EVALUATION OF ANTHILL SOIL AS A FERTILITY ENHANCER IN MAIZE CROP PRODUCTION

BY

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A THESIS SUBMITTED TO THE SCHOOL OF AGRICULTURAL SCIENCES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN AGRICULTURE

DEPARTMENT OF SOIL SCIENCE

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ABSTRACT

Anthill soil is soil carried by ants from underground as they form their nests making a mound at the entrance. Active anthills are thus enriched with soil organic matter and inorganic nutrient elements, such as Ca, K, Mg and P, compared with adjacent surface soils. This study was carried out to determine the nutrient composition of anthill soil in Batoka district (Southern Province, Zambia) and to determine the response of maize biomass yield to anthill soil. Different proportions of anthill soil to surrounding soil were used. The anthill soil was found to have a higher pH and more Ca, P, Mg and Zn than the surrounding soil. It was also established that there were significant differences in the biomass yield of the different treatments.

ACKNOWLEDGEMENT

I would like to thank God for seeing me through and making it possible for me to reach this far. Many thanks to my supervisor Dr B.H. Chishala. I would also like to extend my appreciation to Mr V. Shitumbanuma, Mr M. Moombe and the technicians in the soil science department Mr Musukwa, Mrs M.Chishala, Mr Bwalya, Mr Mpande, Mr Simbule, Ms. C. Nachalwe and Ms Q. Isoni for the help rendered to me when carrying out this study.

My classmates are not to be forgetten especially Mirriam Chibesa who helped and advised me like a sister.

I also appreciate the support from my fiancé Praise Moonde.

Lastly, I would like to express my gratitude to my parents Mr Chunga Musonda and Mrs Duba Musonda, my brother Ipalo Musonda and my sisters Taonga and Bupe Musonda for their financial, emotional and moral support that they rendered to me throughout the programme.

DEDICATION

To my parents, Mr Chunga Musonda and Mrs Duba Musonda.

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CHAPTER 1

1 INTRODUCTION

Decline in soil fertility is one of the challenges that farmers in Zambia are facing. Mono cropping and improper use of fertilizer have contributed to the decline in soil fertility. Southern province which was once considered the maize belt of Zambia is also faced with this challenge. Farmers use mineral fertilizers to maintain soil fertility. Most of the small scale farmers find the mineral fertilizers expensive for crop production. They have therefore resorted to using alternative sources of nutrients for crop production. Anthill soil is one such source.

Anthill soil is soil carried by ants in digging there underground nests and heaped in a mound around its entrance. Ants are important components of ecosystems not only because they constitute a great part of the animal biomass but also because they act as ecosystem engineers. Ant biodiversity is incredibly high and these organisms are highly responsive to human impact, which obviously reduces its richness.

Ecologists view anthills as natural disruptions that maintain heterogeneity in an ecosystem (Wagner *et al.*, 1997). There are different types of anthills which depend on the species of ants which engineered the anthill, the soil and age of the anthill.

The anthills are found throughout the country in areas where the soil is not purely sand. Before a termite mound can be formed the soils should have at least 10% clay plus silt. Soils found on termite mounds have a high amount of clay and silt. Mounds are utilized agriculturally, by growing crops on them during the rain season. Studies have shown that the soil and vegetation of ant mounds differ from those of their surroundings in pH of the soil, organic matter content, soil moisture and composition of vegetation (Kristiansen *et al.*, 2001).

However, it is not clear how such changes in the soil damage the maintenance of ant services to the ecosystem. Termites are important in below ground processes through the alteration of the physical and chemical environment and through their effects on plants, microorganisms, and other soil organisms.

Apart from use in agricultural field, the soil is also used as a source of income when sold to farmers. Many small scale farmers use anthill soil as a soil conditioner and amendment. The aim of this study was to investigate the effect of anthill soil on soil chemical fertility and crop production.

1.1 STATEMENT OF THE PROBLEM

Many small scale farmers use anthill soil as a soil conditioner. With no subsidies, the inputs of agricultural produce are becoming expensive. It is therefore important to find other ways of improving the fertility of the soil at a lower cost. Anthill soil has been used to improve soil fertility. However, the effect of the anthill soil on soil fertility is not clearly understood.

1.2 HYPOTHESIS

The hypothesis is that anthill soil increases crop yield.

1.3 MAIN OBJECTIVE

The main objective of this study is to determine the contribution of anthill soil to soil chemical fertility.

