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Soil Acidity Management by Farmers in the Kenya Highlands

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Authors' contributions

This work was carried out in collaboration between all authors. Author EMM designed the study, wrote the protocol, involved in data collection, data analysis, interpretation and writing the first draft of the manuscript. Authors ES, JPM, PWM and CKG guided on study design, data collection, evaluation and interpretations. All authors read and approved the manuscript.

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ABSTRACT

Declining soil fertility attributed to soil acidity is a major soil productivity problem in sub-Saharan Africa. A study was carried out in nine counties across the Kenya highlands, namely Meru, Embu, Kerugoya, Nyeri, Kiambu, Kinangop, Siaya, Busia and Eldoret, where the problems associated with soil acidity are prominent. The study aimed at assessing farmers' awareness of soil acidity, and establishment of common acidity management practices following administration of structured questionnaires. From the information gathered through personal interviews via questionnaires, <37% of the farmers were attached to a farmers training group in all study sites; among them, <4% were aware of soil acidity problems and <8% had carried out chemical analysis of their soils. The farmers who had applied lime at least once on their farms were <3% in all sites. Most farmers (>80%) used both inorganic fertilizers and manure on their farms, with the majority using DAP, CAN and farmyard manure. On cultural soil fertility management, choice of subsequent crop was

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dictated by sustainability rather than cropping system like rotation. There was a significant ($P<0.05$) negative relationship between livestock keeping and soil fertility management, with <30% of the farmers returning crop residues back to the farm. Most of them fed crop residues to their livestock. Only 8% of the farmers incorporated crop residues into the soil. There was a significant ($P\leq 0.05$) positive correlation between education level and inorganic fertilizer use in crop production. Farmer's age and maize yields correlated negatively with each other. Additionally, farmers' training programmes and frequencies positively influenced choice of inorganic fertilizers and levels of application. Training is therefore one of the most significant issues affecting soil fertility management in the Kenya highlands. To further enhance the understanding of soil acidity and fertility management in Kenya highlands, farmers training should be prioritized.

Keywords: Inorganic fertilizers; soil fertility; soil fertility management; soil acidity; Kenya highlands; farmers training.

1. INTRODUCTION

Soil acidity is a major problem for agricultural productivity worldwide [1,2]. Acid soils account for about 4 billion ha of the total world land area [3]. This is 30% of the total world land area and 58% of land suitable for agriculture, inhabited by 73% of the world's population. Most acid soils are found in South and North America, Asia and Africa, due to extensive weathering and leaching. The acid soils occupy 29% of the total land area in the sub-Saharan Africa (SSA) zone and 13% of Kenyan land area [4,5]. Soil acidity is associated with hydrogen (H), aluminium (Al), iron (Fe) and manganese (Mn) toxicities to plant roots and corresponding deficiencies of plant available P, molybdenum (Mo), calcium (Ca), magnesium (Mg) and potassium (K) [6,7], which negatively affect soil fertility and productivity.

The agricultural sector is the backbone of the Kenyan economy [8]. It contributes 25% of the total GDP and employs about 75% of the national labour force [9]. Although Kenya's food policy emphasizes self-sufficiency, food insecurity is a big problem [10]. More than 10 million Kenyans (nearly one third of the population) are chronically food insecure [8,9] due to declining food production and non-uniform distribution of agricultural products. Crop production in Kenya has been on the decline over the years, leading to importation of food [9]. The low food production has been attributed to declining soil fertility, poor crop management practices, poor post harvest handling procedures [11] and uneven and inadequate natural precipitation. Plant nutrient depletion from soils is greatest when no or only minimal quantities of nutrient inputs are added to the soils under crop production [12] to replenish those removed by plants or crop harvests. Studies carried out in Kenya indicate that the amount of chemical inorganic fertilizers used for maize production by most farmers is below the recommended rates [13,14]. This is attributed to the lack of knowledge on the effects of inorganic fertilizers on crop yields, lack of capital due to the low wealth status of the farmers or lack of the appropriate agricultural inputs.

