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ROLE OF CATTLE MANURE AND INORGANIC FERTILIZERS IN IMPROVING MAIZE PRODUCTIVITY IN SEMI-ARID AREAS OF ZIMBABWE

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Abstract: Inherent soil fertility has led to poor maize productivity in arid and semi-arid areas. The main objective of the study was to assess the effects of cattle manure and inorganic fertilizer on maize productivity. The study was carried out as an experiment was carried out in ward 7 of Zaka district as a complete randomised block design with two main treatments (cattle manure applied at 0, 2.5 and 5t/ha) and inorganic fertilizer (applied at 0, 50 and 100 Kg N/ha). The treatments were replicated three times. Data was subjective to analysis of variance (ANOVA) using IBM SPSS version 25. The results showed that grain yield, weight of 1000 grains and stover yield were influenced significantly ($P<0.05$) by the application of cattle manure and inorganic fertilizers. Application of 2.5 t/ha cattle manure showed an increase of 29.7% from 3.32 t/ha from control treatments to 4.72 t/ha. Continuous increase of cattle manure application to 5.0 t/ha with zero application of inorganic fertilizer show a significant ($P<0.05$) increase of 1000grain weight, grain and stover yields. The combined treatments produced yields which were significantly higher than those produced by cattle manure and inorganic fertilizer applied separately. Treatment N50C2.5 produced 341.6 g, 5.19 t/ha and 9.34 t/ha of 1000 grain weight, grain and stover yields respectively which were significantly ($P<0.05$) higher than the control treatments which produced 279.8g, 3.32 t/ha and 5.67 t/ha of 1000 grain weight, grain and stover yields respectively. The correlation and regression analyses revealed significant positive relationships between the grain yield and 1000 grain weight. A very close positive correlation ($R = 0.88$; $R2 = 0.773$ and $P<0.0001$) was found between the grain yield and the values of weight of 1000 grains. The results show that cattle manure applied in as a sole nutrient source raises soil pH. Total N decreased from 0.12% to 0.06% on the control to 0.11% on treatments with maximum application of cattle manure and inorganic nitrogen. All treatments with cattle manure in sole application increased CEC values. Addition of inorganic fertilizer in treatments decreased CEC.

Keywords: Cattle manure; Effects; Inorganic fertilizer; Maize; Productivity; Semi-arid; Zimbabwe.

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INTRODUCTION

Agriculture is the backbone of Zimbabwe and most African countries. It is expected to be the driver of Zimbabwe's economy. Zimbabwe has been cited as the southern Africa's food supplier for both maize and impotent cereals such as sorghum (Kugedera *et al*., 2018). Land productivity has declining, potentially causing a major problem in food security for most sub-Saharan countries (SSA) including Zimbabwe. Increased soil erosion and surface runoff with prolonged dry spell also contributed to poor crop productivity (Kugedera and Kokerai, 2019a). Low inherent soil fertility status coupled with little or no external nutrient inputs have contributed to low maize yields that rarely exceed 1.0 t/ha in Southern Africa, threatening household food security (Kanonge *et al*., 2009; Mafongoya *et al*., 2006; Bationo *et al.,* 2004). Maize (*Zea mays* L.) is the staple food for a majority of the people in Southern African countries, but it is also grown as a cash crop by both small- and large-scale farmers. About 70% of consumers rely primarily on maize grain which is ranked first in Zimbabwe. Declining maize production has been attributed to degradation of soil physical-chemical properties, soil acidity with high P sorption and soil nutrient depletion due to low chemical fertilizer use by most small-scale farmers who cannot afford the expensive fertilizers (Vanlauwe *et al*., 2010; Bationo *et al.,* 2004). Fertilizer consumption rate is estimated at 3.5 kg/ha which is one the lowest in the tropical world (Morris *et al*., 2007).