1.4 SPECIFIC OBJECTIVES;

- To determine the chemical fertility of anthill soil
- To evaluate the effect of anthill soil on maize biomass production

CHAPTER 2

2 LITERATURE REVIEW

2.1 Soil fertility

Soil fertility is the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth (Farji-Brener and Silva, 1995)

For normal plant growth, a plant needs both macro and micro nutrients. These are therefore known as essential elements. An essential element is one for which the plant cannot complete its cycle without, cannot be replaced by another element and its absence or presence in insufficient quantities causes disorders to plant growth (Tisdale *et.al.*, 1985)

A macronutrient is an essential element required in large amounts for normal plant growth. They include N, P, K, Ca, Mg and S. A micronutrient is an essential element required in comparatively small amounts by the plant. They include Cl, B, Zn, Mn, Fe, Cu and Mo (Tisdale *et.al.,* 1985)

Of all the essential elements, the major elements supplemented to the soil are N, P and K. Farmers use different methods of soil amendments to ensure that the soil has the necessary nutrients required for normal plant growth.

2.2 Use of anthill soil in agriculture

Mound-building ants collect woody debris for their nests and forage for large quantities of insect prey and honeydew as food for their colonies. Active anthills are thus enriched with soil organic matter and inorganic nutrient elements, such as Ca, K, Mg, and P, compared with adjacent surface soils (Folgarait, 1998; Lobry de Bruyn & Conacher, 1990; Kristiansen *et al.*, 2001). Ant activity can also alter:

(i) physical soil properties, such as infiltration and porosity (Wang *et al.*, 1995),

(ii) soil microbial community and faunal biomass (Laakso & Setala,1997), and

(iii) rates of decomposition of organic matter (Petal & Kusisnka, 1994)

Soil activities of ground- dwelling ants are evident when observing the construction of nest and mounds. Ants' nest-building activities transform underlying soil into nutrient-rich patches that may favour seed germination (Levey and Byrne, 1993; Andersen and Morrison, 1998). There are other researchers who have associated modifications to soil physicochemical properties with mound construction by ants (Nkem *et al.*,2000 ; Lenoir *et al.*, 2001 ; Lafleur *et al.*, 2002), while others have associated these activities with plant distribution patterns (Culver and Beat-tie, 1983 ; Dean *et al.*, 1997 ; Garrettson *et al.*,1997) and vegetation succession (King, 1977 ; Farji-Brener and Silva, 1995). There are other researchers who have tried to link this soil enrichment to plant growth (Kristiansen *et al.*, 2001).

A research conducted at the University of Zambia (UNZA) on the use of mounds of termite *marotermitermes faciger* as a soil amendment by Vasco (2004) showed that Termite mound improves soil chemical status by increasing the levels of Calcium and Magnesium. It was also found that termite mound was not as good as fertilizer in enhancing growth and increasing yield, but better than the non-treated soil.

2.3 Examples of anthill use in agriculture

Farmers in southern Zambia have been utilizing anthill soil as an option to improve soil fertility at farm level to avert the challenge of inputs especially fertilizer. According to a rapid rural appraisal conducted by Zambia Agricultural Research Institute (ZARI, 2010) amongst anthill soil users indicate that once applied in the agricultural lands, the field does not require fertilizer to be applied for at least 2 years.

A farmer in Batoka district, Sibooli (personal communicaton) also indicated that fertilizer was not required for crop production once anthill soil was added, especially if animal manure is incorporated.

In Zimbabwe, agriculture is divided into two distinct sectors: large-scale commercial agriculture which is mainly privately owned and the communal sector which is dominated by subsistence farming. The communal lands are predominantly found in regions with low rainfall and poor soils. Farmers of Zimbabwe use a variety of practices to manage soil fertility. These include winter ploughing to incorporate residues and conserve moisture, crop rotation, fallowing, application of leaf litter, compost, manure and ash. Farmers choose their methods according to the amount of materials available, labour requirements and availability of land and draught power (Giller, and Mapfumo, 2001)

One example of nutrient management by poor farmers is the application of anthill soils. Owing to shortage of land and financial resources, small-scale farmers in Zimbabwe improve poor agricultural land by spreading anthill soils in the field. Before planting, soil is dug from the termite mounds, evenly spread, and mixed with the sandy soils. White ants are regarded as beneficial insects and protected because they provide the farmers with cheap natural fertilizer. When applying the soil, farmers ensure that the anthills are not destroyed in order to rely on them again after some years of recovery. The productivity of the land is reported to increase after the application of anthill soil (Giller, and Mapfumo, 2001).