Maize (*Zea mays* L.) is the staple food crop for the majority of Kenyans [15]. However, maize production has been declining over the years [16]. Both commercial and small-scale farmers grow the crop but in most areas the production is constrained by low soil nitrogen and phosphorus availability and high soil acidity [17-21] and inadequate natural precipitation in some areas. Phosphorus availability in acid soils is greatly influenced by aluminium ion concentration in the soil. Unfortunately, most improved maize germplasms and landraces used by Kenyan farmers are sensitive to the high (>20%) Al saturation and high exchangeable Al (>2 cmol kg^{-1}) commonly encountered in many acid soils of the Kenya highlands [22,23]. Use of calcitic and dolomitic liming materials which ameliorate Al toxicity, raising soil pH and promoting increased base saturation and soil extractable P [2,24-26] is, therefore, important in management of P in these soils.

Soil acidity and fertility can be managed through the use of tolerant plant germplasms; improved agronomic, cultural and biological practices and use of inorganic fertilizers. Some of these management practices are known to farmers, who undertake them routinely within their farming protocols. However, some of the relevant management practices are not undertaken due to various reasons including lack of credit to purchase the required inputs, knowledge on the importance of lime, improved crop varieties tolerant to soil acidity constraints, and inadequate amount of organic materials [25]. Several studies have been undertaken in Kenya to assess the best management practices for soil acidity amelioration. Research findings by [27-30] indicated that integrated plant nutrient management (IPNM) by combining inorganic and organic fertilizers improves maize yields. Additionally, [23,31,32] reported some success in development of P - use efficient maize germplasms which are tolerant to Al toxicity in acid soils.

The many studies undertaken on soil acidity and fertility status in Kenya have concentrated on nutrient management issues [24,30,33]. Limited research has focused on farmers' knowledge, attitudes and current adoption levels of the management recommendations. Farmers' knowledge of the cause of the problem and potential solutions is often the first step towards identifying and designing appropriate strategies for any successful management practice. In addition, their perception of how well a technology performs is understandably one of the key factors influencing their decision to adopt new technologies [34,35]. It is also generally recognized that the technology adoption process may be hindered by failure to incorporate views and perceptions of intended users during the design or development process. For the effective adoption of soil fertility management, soil fertility gaps identification and addressing of farmers' views and perceptions is paramount. The information generated would be useful in guiding future soil acidity management programme designs for the Kenya highlands. Therefore, the objective of the research was to evaluate farmer's awareness of soil acidity and assess the current soil fertility management practices in the Kenya highlands.

2. METHODOLOGY

2.1 Location of the Study Sites

Sites were selected to represent the major agro-ecological areas with acid soils in the Kenyan highlands where the staple food crop, maize, is grown east and west of the Rift Valley [5,36]. The study sites had been under continuous crop cultivation for years with minimal attention to the state of the art maize production practices. Descriptions of the selected sites are shown in Table 1. From the information in Table 1, Meru, Embu, Kerugoya, Nyeri, Kiambu and Kinangop represented the highlands east of the Great Rift Valley while Siaya, Busia and Eldoret represented the highlands west of the Great Rift Valley.

2.2 Administration of the Questionnaire

A systematic sampling procedure [37] was used to select farmers who acted as responders in the nine study sites. The farmers were selected after a distance of 500 metres apart, resulting in a sample size of 20 farmers per site and 180 for the whole study (9 counties). Data were obtained from the sampled farmers through interviews and structured questionnaires. The Farmers' survey was undertaken in October/December, 2013, using a single - visit survey approach [38]. Data collected included information on farmers' socio - economic status, soil acidity and fertility management practices.

2.3 Data Analysis

The social data was coded and analyzed by using the SPSS software, version 17 [39].

Table 1. Description of the study areas

County	Site	GPS of sites		Elevation (m)	Soil type
Meru	Kaguru	00 05 S	037 39 E	1460	Humic Nitisols
Embu	Kavutiri	00 25 S	037 30 E	1700	Ando- humic Nitisols
Kerugoya	Inoi	01 04 S	036 47 E	1539	Ando- humic Nitisols
Nyeri	Chehe	00 25 S	037 10 E	1920	Nitisols
Kiambu	Githunguri	01 03 S	036 45 E	1720	Nitisols
Kinangop	Magumu	00 46 S	036 35 E	2691	Eutric Nitisols
Eldoret	Turbo	00 38 N	035 10 E	1835	Chromic Acrisols
Siaya	Sega	00 13 N	034 14 E	1228	Orthic Acrisols
Busia	Bumala	00 16 N	034 12 E	1248	Orphic Ferralsols

Soil type information sourced from FURP, 1988

Descriptive analysis was applied whereby frequencies of scores were computed. Dependency tests were also conducted to find out if there were any relationships between the various variables addressed by the questionnaires.

