This was achieved by plotting box-plots for each data set in order to identify the pattern or skewdness of the distribution (Gomez and Gomez, 1984). Where the data were not normally distributed, they were transformed using the logarithmic scale (that is, log X, where X is the original data). Analysis of variance (ANOVA) was done using Genstat statistical package (Version 4.1).

RESULTS

Types of soil amendments

The major types of soil amendments used by farmers in the 16 selected villages were animal manure, leaf litter, composts, anthill soil, mineral fertilizers, and ash. Cattle produced the largest quantity of livestock manure used in the area. Livestock owners had on average 9 cattle, 7 goats, 3 donkeys, and 12 chickens (Figure 1). There was only one farmer with sheep (10) in all the 16 selected villages.

The total number of cartloads (with an approximate average dimensions of 2 × 1.5 × 0.5 m, measured to contain approximately 1 ton) of manure or compost that farmers in the selected villages generated in each season ranged from 1 to 60 (median, 6.5). A summary of the sources, uses, and management of soil amendments in the 16 selected villages is given in Table 1.

Nutrient levels in soil amendments

There were no significant differences ($P > 0.05$) in N, P, K, Ca, Mg, Zn, Fe, Mn, and B levels between villages identified as the 'best' and the 'worst' in the four wards. Similarly, no significant differences ($P > 0.05$) in N, P, K, Ca, Mg, Zn, Fe, Mn, and B levels were found among the different types of soil amendments (cattle, goat, poultry, donkey, anthill, compost, and leaf litter) (Table 2). However, significant differences ($P < 0.05$) in Cu were found among the different types of organic amendments (Table 2).

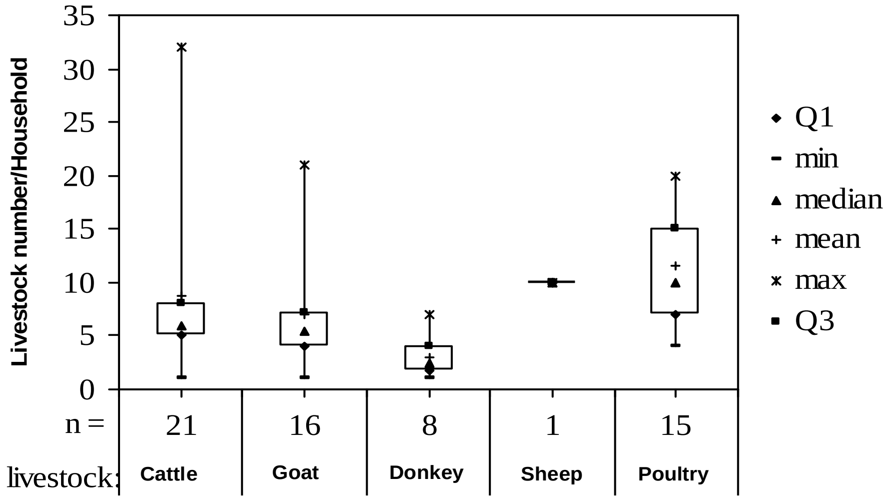

Figure 1. The distribution of livestock among farmers (n) in the 16 selected villages from Chivi district.

Table 1. Sources, uses, and methods of application of soil amendments used in 16 selected villages from Chivi district.

Amendment	Source	Uses and method of application
Animal manure	Livestock kraals and cages. Non-livestock owners access by exchanging with crop residues, buying or when owners loan them livestock.	Applied on sandy soils for crops like maize. Poultry manure is used all-year-round in gardens where vegetables are grown and sometimes applied as liquid manure. Kraal manures are cleared every year or after 2 seasons. Manure is broadcast and ploughed under or dribbled in the planting holes.
Anthill (termitaria)	Farmers have sole access to anthills in their fields. Those in grazing areas are free for all farmers.	Used for crops like maize, groundnuts, and finger millet. Sometimes mixed with litter/compost to neutralize burning effects. Anthills are limited in number and a lot of labour is required for digging, transporting, and spreading them onto the field.
Leaf litter	Forests in the neighborhoods. Mainly by farmers living near or in mountainous areas.	Used mainly in vegetable gardens and as mulch. May be composted first. Applied by broadcasting or spreading and hole-applied to patches of particularly low fertility.
Composts	Grass and crop residues. The composts accumulate over a season.	Mainly in gardens. Grass and crop residues are added to kraal manure and heap or pit composted. Applied by dribbling in planting furrows, broadcasting, and ploughing under into planting holes. Soil also gets mixed with the compost.
Household wastes and ash	Rubbish pits for homestead yard wastes including leaves from trees around the yard and ash.	Limited to patches on home fields and gardens. Composite mixtures of ash, food left-overs, groundnuts shells, maize cobs, etc., are applied by spreading on the field or placing directly in planting holes.
Mineral fertilizer	Dealers, fertilizer companies, donor agencies	Mainly compound D (7N:14P_2O_5:7K_2O) and ammonium nitrate are used by few farmers mostly on maize.