Farmers in the Yala area of Siaya County in Kenya use anthills to fertilize their soils in sandy soils at a time when the price of mineral fertilizers have gone beyond their reach (Koigi, 2014).

CHAPTER 3

3 MATERIALS AND METHODS

3.1 Experimental Site

The pot experiment was carried out in the green house, School of Agricultural sciences, University of Zambia, Great East road Campus, Lusaka, Zambia.

3.2 Soil sampling

Samples were collected from Batoka district (Southern Province, Zambia) from four different anthills and soils around them at a depth of 0-20 cm. From each sample, about 500 g of soil was air dried and sieved using a 2 mm sieve. The sieved samples were used for soil characterization.

3.3 Soil characterisation

The soil was characterized for the following selected parameters:

3.3.1 Determination of soil reaction (pH)

The soil pH was analysed by using $CaCl_2$ solution. Ten grams of air-dried soil samples were placed in 50 mL beakers to which 0.01M $CaCl_2$ was added. The beakers were shaken for 30 minutes and allowed to stand for 5 minutes before the pH was determined using the pH meter (McClean, 1965; Peech, 1965)

3.3.2 Determination of particle size analysis

Fifty grams air dry soil passed through a 2 mm sieve was placed into a dispersing cup. Fifty milli-litres of the dispersing agent (calgon) and filled the cup up to half with distilled water. The cup was stirred continuously for 5 minutes.

The suspension was transferred to the sedimentation cylinder using a stream of distilled water to complete the transfer and the level of the liquid was brought to the one litre mark with distilled water. The temperature of the suspension was measured and recorded.

The plunger was inserted, held the cylinder firmly, and moved the plunger up and down to mix the contents thoroughly.

After 20 seconds, the hydrometer was lowered carefully and a reading after 40 seconds was taken. This measurement enabled to determine the silt and clay content.

In order to obtain information on the clay content of the sample, a hydrometer reading was carried out 2 hours later without mixing the suspension. (Donahue *et al.*, 1983). The following formulae were used;

% sand = 100% - %(silt + clay)

%(silt + clay) = (40_s reading- C1 +/- C2) × 2

% clay = (2 hours reading - C1 +/- C3) × 2

% silt = 100% - % sand- % clay

C1 (correction factor of dispersing agent due to temperature)

C2 (40_s correction), C3 (2 hours correction)

3.3.3 Determination of exchangeable acidity

Ten grams of air dry soil samples, passed through a 2 mm sieve, were placed into a 250 mL Erlenmeyer flask to which 100 mL of 1M KCl was added, covered with parafilm. The flasks were shaken for 1 hour and then the suspensions were filtered. 25 mL of the KCl extract were pippeted into a 250 mL conical flask, to which $100cm^3$ of distilled water was added. 5 drops of phenolphthalein indicator were then added before titrating with a standard 0.01M NaOH solution to a permanent pink end point. Thereafter, 10 mL of NaF solution had to be added to the flask. Then while shaking constantly, the solution was titrated with 0.01M HCl till the pink colour disappeared. Finally, the milli-equivalents of the acid used were computed to represent the exchangeable acidity (Cottenie and Verloo, 1982).

3.3.4 Determination of Calcium, Magnesium, Sodium and Potassium

Ten grams of air-dry soil samples were placed into a 250 mL Erlenmeyer flasks, then 50 mL of NH_4OAc, at pH 7.0 was added. The flasks were shaken for 30 minutes before filtering the suspension using No. 42 Whiteman filter paper. The Ca, Mg, Na and K were determined in the filtrate using the flame emission and the Atomic Absorption Spectrophotometer machine (AAS) (Doll and Lucas, 1973).

3.3.5 Determination of available Phosphorus

The Bray I method was used to determine the available phosphorus. The extracting solution is a combination of NH_4F and HCl. Three grams of air-dry soil sample was weighed into 250 mL flat bottled flask, to which 21 mL of extracting solution was added. It was shaken for 1 minute then filtered. Five milli-litres of the filtrate was pippeted into a 25 mL volumetric flask, to which 10 mL of distilled water were added. Then 4 mL of molybedenum blue (reagent B) was added before making up to the mark with distilled water. The colour was allowed to develop for 15 minutes before determining P-content in the solution on a spectrophotometer at 882 nm wavelength. The blank and P (1mg/L) standard which contained the same volume of the extracting solution was used for standardizing the spectrophotometer (Bray and Kurt, 1945).