3. RESULTS

3.1 General Information about Respondents Gender and Education Levels

More than 50% of the respondents were men except for Kiambu and Kinangop counties where female respondents were more than their male counterparts (Table 2). The education levels of the respondents varied greatly from site to site. More than 50% of the respondents in Meru, Embu, and iaya had only attained primary school education, except in Kerugoya and Nyeri where most of the respondents had tertiary education.

3.2 Membership to Farmers Training Groups

Most of the farmers in some of the research areas did not belong to any particular agricultural training group (Fig. 1), except for Kerugoya, Nyeri and Eldoret where 80%, 80% and 40%, respectively, of the farmers were members. On average, less than 37% of the interviewed farmers were members of a training group. It was found out that most farmers were not interested in farmers' training groups because of unavailability of regular training programs.

3.3 Seasonal Choice of Type of Crop to Grow

The criteria governing the choice of crops to be grown per season varied among sites and individuals (Fig. 2). The majority of farmers in Meru (82%), Embu (80%) and Eldoret (85%) chose crops depending on level of sustainability - whether the crops would be able to meet their food needs or not, while majority of farmers in Kerugoya (60%), Nyeri (60%), Kinangop (60%) and Siaya (50%) chose crops depending on their level of profitability.

3.4 Soil Acidity Perceptions or Awareness among Farmers

Most farmers were not aware of soil acidity problems (Fig. 3). Kiambu, Kinangop and Busia respondents were totally unaware of soil acidity problems while less than 15% were aware in the other areas. Only 20% of the farmers in Meru and Embu had carried out physical and chemical analyses for their soils at least once while the rest of the respondents had never analysed the soils of their farms. On average, < 4% of all the interviewed farmers were aware of soil acidity and less than 8% had carried out nutrient analysis on their soils.

3.5 Soil Acidity Management through Liming

Farmers reported minimal use of lime in soils (Fig. 4). Only 10% of the farmers from Embu and Siaya and 5% of farmers in Nyeri and Eldoret had used lime.

3.6 Inorganic Fertilizer and Manure Use

Use of inorganic fertilizers and manures varied from site to site (Fig. 5). More than 75% of the respondents used both inorganic fertilizers and manures on their farms, except in Kiambu and Eldoret counties where only 60% of respondents applied both.

Table 2. Respondents gender and education levels

County	Gender (% of respondents)		Education level (% of respondents)		
	Female	Male	Primary	Secondary	Tertiary
Meru	33.3	66.7	60	25	15
Embu	33.3	66.7	60	25	15
Kerugoya	33.3	66.7	10.5	36.8	52.6
Nyeri	33.3	66.7	10.5	36.8	52.6
Kiambu	55	45	45	25	20
Kinangop	55	45	45	25	20
Eldoret	30	70	21.1	42.1	26.3
Siaya	45	55	52.6	15.8	15.8
Busia	40	60	26.3	36.8	36.8

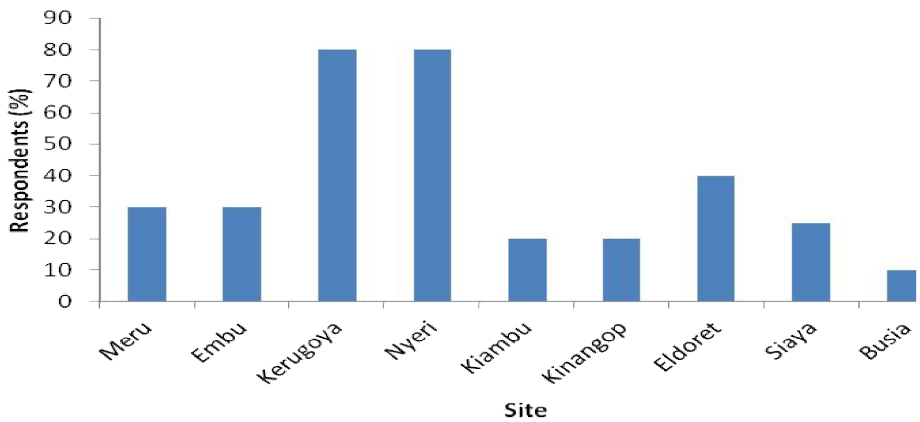

Fig. 1. Percentage of farmers in each site who are members of some training groups