Improving maize productivity has been a major goal of the Zimbabwean Government which went onto launch Command Agriculture program to boost maize productivity. However, it has been very difficult to raise maize yields and maintain household food security in country due to low yield on maize production caused by poor soil fertility and erratic rains especially in the smallholder farming areas. In southern Africa, only less than 7% of smallholder farmers owning cattle use cattle manure as an amendment for crop production (SIMA, 2008; World Bank, 2006). The challenge therefore lies in ensuring that the limited nutrient inputs available to smallholder farmers are effectively utilized to increase efficiency and sustain crop productivity. Most smallholder farmers lack technical knowhow in the use of cattle manure as most of the farmers believe that cattle manure reduces crop productivity if rainfall received is low. Kugedera and Kokerai (2019b) reported that cattle manure has the potential of improving cereal grain yields such as sorghum. The use of cattle manure and mineral fertilizer can improve maize productivity if amended in good proportion. The objective of the study was to assess the role of cattle manure and inorganic fertilizer in improving maize productivity in semi-arid and arid areas of Zimbabwe.

EXPERIMENTAL

Study Area

The experiment was up in the experimental plot at Zivavose Secondary School in Zaka, Masvingo Province, Zimbabwe. Located within the latitude 20° 2' 43" S and longitude 30° 30' 29" E in the south eastern part of Zimbabwe. The experimental plots were located in the semi-arid areas of Zimbabwe where rainfall received is between 450 mm to 550 mm per annum. The area is characterized with high temperatures ranging from 18-32°C. The soils of the experimental site were medium loam soils as indicated in Table 1. The area is dominated with medium tall grass and if rainfall is well received maize production will be achieved at higher rates.

Table 1. Initial Soil Physical and Chemical Characteristics of the Experimental Site

Soil parameters	0 – 20 cm depth
pH (1:1 H_2O)	5.8 ± 0.14
Organic C (%)	0.38 ± 0.015
Total N (%)	0.12 ± 0.006
Available P (mg/kg)	4.07 ± 0.72
Exchangeable bases (cmolc/kg)	
K	0.25 ± 0.01
Ca	1.282 ± 0.09
Mg	0.98 ± 0.11
Na	0.13 ± 0.02
CEC (cmolc/kg)	3.42 ± 0.46
Bulk density (g/cm^3)	1.25 ± 0.06
Sand %	43.13 ± 0.44
Silt %	30.65 ± 0.15
Clay %	26.22 ± 0.09
Texture	**Medium loam**

Experimental Design and Treatments

The Complete Randomized Block Design was used in the experiment with 2 main treatments cattle manure and inorganic fertilizer. Different rate of cattle manure (0, 2.5 and 5t/ha) and inorganic fertilizer (0, 50 and 100 Kg N/ha) were used. Maize was planted on flat land and total of 9 (4m by 2m) plots were prepared and planted according to the described treatments (Table 2). There were four rows of maize in each plot planted at a 0.90 m row spacing and 0.3cm plant spacing. The maize seed was planted at a 50 mm soil depth. Cattle manure was evenly applied for all treatments indicated addition of manure.

Table 2. Experimental Treatments Used in the Study Treatment

No.	N kg/ha	Cattle manure (t/ha)	Treatment combination
1 (Control)	0	0	N0C0
2	0	2.5	N0C2.5
3	0	5	N0C5
4	50	0	N50C0
5	50	2.5	N50C2.5
6	50	5	N50C5
7	100	0	N100C0
8	100	2.5	N100C2.5
9	100	5	N100C5

Cattle Manure and Mineral Fertilizer Acquisition

Cattle manure was obtained from a local farmer and it consisted of faecal matter, urine and which was collected from the kraal after accumulating from July to June. The kraal had no roof and the manure was exposed to the weather and lost nutrients through leaching, denitrification and volatilization leading to reduced quality. Ammonium nitrate was obtained from N. Richards Hardware at Jerera Growth Point.