3.3.6 Determination of total Nitrogen

The method used to determine total nitrogen was the Macro Kjeldahl method. One gram of soil sample was placed in a 500 mL Kjeldahl flask. Then 4 g of the catalyst mixture were added to it, before adding 10 mL of the concentrated sulphuric acid, the flask was then swirled thoroughly. The flask was placed on the Kjeldahl digestion stand where it was heated to a temperature of about 450°C.

The digests were transferred into a clean 100 mL bottle. The sand particles were all retained in the original digestion flask. The residue sand was washed with 50 mL of distilled water four times and the aliquot into the same flask. 20 mL H_3BO_3 indicator solution into a 250 mL Erlenmeyer flask that was then placed under the condenser of the distillation apparatus. Then 10 mL of 10M NaOH was poured into the distillation flask gently; the Kjeldahl flask was quickly attached to the distillation apparatus. The condenser was kept cool by allowing sufficient cold water to flow through. Distillation was done for five minutes.

The distillate was titrated with 0.01M standard HCl till the colour changed to pink. The result was corrected by subtracting the titration value with that of the blank value. (Brenner, 1960)

The results are expressed on the oven-dry weight basis.

Thus:

$$\%N = \frac{(a-b)\ 0.14 \times 10^{-3}g \times 100\%}{W_{od}\ (g)}$$

3.3.7 Determination of available nitrogen

Exactly, 5 g of the soil was weighed into a 100 mL plastic bottle and 50 mL of 1M KCl was added. After shaking for 1 hour the solutions were filtered and the filtrate collected for analysis. To determine NH_4-N, 10 mL of the filtrate was pipetted into the digestion tube to which 0.1 g of MgO was added. This was distilled for 3 minutes and the distillate was collected in a 100 mL cornical flask containing 2% boric acid indicator-solution. The distillate was titrated using 0.005N H_2SO_4. To the same solution a pinch of devarda alloy was added and distilled for 3 minutes in order to determine NO_3-N (Cottenie and Verloo, 1982).

Available N was then calculated as follows:

$$mgNH_4 - N/kg = \frac{Normality\ x\ volume\ of\ titre\ (mL)x\ volume\ of\ extactant(mL)}{Weight\ of\ sample\ (kg)x\ volume\ distilled\ (mL)}$$

NO_3-N was calculated the same way.

3.3.8 Determination organic matter

Ten grams of air dried soil was weighed into a 250 mL conical flask. 10 mL of 1N $K_2Cr_2O_7$ was pippeted into the conical flask then 20 mL of concentrated sulphuric acid was rapidly added, concentrating the stream into the suspension using an automatic pippete. Gentle swirling followed until the soil eand solution had mixed then vigorously for one minute. The suspension was stored in the fume hood for 30 minutes after which 150 mL of distilled water and 10 mL concentrated H_3PO_4 was added. 10 drops of the indicator was added and titration with iron (II) sulphate solution followed to a green end point (Walkley, A).

3.3.9 Determination of Zinc

Twenty grams of air dried soil was weighed into a 250 mL conical flask and 40 mL of diethylene triamine pentaacetic acid-triethanolamine (DTAP-TEA) extracting solution added to it. The mixture was shaken for 2 hours on a mechanical shaker. It was then filtered and Zinc was read in the filtrate using the AAS machine (Katyal and Randhawa, 1983).

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3.4 Green house pot experiment

3.4.1 Treatments and design

The experiment was arranged in the complete randomized design (CRD). The treatments were as follows:

- ✓ A - anthill soil solely
- ✓ SF - field soil with fertilizer (200 kg/ha of D-compound)
- ✓ $AS_{1:5}$ - mixture of 1 part anthill soil and 5 parts field soil

- ✓ $AS_{1:10}$ -mixture of 1 part anthill soil and 10 parts field soil

3.4.2 Planting, Management and Harvesting

Maize (Zea mays) pannar 33 variety was planted in pots containing 2 kg of the different soil treatments in the green house. The plants were watered when necessary and kept weed free at all times. 8 weeks after planting, the maize was harvested and oven dried at 65^0C. Thereafter, biomass yield and plant analysis was carried out.