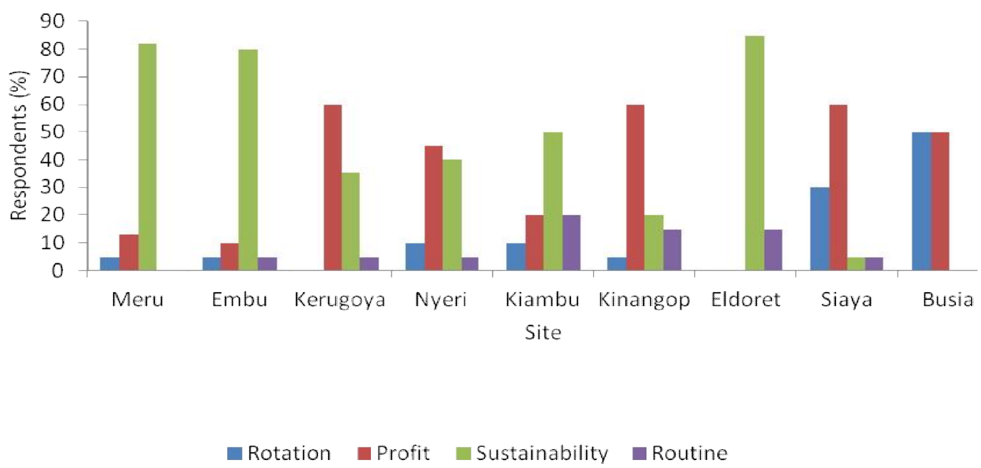

Fig. 2. Criterion applied by farmers when choosing the type of crop to plant per season in the nine sites

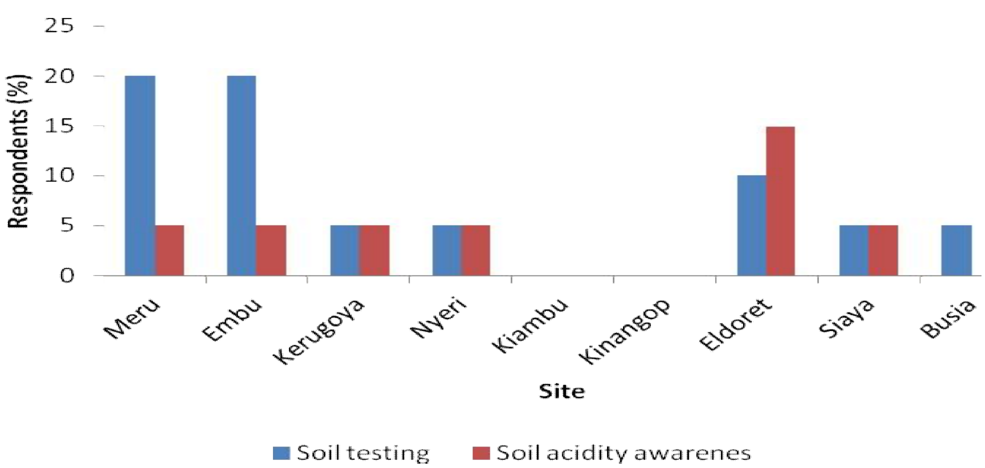

Fig. 3. Percentage of farmers having soil acidity knowledge and have tested their soils in the nine sites