Land Preparation and Experimental Set-up

The trials were established at one site during the short rain season (December 2018 to March 2018) and a short season variety SC303 was used under supplementary irrigation. Land was prepared using ox-plough to approximately a depth of 20 cm. The size of each plot was 4.5 x 4.5 m with spacing of 90cm between the rows and 30 cm within the rows. Maize seeds (SC303) obtained from SEDCO Seed Unit were used. Two seeds were planted per hole and thinned to two 14 days after emergence. Ammonium Nitrate (AN) was top-dressed four and eight weeks after emergence using split application. Cattle manure was applied at planting and was placed in the prepared holes where it was mixed thoroughly with soil using three rates of 0, 2.5 and 5 t/ha. Fertilizers were pre-weighed for each plot before going to the field and applied using dollop cups to ensure uniform distribution within the plot. Weeding was done two times during the growth period and vegetative stage to create a free weed environment.

Data Collection

Grain and Stover Yield: Plants in the area reserved (net plot) for final harvest were harvested after 95 days from a delineated area of 3 m x 3 m (9 m^2) in the middle of each treatment plot leaving the border rows. Ears were sun – dried for five days. After threshing of ears of each treatment, grain was weighed at 12 % moisture content and converted into grain yield (kg/ha).

$$Grain\ yield\ (kg/ha) = \frac{Yield\ in\ the\ treatment\ X\ 10{,}000}{Harvest\ area}$$

Where, harvest area = 9 m^2 and 10000 is equivalent to area of one hectare.

Stover yield was also measured from the net plot by cutting stover into small pieces and weigh using a digital scale and convert the mass to kg/ha.

$$Stover\ yield\ (kg/ha) = \frac{Yield\ in\ the\ treatment\ X\ 10{,}000}{Harvest\ area}$$

Where, harvest area = 9 m^2 and 10000 is equivalent to area of one hectare.

Data Analysis

Data was subjective to analysis of variance for RCBD using SPSS IBM 25 and statistical significance treatments of means were estimated using least significance difference (LSD).

RESULTS AND DISCUSSION

Effects of Cattle Manure and Inorganic Fertilizer on Maize Grain and Stover Yields

The results show that application of cattle manure significantly increases grain and stover yields ($P<0.05$). The fertilizer treatments had a significant effect on the grain yield and yield components. The results showed that grain yield, weight of 1000 grains and stover yield were influenced significantly ($P<0.05$) by the application of cattle manure and inorganic fertilizers (Table 3). Application of 2.5 t/ha cattle manure showed an increase of 29.7% from 3.32 t/ha from control treatments to 4.72 t/ha. Continuous increase of cattle manure application to 5.0 t/ha with zero application of inorganic fertilizer show a significant ($P<0.05$) increase of 1000grain weight, grain and stover yields. Cattle manure has the potential to increase maize grain yields with 30.3 % compared to plots with no addition of cattle manure and inorganic fertilizer. The combined treatments produced yields which were significantly higher than those produced by cattle manure and inorganic fertilizer applied separately. Treatment N50C2.5 produced 341.6 g, 5.19 t/ha and 9.34 t/ha of 1000 grain weight, grain and stover yields respectively which were significantly ($P<0.05$) higher than the control treatments which produced 279.8g, 3.32 t/ha and 5.67 t/ha of 1000 grain weight, grain and stover yields respectively (Table 3). An increase in cattle manure to 5.0 t/ha in combination with 50 kg/ha N increase grain and stover yields by 3.7 % and 2.4 % compared to yields produced from N50C2.5 treatments respectively. Application of cattle manure at 5.0 t/ha and inorganic fertilizer at 100kg/ha significantly ($P<0.05$) increase 1000grain weight, grain and stover yields compared to all other treatment used in the experiment (Table 2).

The results in table 2 were also presented in figure 1 to show clear differences between grain and stover yields from different treatments. The results on figure 1 show that maize grain yields can be achieved at maximum by combining 100kg/ha N and 5.0 t/ha cattle manure. This combination also produces higher maize stover yields which can be used by farmers to recycle nutrients absorbed by plants back to the field. The results also show that a minimum of 3.32 t/ha grain yields can be obtained by farmers without any addition of cattle manure and inorganic fertilizer if all other factors are kept constant (Figure 1).