3.5 Plant analysis

A gram of each sample was weighed into a crucible and ashed at 500°C for one hour. The crucible was removed and cooled in a dessicator for 30 minutes. Ash was quantitatively transferred into a 100 ml beaker using 30 mL 1M HNO_3 and filled up to the mark (Katyal and Randhawa, 1983).

Potassium, Calcium, Magnesium and Zinc were then read using the AAS.

%Ca, Mg, and K were calculated as follows:

$$\%Ca, Mg\ or\ K = \text{mg /L read x volume of extractant x dilution factor (DF)}$$

Amount of Zn was calculated using the following formula:

$$Zn\ ppm = \frac{\frac{mg}{L}\ read\ x\ volume\ of\ extracnt\ x\ DF}{Weight\ of\ sample\ in\ kg}$$

To determine P in a sample, 0.5 mL of digest was pipetted into a 25 mL volumetric flask, to which 10 mL of distilled water and 4 mL of reagent B were added. The solution was thoroughly mixed by shaking and filled up to the mark using distilled water. After 15 minutes the absorbency at 882 nm wavelength was read using the spectrophotometer. Percent P was then calculated as follows:

$$\%P = mg/L\ read\ x\ 10^{-3}\ x\ dilution\ factor\ (DF)$$

3.6 Statistical analysis

Analysis of Variance was done to determine the significant differences in maize biomass yield, Ca, Mg and K levels. To do this, genstat software was used.

CHAPTER 4

4 RESULTS AND DISCUSSIONS

4.1 Soil characterization

4.1.1 Soil particle size analysis and pH

Particle size analysis and pH results are shown in ps is 5.5-6.7 (Rorison, 2004). At this pH, most nutrients are available for plants in adequate amounts.

Table 1 below. Both anthill and surrounding soil had high sand percentage (61.2% and 78.2%, respectively), followed by silt (24% and 19.5%) and lastly clay (14.8% and 2.3%).The anthill soil had a sandy loam texture while the field soil had a loamy sand texture.

The average pH for the anthill soil was 7.62 (slightly alkaline) and 5.8 (slightly acidic) for the field soil. The optimum soil pH range for most crops is 5.5-6.7 (Rorison, 2004). At this pH, most nutrients are available for plants in adequate amounts.

Table 1: Particle size distribution and soil pH

Soil	pH (0.01M $CaCl_2$)	Texture	Sand %	Silt %	Clay %
Anthill soil	7.62	Sandy loam	61.2	24.0	7.62
Surrounding soil	5.80	Loamy sand	78.2	19.5	5.80

4.1.2 Available P, Available N and CEC

The results for available P, available N and cation exchange capacity are in Table 2 on the next page. The anthill soil had a higher CEC compared to the field soil. The bases were generally high in the anthill soil. The available nitrogen was low in both soils although the anthill soil had higher levels. The nitrogen levels were less than the nitrogen requirements for maize. Phosphorus levels were also higher in the anthill soil compared to the field soil. The critical nutrient concentration is 10 ppm according to Tisdale (1985). The field soil therefore had less than the critical P concentration.

Table 2: Available P and N, CEC

Soil	Avail P (Bray I) mg/kg	Avail N mg/kg	Ca	Mg	K	Na	Al	H	CEC
			Cmol/kg						
A	10.95	117.25	33.52	6.1	35.37	39.36	0.265	0.35	114.97
S	6.6	42	5.5	1.26	32.0	36.99	0.165	0.36	76.28

4.2 Crop performance

From figure 4.5, the purple and yellowish colour in leaves of $AS_{1:5}$, $AS_{1:10}$ and A treatments were showing phosphorus and nitrogen deficiencies respectively.