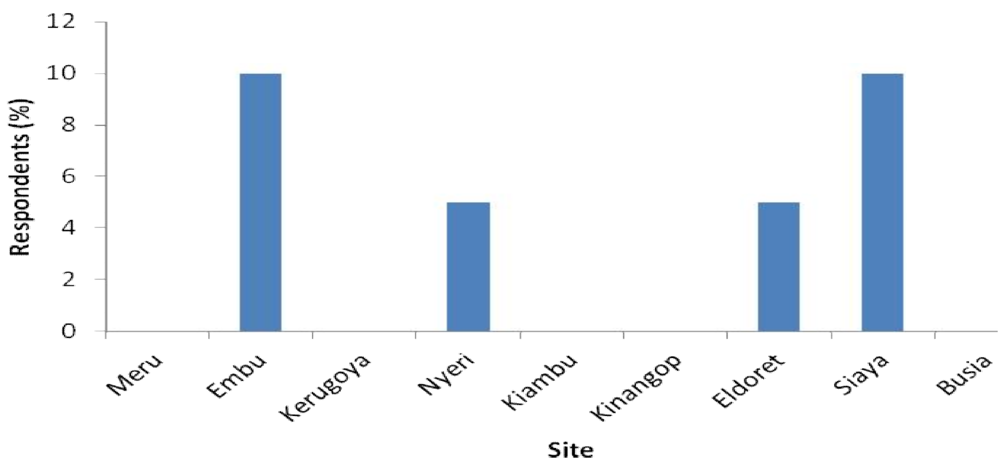

Fig. 4. Percentages of farmers applying lime in their farms at the nine sites

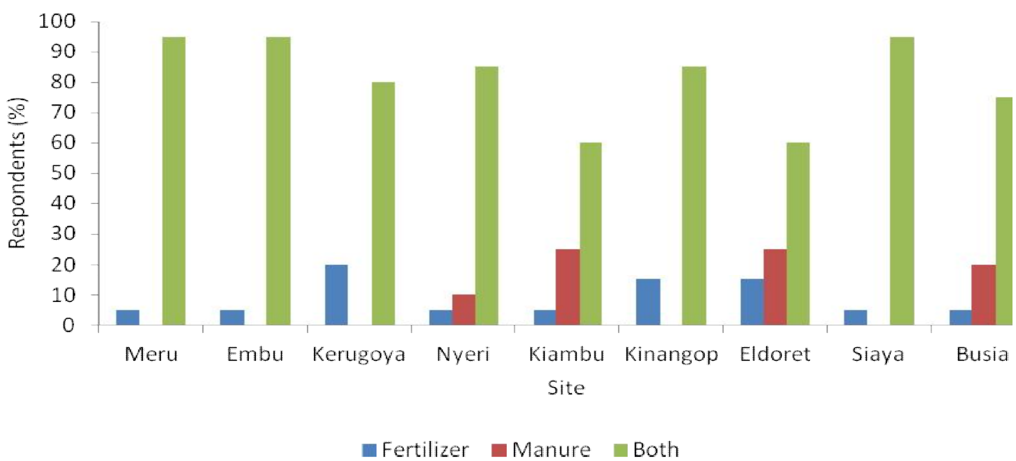

Fig. 5. Percentages of farmers applying manures or inorganic fertilizers in their farms at the nine sites

3.6.1 Manure type and sources

Farmers used only farmyard or compost manure (Fig. 6). More than 75% of the manures were from own sourcing, with only few (<1%) farmers sourcing the manures from relatives and friends and others purchasing. The proportion of farmers using farmyard manure was >70%, with <10% using compost manure.

3.6.2 Choice of inorganic and organic fertilizers in the Kenya highlands

Farmers' choices of types of inorganic fertilizers and organic fertilizers (manures) was dictated by availability, advice from agricultural extension staff, what they are used to, and advice from other farmers (Table 3). About of 50% and 74% chose inorganic fertilizer, and manure, respectively, depending on local availability, while 30% and 21% of the farmers chose inorganic fertilizer and manure type depending on what they were used to. Most farmers used inorganic fertilizers and manures mainly for soil fertility enhancement, hence expecting crop yield increases. More than 50% of the farmers had benefited from inorganic fertilizer and manure use, with <50% of the farmers indicating that sometimes the costs of production were higher than the income. The inorganic fertilizers commonly used by farmers were diammonium phosphate (DAP) [$(NH_4)_2$ HPO_4], calcium ammonium nitrate (CAN) [$Ca\ (NO_3)_2.NH_4.NO_3$], and triple super phosphate (TSP) [$Ca\ (H_2PO_4)_2$] while the common manure types were farmyard manure (FYM) and compost.