DISCUSSION

The levels of crop nutrients in the soil amendments were comparable among the different villages and wards selected from Chivi district. This was despite the categories ('best' and 'worst') that were established among the villages earlier on the basis of their perceived food security status, soil productivity, and ecological status of the villages. Analytical results did not reflect significant correlations to villagers' perceptions. Thus,

Table 2. Nutrient levels across different soil amendments sampled from 16 villages from four wards in Chivi district, Masvingo, Zimbabwe.

Source	n	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Anthill	6	10.7 (1.8)	3.2 (0.5)	8.0 (1.2)	14 (4)	2.6 (0.4)	3086 (348)	174 (31)	41 (7)	21 (12)^{a}	34 (9)
Cattle	50	13.3 (0.9)	2.8 (0.3)	9.1 (0.7)	12 (1.1)	2.7 (0.2)	2506 (249)	178 (13)	42 (3)	7.7 (0.4)^{b}	24 (2)
Compost	15	11.4 (1.8)	2.9 (0.5)	8.7 (1.4)	24 (6.4)	3.1 (0.4)	3732 (544)	186 (22)	44 (5)	11 (4.0)^{b}	30 (2)
Donkey	3	12.3 (0.8)	2.3 (0.4)	10.7 (0.9)	9.0 (2)	2.4 (0.1)	2405 (1649)	129 (13)	42 (8)	6.0 (1.5)^{b}	18 (4)
Goat	24	14.5 (1.2)	3.1 (0.4)	10.7 (1.1)	16 (3)	3.6 (0.4)	2497 (339)	232 (26)	47 (3)	9.2 (1.2)^{b}	28 (3)
Leaf litter	3	14.3 (5.0)	5.1 (2.0)	4.0 (0.4)	26 (18)	2.9 (1.1)	4398 (543)	171 (20)	86 (32)	10 (1.8)^{b}	25 (8)
Poultry	29	12.7 (1.7)	2.9 (0.3)	9.0 (1.0)	14 (3)	2.9 (0.3)	2414 (254)	161 (14)	55 (9)	8.2 (0.9)^{b}	23 (2)
Rabbit	1	23.0	3.6	9.3	24	3.6	590	790	39	12	52
Ash	1	10.2	1.8	9.9	6.0	1.9	743	105	39	3.0	16
Significance	-	ns	ns	ns	ns	ns	ns	ns	ns	*	ns
CV (%)	-	54.6	64.2	57.1	96.3	51.0	63.7	51.6	39.6	82.2	52.7

Numbers in brackets denote standard errors of means. Numbers without SEM were not used in ANOVA because the samples had no replication. N indicates number of samples. ns, *Not significant, significant at P < 0.05, respectively. Means followed by different letters within the same column are significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test.

nutrient levels in soil amendments at farm scales did not reflect the food security or ecological status at village and ward scales. The high variability in nutrient composition of each soil amendment (reflected in the high coefficient of variance, CV) would reflect the expected wide range of management practices, age of the amendments, and fertility of grazed pastures. These parameters could not be captured accurately during the survey, because the farmers did not keep any physical record of their management practices, but they would be important in explaining potential yield differences.

The perceived or reported higher yields in the villages labeled good may be due to other factors like the amount of inorganic fertilizer added or differences in inherent soil fertility, since the indications are that farmers in all villages have similar conventional knowledge on the handling of their organic sources of plant nutrients, and follow common management practices associated with each type of soil amendment. In contrast, Mtambanengwe and Mapfumo (2005) reported a study in which the farmers' separation of fields into rich (fertile) and poor (infertile) was confirmed by laboratory physico-chemical indices.

With the exception of Cu, no significant differences were found in nutrient levels among the different types of soil amendments. It was expected that N would be significantly lower in ash than in other amendments, because of losses during combustion resulting in the ash. According to the farmers' perceptions, goat and chicken manure were expected to have the highest levels of nutrients. The farmers from all villages regarded goat and poultry manure as the richest in terms of ability to supply crop nutrients and improve soil productivity. Such manure was reserved for high value crops like leafy vegetables, tomatoes, and onions grown in the gardens. The close similarities in the level of crop nutrients among the different types of amendments could be attributed to management, that is, storage and handling. Nutrients are subjected to high leaching and volatilization (N) during storage (Nzuma et al., 1998; Mugwira and Murwira, 1997). From the responses that were obtained, it emerged that farmers handled manure in ways that predisposed the manure to high nutrient losses. Most of the manure was exposed to direct sunlight and rain. Thus, the manure was prone to losing nitrogen through volatilization (Mugwira and Murwira, 1997) whist mineral elements could have been lost through leaching in the kraal.