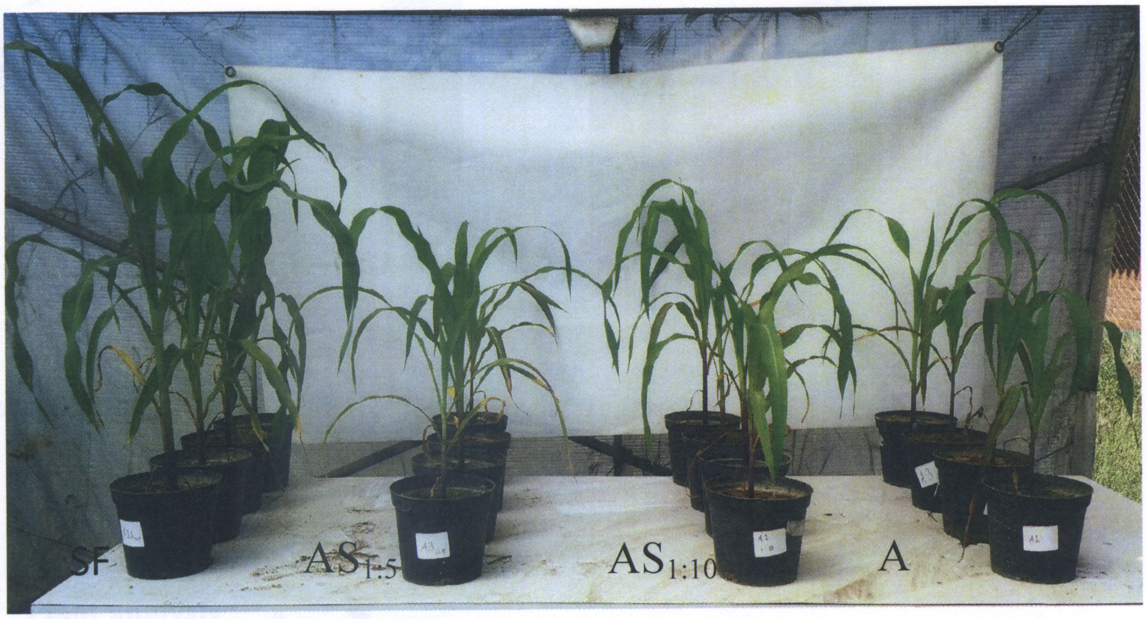

Figure 1: Crop stand at 7 weeks after planting

The deficiencies of N and P which were observed in the plant resulted from the low levels of N and P in the soils leading to poor crop performance in A, $AS_{1:5}$ and $AS_{1:10}$ treatments. The AF treatment performed better than the other treatments because of the fertilizer that was added which increased the N and P levels of the soil. The other factor that would have led to poor crop performance is the high pH (7.62) of the anthill soil which could have affected the solubility of certain nutrients such as zinc, copper and iron.

4.3 Maize biomass yield

Figure 2 below shows the biomass yield of maize for different treatments. SF had significantly higher biomass yield compared to A, $AS_{1:10}$ and $AS_{1:5}$ treatments. The differences in yield would have resulted from the N and P deficiencies and high pH of the anthill soil. This conforms to the crop performance of the different treatments.