Table 3. Effects of Cattle Manure and Inorganic Fertilizer on 1000 grain Weight, Grain and Stover Yields

TREATMENT	Weight of 1000grain (g)	Grain (t/ha)	Stover (t/ha)
N0C0 (Control)	279.8^{f}	3.32^{e}	5.67^{e}
N0C2.5	292.4^{ef}	4.72^{cd}	8.81^{cd}
N0C5	302.9^{e}	4.76^{d}	8.97^{cd}
N50C0	321.4^{d}	4.81^{cd}	8.99^{cd}
N50C2.5	341.6^{cd}	5.19^{c}	9.34^{bc}
N50C5	352.9^{c}	5.39^{abc}	9.57^{bc}
N100C0	381.8^{b}	5.42^{ab}	9.88^{ab}
N100C2.5	389.3^{ab}	5.49^{ab}	9.97^{ab}
N100C5	399.6^{a}	5.70^{a}	10.02^{a}
Same superscripts in same column denotes no significant different between treatments at p =0.05.			

Relationship Between 1000 Grain Weight and Maize Grain Yields

The correlation and regression analyses revealed significant positive relationships between the grain yield and 1000 grain weight. A very close positive correlation ($R = 0.88$; $R^2 = 0.773$ and $P<0.0001$) was found between the grain yield and the values of weight of 1000 grains (Figure 1.1).

Effect of Inorganic Fertilizer and Cattle Manure on Soil Physio-chemical Properties

Effect of cattle manure and inorganic fertilizer on soil pH: The results show that cattle manure applied in as a sole nutrient source raises soil pH. An increase in cattle manure application significantly raises soil pH to levels which promote crop growth. Application of inorganic fertilizer as a sole application decreases soil pH. Treatments with combined maximum cattle manure and inorganic fertilizer raise soil pH (Table 4).

Effect of cattle manure and inorganic fertilizer on soil total: Total Nitrogen at the of experiment ranged from 0.12% to 0.06% and 0.11% with respect to control and all other treatments as shown in Table 4. Total N decreased from 0.12% to 0.06% on the control to 0.11% on treatments with maximum application of cattle manure and inorganic nitrogen. Generally, as a result of nutrient uptake by the maize, soil total nitrogen content decreased in all the treatments after harvest (Table 5).

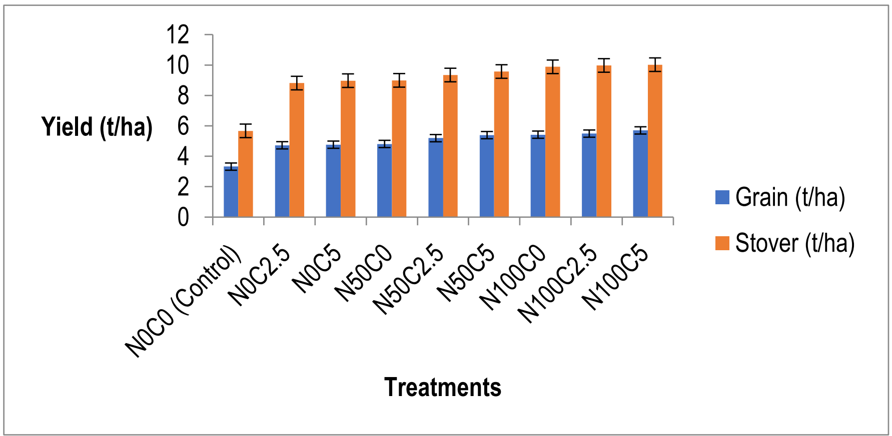

Figure 1. Effects of Cattle Manure and Inorganic Fertilizer on Grain and Stover Yields