Studies have been conducted on the efficacy of manure as a fertilizer as well as on chemical composition. Studies by Mugwira and Murwira (1997) indicated that cattle manure from communal lands contain an average of 1.04% N, 0.15% P, and 0.78% K when compared with 1.87% N, 0.58% P, and 0.78% K for manure from commercial feedlots. From earlier study, Tanner and Mugwira (1984) report that the N content of communal area manures ranged from 0.5 to 1.4% of dry matter. It would appear from these studies that the nutrient status of communal area manures varies from place to place and from time to time, but is invariably low. It has been argued that the quality of manure is a function of the nutritional status of the vegetation that the livestock feed on (Irungu et al., 2005; Nzuma et al., 1998; Mugwira and Murwira, 1997).

Generally, soils in Chivi and other communal areas in Zimbabwe are inherently infertile (Zingore et al., 2007; Nyamangara et al., 2000; Dhliwayo, 1998; Nzuma et al., 1998). The general conclusion from manure studies in Zimbabwe is that manure applied alone produces low crop yields and needs to be supplemented with inorganic fertilizers (Kanonge et al., 2009; Dhliwayo, 1998; Nzuma et al., 1998). In the current study, farmers added stover in the kraals for various reasons. Some indicated that animal manure was sometimes mixed with grass and crop residues such as maize and/or groundnut stover.

According to some, this was to increase the manure volumes, but according to other farmers, this was to prevent mud that would lead to diseases. Addition of stover to the kraals during the dry season was done to supplement inadequate veldt feed. However, the tough part of the stover was not eaten and got mixed with the manure.

Besides the addition of stover and grass to their kraals, farmers in the study area had various methods of handling manure. Some simply left the manure in the kraal and dug it out during the dry season and spread in the field. Some dug out the manure soon after the rainy season and left it in heaps to cure, and later spread in the fields just before the onset of the rains. Others dug pits into which manure flowed during the rainy season. The methods of handling and treating manure by farmers in the present study were similar to those by other communal farmers in Mangwende communal lands (North-eastern Zimbabwe), perhaps suggesting that communal farmers in Zimbabwe share the same knowledge and methods for handling soil amendments. At the end of the season, the pit was covered and was only opened at the onset of the next rainy season. The method of manure storage has been reported to influence the nutrient status of manure (Nzuma et al., 1998). Such factors as storage and handling conditions, exposure to high ambient temperature, and exposure to rainfall have been known to affect manure quality (Mugwira and Murwira, 1997). Results from other studies suggested that the management practice of adding stover caused immobilization of nutrients (especially N) by microbial tissue during the first six to eight weeks, because stover has a high carbon to nitrogen (C:N) ratio (Nyamangara et al., 2009; Tanner and Mugwira, 1984; Giller et al., 1998a, b) leading to temporary N deficiency at the beginning of the season.

Conclusions

Livestock owners had on average 9 cattle, 7 goats, 3 donkeys, and 12 chickens and generated 1 to 60 (median, 6.5) cartloads of manure or compost (weighing about 1 ton each) each season. Farmers added grass and crop residues to their kraals to increase the quantity of manure as well as prevent mud. Majority of the amendments sampled had medium to low levels of crop nutrients, and that these levels were similar among the soil amendments, with the exception of Cu. Although, farmers regarded goat and poultry manure as the richest in terms of the ability to supply nutrients to crops, no significant differences ($P > 0.05$) in the studied nutrients, except Cu were found among the different types of soil amendments, and this was attributed mainly to their management. The results indicated that most of the amendments sampled had medium to low levels of nutrients, and that these levels were similar among the villages and wards. It can be concluded from these results that most of the soil amendments in the selected villages are of poor nutrient status. It is recommended to find management practices that minimize nutrient losses as well as to supplement the nutrients with inorganic fertilisers.

ACKNOWLEDGEMENTS

This publication is an output from the Desert Margins Programme (DMP) jointly funded by the Global Environment Facility (GEF) and the Government of Zimbabwe. DMP operates in Zimbabwe under a Memorandum of Understanding with the Department of Agricultural Research and Extension. The African Centre for Fertilizer Development and the Chemistry and Soil Research Institute are also acknowledged for seconding researchers to the DMP programme as part of co-funding.

REFERENCES

Anderson JM, Ingram JSI (1993) Tropical Soil Biology and Fertility: A Handbook of Methods. Second Edition. CAB International. Wallingford, UK. p.221.

Dhliwayo DKC (1998). Beneficiation of Dorowa phosphate rock through composting with cattle manure: residual effects on groundnuts. In: Waddington SR, Murwira HK, Kumwenda JDT, Hikwa D, Tagwira F (Eds.) (1997). Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of the Soil-Fert Net Results and Planning workshop held from 7 to 11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe p.312.