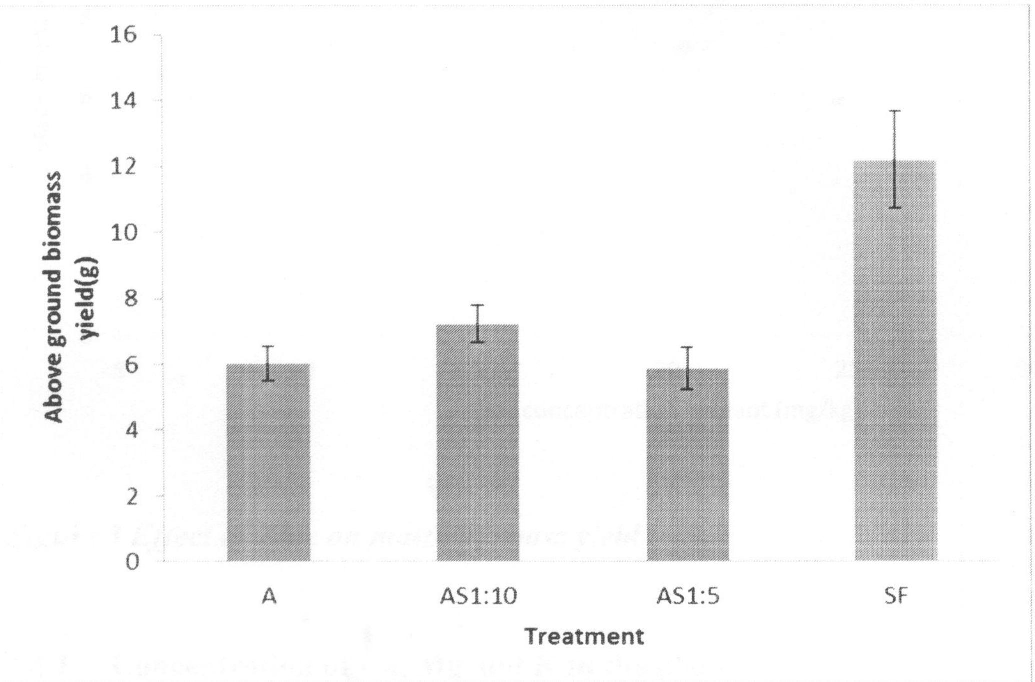

Figure 2: Biomass yield of maize for different treatments

4.4 Plant analysis

4.4.1 Effect of Zinc concentration on biomass yield

Figure 3 below shows the effect of Zn concentration on maize biomass yield. The biomass yield increased with decreasing Zn concentrations. Phosphorus and Zinc have antagonistic effects on each other (Tisdale, 1985). The biomass yield was increasing with increasing phosphorus concentrations and reducing with increasing zinc concentrations. It is possible that the compound D that was added to AF increased the P concentrations resulting into less uptake of Zinc.

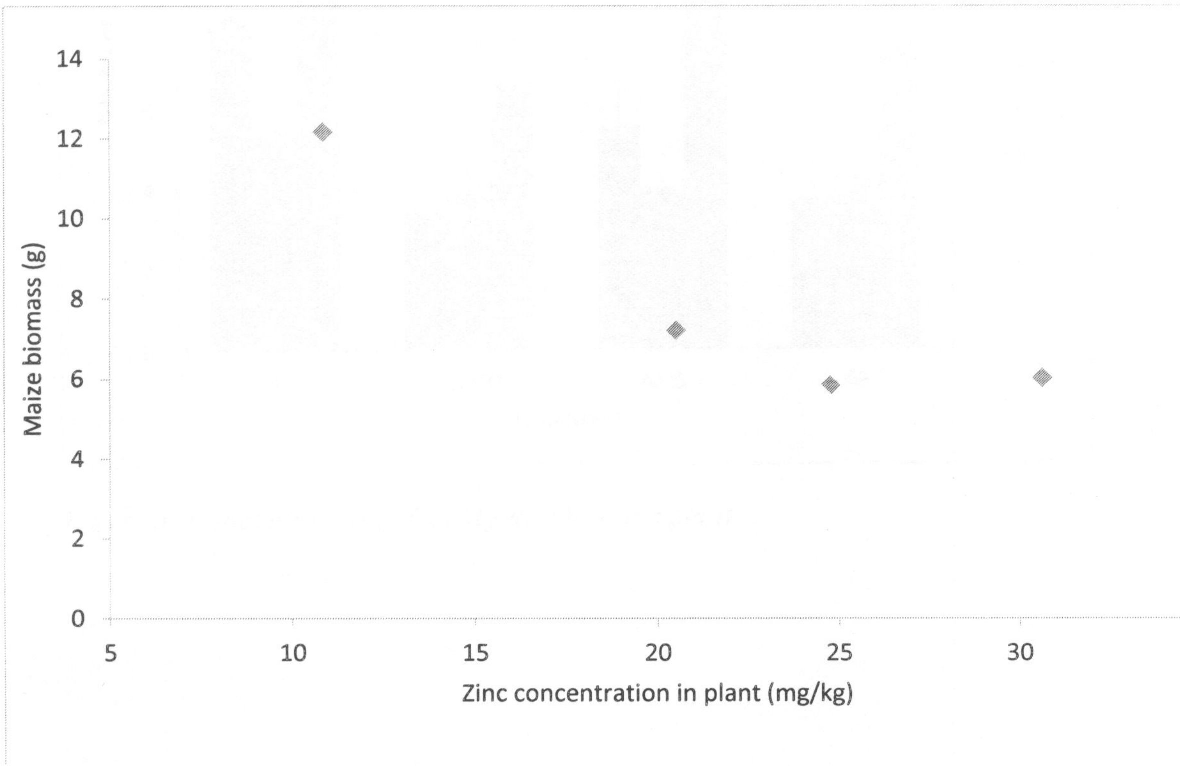

Figure 3 Effect of Zinc on maize biomass yield

4.4.2 Concentration of Ca, Mg and K in the plant

Figure 4 below shows the concentrations of Ca, Mg and K in the plant for different treatments. The plants grown with anthill soil showed higher percent concentrations in Ca, Mg and K. These nutrients are required in high amounts for plant growth. However, they are not the only nutrients required for optimal plant growth. The Ca/Mg ratio recommended is 5:1 and 7: 1 for Ca/ K (Tisdale, 1985). Exceeding these ratios causes nutrient imbalances in the soil which may lead to nutrient deficiencies and poor crop growth and yield.