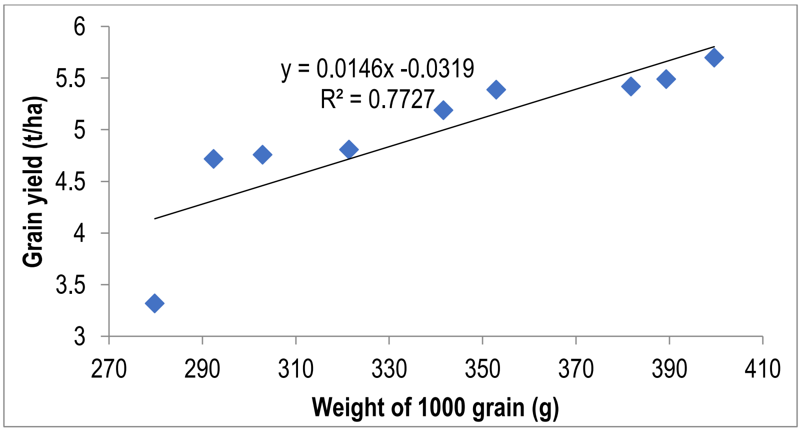

Figure 1.1. Relationship between 1000 grain weight and maize grain yields

Table 4. Effect of Cattle Manure and Inorganic Fertilizer on Soil pH

Treatment	Initial	End of experiment	Difference
Control	5.8	5.5	+0.20
N0C2.5	5.8	6.0	-0.30
N0C5	5.8	6.2	-0.4
N50C0	5.8	5.5	+0.30
N50C2.5	5.8	5.9	-0.10
N50C5	5.8	6.1	-0.30
N100C0	5.8	5.4	+0.4
N100C2.5	5.8	5.7	+0.1
N100C5	5.8	5.9	-0.1

Table 5. Effect of Cattle Manure and Inorganic Fertilizer on Soil Total Nitrogen

Treatment	Initial	End of experiment	Difference
Control	0.12	0.06[c]	-0.06
N0C2.5	0.12	0.09[b]	-0.03
N0C5	0.12	0.10[a]	-0.02
N50C0	0.12	0.06[c]	-0.06
N50C2.5	0.12	0.09[b]	-0.03
N50C5	0.12	0.11[a]	-0.01
N100C0	0.12	0.10[a]	-0.02
N100C2.5	0.12	0.11[a]	-0.01
N100C5	0.12	0.11[a]	-0.01

Same superscripts in same column denotes no significant different between treatments at p =0.05.

Table 6. Effect of Cattle Manure and Inorganic Fertilizer on CEC

Treatment	Initial (cmolc/kg)	End of experiment	Difference
Control	3.42	1.98[f]	-1.44
N0C2.5	3.42	3.45[b]	0.03
N0C5	3.42	3.57[a]	0.15
N50C0	3.42	3.23[d]	-0.19
N50C2.5	3.42	3.43[b]	0.01
N50C5	3.42	3.46[b]	0.04
N100C0	3.42	2.46[e]	-0.96
N100C2.5	3.42	3.39[bc]	-0.03
N100C5	3.42	3.45[b]	0.03

Same superscripts in same column denotes no significant different between treatments at p =0.05.

Effect of cattle manure and inorganic fertilizer on Cation Exchange Capacity (CEC): Table 6 presents results on CEC as influenced by different treatments. The results show that treatment **N0C5** recorded the highest CEC of 3.47 cmolckg and the control recorded the lowest CEC value of 1.98cmolc kg-1. All treatments with cattle manure in sole application increased CEC values. Addition of inorganic fertilizer in treatments decreased CEC. There was a significant different (P<0.05) between all treatments applied cattle manure in sole as compared to treatments where inorganic fertilizer was applied in sole. A combination of cattle manure and inorganic fertilizer show a decrease in CEC and this situation is mainly not accepted.

Effects of Cattle Manure and Mineral Fertilizer on Maize Grain and Stover Yields

Increased maize grain and stover yields due to application of cattle manure and inorganic fertilizer was recorded. These results coincide with results by Silva *et al.* (2004) and Chivenge *et al*. (2009) who also reported an increase in maize grain and stover yields from plots applied cattle manure compared to those without cattle manure. This study results concurs with previous findings on the role of manure and chemical fertilizer in increasing grain yield of maize (Silva *et al*., 2004). The results showed that manure and chemical fertilizer separately can increase grain yield of maize but a combination of them has more effect on increase in grain yield. Application of cattle manure to the soil improves soil physio-chemical properties, macronutrients and micronutrients which improves crop growth (Kokerai and Kugedera, 2019; Tirol-Padre *et al*., 2007). Cattle manure also improves soil water retention which increases water availability in the plant root zone. By raising soil organic matter, cattle manure increases cation exchange capacity and improves soil physical properties, such as soil structure (Bationo *et al*., 2006). This also increases nutrient availability for plant growth leading to higher grain and stover yields.