FSRU (1993) Soil fertility management by smallholder farmers. A participatory rapid appraisal in Chivi and Mangwende Communal Areas, Zimbabwe. Farming System Research Unit, Department of Research and Specialist Services, Harare, Zimbabwe.

Giller KE, Gilbert R, Mugwira LM, Muza L, Patel BK, Waddington SR (1998a). Practical approaches to soil organic matter management for smallholder maize production in Southern Africa. In: Waddington SR, Murwira HK, Kumwenda JDT, Hikwa D and Tagwira F (Eds.), Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of the Soil-Fert Net Results and Planning workshop held from 7 to 11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe p.312.

Giller KE, Gilbert R, Mugwira LM (1998b). Potential benefits from interactions between mineral and organic nutrient sources. In: Waddington SR, Murwira HK, Kumwenda JDT, Hikwa D and Tagwira F (Eds.), Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of the Soil-Fert Net Results and Planning workshop held from 7 to 11 July 1997 at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe p.312.

Gomez KA, Gomez AA (1984) Statistical Procedures for Agricultural Research, Second Edition. A Wely Inter-Science Publication, John Wiley and Sons, New York p.680.

Grant PM (1981). The fertilisation of sandy soils in peasant agriculture. Zim. Agric. J. 78:169-175.

Irungu KRG, Ashiono N, Ondabu N, Indetie D (2005). Manure output and its nutrient composition when sheep were fed on three cultivars of sweet potatoe vines. African Crop science Conference Proceedings 7: 551-554.

Kanonge G, Nezomba H, Chikowo R, Mtambanengwe F, Mapfumo P (2009). Assessing the potential benefits of organic and mineral fertiliser combinations on maize and legume productivity under smallholder management in Zimbabwe. African Crop Science

Conference Proceedings 9:63-70.
Mapanda F, Mavengahama S (2011) Assessment of selected soil nutrients and irrigation water quality in the dryland area of Chivi District, Zimbabwe. Sci. Res. Essays 6:2918-2927.
Mavedzenge BZ, Mudziwo C, Murimbarimba F, Hakutangwi M, Scoones I (1996). Evaluation of the Chivi Food Security Project, ITDG, Zimbabwe (unpublished paper), p. 53.
Mombeshora BG, Mudhara M (1994). Indigenous Technology and Farmer Concepts: A case on land husbandry for sustainable crop production in two districts of Zimbabwe (unpublished paper).
Mtambanengwe F, Mapfumo P (2005). Organic matter management as an underlying cause for soil fertility gradients on smallholder farms in Zimbabwe. Nutr. Cycl. Agroecosyst. 73:227-243.
Mugwira LM, Mukurumbira LM (1984). Comparative effectiveness of manure from communal areas and commercial feedlots as plant nutrient sources. Zim. Agric. J. 81(6):241-250.
Mugwira LM, Murwira HK (1997). Use of cattle manure to improve soil fertility in Zimbabwe: Past and current research and future research needs. Soil Fert Net Network Research Results working Paper, Number 2. CIMMYT Maize Programme and Natural Resources Group, Harare, Zimbabwe p.33.
Murwira HK, Kirchmann H (1993). Nitrogen dynamics and maize growth in a Zimbabwean sandy soil under manure fertilization. Commun. Soil Sci. Plant Anal. 24:2343-2359.
Nyamangara J, Mugwira LM, Mpofu SE (2000). Soil fertility status in in the communal areas of Zimbabwe in relation to sustainable crop production. J. Sustain. Agric. 16(2):15-29.
Nyamangara J, Mtambanengwe F, Musvoto C (2009). Carbon and nitrogen mineralization from selected organic resources available to smallholder farmers for soil ferility improvement in Zimbabwe. Afr. J. Agric. Res. 4(9):870-877.
Nzuma JK, Murwira HK, Mpepereki S (1998). Cattle manure management options for reducing nutrient losses: Farmer perceptions and solutions in Mangwende, Zimbabwe. In: Waddington SR, Murwira HK, Kumwenda JDT, Hikwa D, Tagwira F (1997). Soil fertility research for maize-based farming systems in Malawi and Zimbabwe. Proceedings of the Soil-Fert Net Results and Planning workshop held from 7 to 11 July at Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe p.312.
Okalebo JR, Gathua KW, 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.
Shumba EM, Waddington SR, Rukuni M (1989). Delayed maize plantings in a smallholder farming area of Zimbabwe. Problem diagnosis. Zim. J. Agric. Res. 27:103-112.
Tanner PD, Mugwira LM (1984). Effectiveness of communal area manure as sources of nutrients for young maize plants. Zim. Agric. J. 81:31-35.
Zingore S, Murwira HK, Delve RJ, Giller K (2007). Soil type, management history and current resource allocation: Three dimensions regulating variability in crop productivity on African smallholder farms. Field Crops Res. 101:296-305.