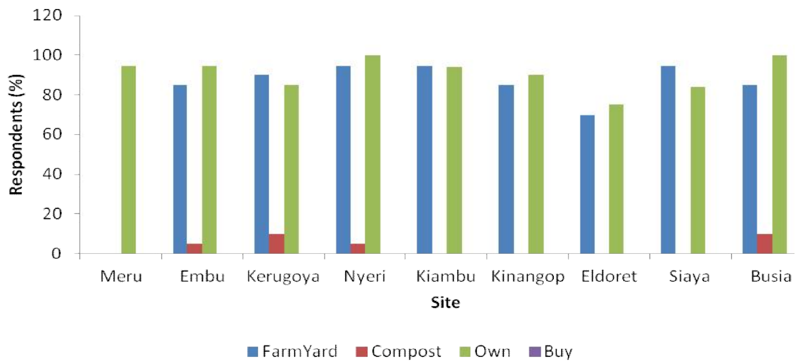

Fig. 6. Sources and types of manures applied by farmers at the nine sites

Table 3. Factors determining inorganic fertilizer and manure choice in the Kenya highlands

Question	Reasons	% respondents	
		Inorganic fertilizer	Manure
Types choice	Availability	50	74
	Advice by extension staff	18	5
	Used to	30	21
	Others	2	0
Why apply	Fertility enhancement	52	5
	Increase yield	45	90
	Others	3	5
Availability of benefit	Yes	60	50
	No	40	40
Acquisition of profit	Yes	28	20
	No	20	27
	Sometimes	32	23
	Don't know	20	30

3.7 Crop Residues Utilization by the Farmers

Methods of crop residue disposal varied greatly (Fig. 7) whereby 70% of the farmers interviewed claimed that they fed all the crop residues to their livestock, 9.4% utilized it for compost manure preparation, 0.5% burned the residues while 2.2% sold it to other progressive farmers. Only 8.3% of the farmers left residues on the farm for soil fertility improvement. For example, more than 85% of the farmers in Meru, Kerugoya and Kiambu fed the crop residues to their livestock while 5% of the farmers in Eldoret disposed of their crop residues by burning. Busia had the highest number of farmers (35%) who left crop residues on the farm to be incorporated into the soil.

3.8 Relationship between Farmers' Practices and Crop Yields

A significant negative relationship was observed between farmers' age and inorganic fertilizer use levels (Table 4). A positive relationship was observed between farmer education level, average maize yield and inorganic fertilizer use levels. Additionally, inorganic fertilizer use was positively correlated with the frequency by which farmers participated in training programmes.

4. DISCUSSION

From the farmers' responses to the questionnaire, most farmers complained of lack of structures for establishment of regular training platform as the reason they did not belong to any farmers' training group. According to [40], training of farmers is mostly through agricultural officials such as extension or field officers. The knowledge acquired by farmers enables them to learn, internalize, evaluate, try and adopt new technologies [41]. However, [40] indicated that the extension officers must be knowledgeable and credible enough to win farmers' trust. This is in agreement with farmers' responses because they indicated that extension officers were knowledgeable but the problem was that they were too few to effectively meet farmers' demand for training and follow up.