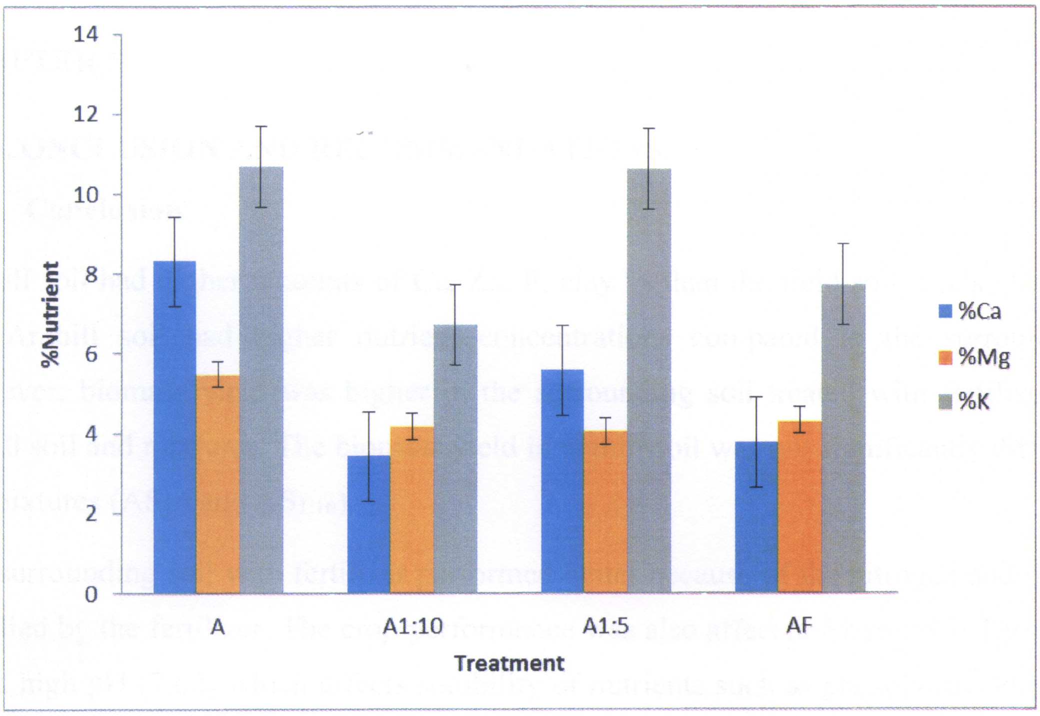

Figure 3: Concentration of Ca, Mg and K in the plant

CHAPTER 5

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Anthill soil had higher amounts of Ca, Zn, P, clay % than the field soil. It also had a higher pH. Anthill soil had higher nutrient concentrations compared to the surrounding soil. However, biomass yield was higher in the surrounding soil treated with fertilizer than the anthill soil and mixtures. The biomass yield in anthill soil was not significantly different from the mixtures ($AS_{1:5}$ and $AS_{1:10}$).

The surrounding soil with fertilizer performed better because of the nitrogen and phosphorus supplied by the fertilizer. The crop performance was also affected by soil pH. The anthill soil had a high pH (7.62) which affects solubility of nutrients such as phosphorus. Phosphorus is less soluble at pH higher than 6.5 (Tisdale, 1985)

5.2 Recommendations

1. Anthill soil can be used as a soil fertility enhancer provided there is a source of nitrogen.
2. More work needs to be done to indicate how anthill soil can benefit the farmers to be used as a soil fertility enhancer.

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7 APPENDICES

Analysis of variance of pH

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
SOIL	1	8.2135	8.2135	49.78	<.001
Residual	6	0.9901	0.1650		
Total	7	9.2036			

Appendix 1

Analysis of variance of Biomass

Variate: BIOMASS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	105.692	35.231	11.21	<.001
Residual	12	37.713	3.143		
Total	15	143.404			

Appendix 2

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	60.414	20.138	8.40	0.003
Residual	12	28.752	2.396		
Total	15	89.166			

Appendix 3