Grain and stover yields produced from treatments in combination of cattle manure and inorganic fertilizer showed an increase compared to where cattle manure and inorganic fertilizer were applied separately. This was caused by an increase in nitrogen level due to application of inorganic fertilizers, increased soil quality and productivity (Ghosh *et al*., 2006) as a result of integration of cattle manure and inorganic fertilizer. Maximum yields were obtained from treatments with maximum levels of cattle manure and inorganic fertilizer. These results coincide with results by Kugedera *et al*. (2018); Tolessa and Friesen (2001) who reported an increase of sorghum yields after adding a combination of cattle manure and inorganic fertilizer at maximum levels of 2.5 t/ha and 60kg/ha inorganic fertilizer. Cattle manure has been seen as a poor source of N hence combining it with inorganic fertilizers which have high N concentration increases maize grain yields (Nyamangara *et al*., 2005).

Effects of Cattle Manure and Inorganic Fertilizer on pH, Total N and CEC

All treatments with cattle manure showed an increase in pH compared to all treatments without cattle manure where pH decline to acidic levels. These results coincide with results by Mugendi *et al*. (2004) who reported that addition of cattle manure improves soil pH. Cattle manure has the potential to absorb hydrogen ions in its humic forms while application of inorganic fertilizers increases hydrogen ions in the soil, causing high acidity of the soil.

Total nitrogen decreased from all treatments with higher decreases from treatments applied cattle manure with no inorganic fertilizer. This was caused by poor nitrogen content in cattle manure (Nyamangara *et al*., 2005) and the decrease was low in treatments which were applied more quantities of inorganic fertilizer amended with cattle manure. This combination increased total nitrogen availability for maize leading to maize plants absorbing little N from the initial N in the soil. Treatments with cattle manure applied in sole application recorded an increase in CEC of the soil. These results concur with results by Norman *et al*. (2000) and Lifeng *et al*. (2006) who recorded an increase in CEC from treatments applied cattle manure as a sole application. However, addition of organic matter into soils in most cases increases CEC due to its humic acids which increase the negative charge (Norman *et al*., 2000; Nyamangara *et al*., 2005; Lifeng *et al*., 2006). CEC in treatments applied inorganic fertilizer in sole application recorded a decline; this was caused by an increase in soil acidity which increases leaching of cations lowering the levels of CEC.

CONCLUSION

The main aim of this study was to assess the effect of cattle manure and inorganic fertilizer on maize grain, stover yields and soil properties. The results obtained in this study show that: Yields were significantly affected by the various treatments applied cattle manure, inorganic fertilizer in sole application. Cattle manure and inorganic fertilizers produced yields which were significantly higher than the values obtained by cattle or inorganic fertilizers separately. The highest grain and stover yield were obtained from 100kg N+5t Cattle manure treatment while the control obtained the lowest grain and stover yields. Maize grain yields responded better to N and cattle manure in combination compared to inorganic or cattle manure applied in sole. The combined treatments of 100kg N+5t Cattle manure treatment indicated significantly 1000 grain weight than the control. However, soil pH and CEC significantly increased due to cattle manure application while soil total N was decreased in all the treatments.

Recommendations: The combined application of organic and inorganic fertilizers at 100Kg N ha^{-1}+ 5t cattle manure can be recommended. Long term studies of the treatments used in this study should be carried out to further ascertain their effects on physical properties of the soil. Further research should be conducted for a longer period using different rates of cattle manure and inorganic fertilizer in the different ecological zones of Zimbabwe in order to come up with a robust figure on the optimum rates for increased maize production.

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