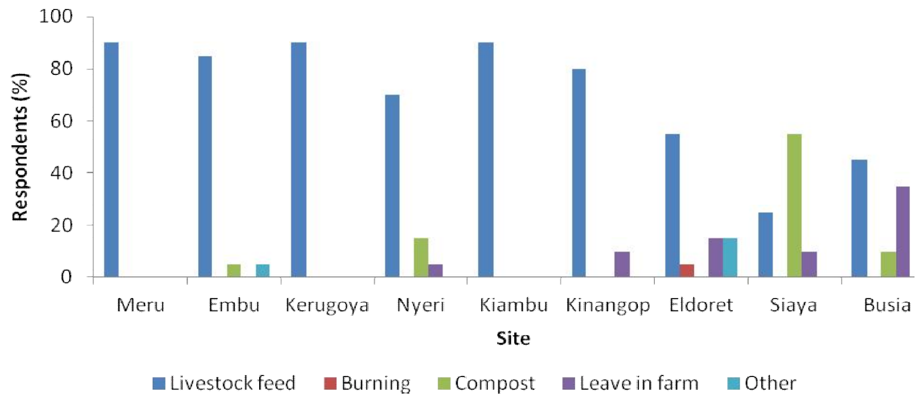

Fig. 7. Disposal of crop residues by farmers from the nine sites

Table 4. Correlations between farmers soil management practices and crop yield

Pair	R	P-value
Farmers age- Inorganic fertilizer use	-0.30**	0.002
Acreage- Average maize yield	0.29**	0.006
Education- Average maize yield	0.24*	0.025
Education- Inorganic fertilizer use	0.23*	0.024
Farmers training- Inorganic fertilizer use	0.40*	0.016
Maize yield- Inorganic fertilizer use	0.31**	0.005

**Significant at 0.05 level; **Significant at 0.01 level*

The farmers (<10%) who had used lime at least one time complained that they were not aware of soil acidity problems, did not vividly know their importance and also that lime was not readily available in the local agricultural input shops. These findings are similar to those from a review conducted by [25] who indicated that very few farmers in Kenya were aware of the soil acidity problem. They further stated that most farmers did not use lime either due to lack of knowledge about its importance or lack of liming materials in the market, or because the liming activity was labour intensive and expensive for smallholder farmers.

The preference of DAP as opposed to other nitrogen sources, despite its acidifying effect on the acid soils, could be attributed to the cost of the N sources available in the market. Studies carried out by [42] to evaluate the cheapest source of N in the Kenyan market for farmers' use indicated that mono-ammonium phosphate (MAP) and DAP were cheaper N sources compared to NPK inorganic fertilizers like 17:17:17, 20:20:0 or 23:23:0. The farmers claimed that they preferred FYM over other organic sources of fertilizer because it is readily available locally, is easy to handle and is cheaper than other manures. Similar findings reported by [30,43] indicated that most smallholder farmers in Western Kenya preferred FYM as compared to other organic sources of plant nutrients whose costs could not be offset by the yields obtained.

Education level influences farmers' access to information as well as their ability to understand technical aspects of innovations which largely affects production decisions [44]. The positive correlation between educational level, maize yields and inorganic fertilizer use is in agreement with the findings of [45], which showed that educated farmers adopted recommended inorganic fertilizer rates with ease, leading to improved crop yields and low levels of environmental pollution. It was also established by [46] that education influenced the rate of adoption of developed technologies or innovations, hence positively influencing the resulting output.

The significant positive correlation between inorganic fertilizer use and participation in farmer trainings could be attributed to access of information and knowledge on handling of inorganic fertilizers. Baah et al. [47] observed that farmers who were members of farmers' associations had better access to inorganic fertilizer information that contributed to the adoption of appropriate inorganic fertilizer use practices. Similarly, [48] attributed non-adoption of some agricultural technologies by farmers to inadequate information and sketchy knowledge, lack of awareness of the technologies and lack of follow-up by extension staffs, which are adequately catered for in training forums.

The significant (P=0.001) negative correlation (-0.30) between farmers' age and inorganic fertilizer use might be attributed to fear of the unknown. The results of this study were in agreement with [49], who observed that farmers who were above 39 years were most likely to have lower adoption rates of new technologies, because older people fear the risk of unexpected events whilst young farmers tend to be more flexible in their decisions to adopt new ideas and technologies more rapidly. Similarly, [48,50] reported that adoption of improved technologies was associated with age, education, farm size, income, exposure, scientific orientation, knowledge level and training received.

5. CONCLUSIONS

The results have revealed that farmers' in the study sites have limited knowledge on soil acidity problems, and management strategies. Additionally, farmers' access to information on new technologies is constrained by failure to participate in farmers' trainings. Strategies should, therefore, be established which would encourage farmers' participation in agricultural training groups to improve their agricultural knowledge base. The approach to be used could be the participatory rural appraisal (PRA), participatory learning and action research (PLAR) or participatory agro-ecosystem management (PAM). This will enhance levels of understanding and adoption of improved soil acidity and fertility management practices, hence improve crop yields and production across the Kenya highlands.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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